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The Relationships among Pre-service Mathematics Teachers' Beliefs about Mathematics, Mathematics Teaching, and Use of Technology in China

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This paper investigated pre-service mathematics teachers' mathematics beliefs, beliefs about information and communication technology (ICT), and their relationships. 787 pre-service mathematics teachers in China completed a survey questionnaire measuring their beliefs about the nature of mathematics, beliefs about mathematics learning and teaching, attitudes toward ICT, and beliefs about ICT use in mathematics education. Descriptive statistics, simple correlation analysis, and step-wise progression analysis were performed in the data analysis. The results indicate that pre-service mathematics teachers' dynamic belief about the nature of mathematics, constructivist belief about mathematics learning and teaching, and positive attitudes towards ICT are more likely to be correlated with their constructivist belief about ICT use. In contrast, their traditional beliefs about the nature of mathematics and its learning and teaching are more likely to be associated with their traditional beliefs about ICT use.

Keywords: belief about mathematics, pedagogical beliefs, pre-service mathematics teachers, ICT use

INTRODUCTION

The rapid development of information and communication technology (ICT) in recent years has dramatically increased its availability in mathematics classrooms worldwide (Geiger et al., 2012; Lagrange & Kynigos, 2014). The wide availability of ICT, including computers, graphic calculators, versatile interactive software, and web-based applications, has fundamentally changed students' mathematical practices, such as ways of constructing and applying mathematics knowledge (Goos & Bennison, 2008; Jimoyiannis & Komis, 2007). ICT is commonly believed to be an effective tool to enable mathematics teachers to evolve from employing teacher-centered teaching strategies to student-centered constructivist teaching strategies

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(Goos & Bennison, 2008; Pierce & Ball, 2009). Furthermore, newly developed and refined technologies are gradually changing the very nature of mathematics and the nature of mathematics knowledge that students learn in schools as well (Leung, 2013).

State of the literature

- Teachers who hold strong constructivist belief about teaching and learning are generally more likely to use technology in the classroom than teachers who have traditional belief about learning and teaching.
- Teachers with more sophisticated beliefs about the source of knowledge are more likely to hold more constructivist-oriented beliefs about learning and teaching, and are more likely to use ICT in practice or hold constructivist beliefs about ICT use.
- The social and cultural context is an important factor which heavily influences the development of teachers' beliefs and the ways of using technology.

Contribution of this paper to the literature

- This paper contributes to the understanding of pre-service mathematics teachers' beliefs about mathematics, mathematics teaching, beliefs about ICT use, and their relationships in the Chinese context.
- Results of the study indicate that Chinese pre-service mathematics teachers' dynamic belief about the nature of mathematics and constructivist belief about mathematics learning and teaching are more likely to be correlated with their constructivist belief about ICT use.
- Findings of the study suggest that Chinese pre-service mathematics teachers' traditional beliefs about the nature of mathematics and its learning and teaching are more likely to be associated with their traditional beliefs about ICT use.

Since the nature of mathematics and its learning and teaching have been changed fundamentally due to the emergency of technology, teachers need to develop corresponding beliefs so as to effectively integrate ICT in their teaching. Previous research has repeatedly shown that whether and how teachers use ICT in mathematics teaching ultimately depend on various beliefs they held, including beliefs about mathematics teaching and learning (Ertmer, 2005; Ertmer & Ottenbreit-Leftwich, 2010), beliefs about and attitudes towards ICT (Pierce & Ball, 2009; Prestridge, 2012), and epistemic beliefs, that is, beliefs about the nature of knowledge (Deng et al., 2014; Kim et al., 2013).

Due to the importance of teachers' beliefs for effective integration of ICT in mathematics teaching, it is important for mathematics teacher educators to identify and develop pre-service teachers' beliefs during the teacher preparation period (Jimoyiannis & Komis, 2007; Teo et al., 2008). To meet this aim, the first step should be a deep understanding of pre-service mathematics teachers' various beliefs and the relationship among these beliefs. However, so far, even though there has been increasing research interest to investigate the relationships between pre-service teachers' pedagogical beliefs and their beliefs about ICT use (e.g., Funkhouser & Mouza, 2013; Gurcay et al., 2013; Teo et al., 2008), teachers' beliefs about the nature of a specific subject have not been stressed in previous studies (Teo et al., 2008; Deng et al., 2014). Subject culture, however, has been clearly pointed out in the literature as an important factor which will influence the ways of teachers' integration of ICT in the subject (Howard et al., 2015). Therefore, teachers' beliefs about the nature of mathematics should be investigated particularly for the understanding of the interactions between mathematics teachers' beliefs and the use of ICT (Deng et al., 2014; Howard et al., 2014).

On the other hand, the social and cultural context has been argued as an important factor which heavily influences the development of teachers' beliefs and their ways of using technology in practice (Hew & Brush, 2007; Liu, 2011; Sang et al., 2010). Indeed, different relationships between teachers' pedagogical beliefs and beliefs about ICT use have been identified among countries with different educational traditions (e.g., Gurcay et al., 2013). However, so far, most of the previous studies were conducted in developed countries and very few studies have been conducted in developing countries such as China. Although there have been discussions on the integration of ICT in mathematics education in developed countries for many decades, technology integration in mathematics education is still a rather recent phenomenon in China (Li et al., 2014). Before the 1990's, technologies were rarely found in Chinese classrooms and therefore were rarely used in mathematics education in China. It is after 2000 that the idea of ICT integration in mathematics teaching and learning started to be emphasized and encouraged in the most recent national mathematics curriculum standard. Due to the huge increase in investment in education, the availability of technology in classrooms has also been increased dramatically in schools in China. In addition to scientific calculators and computers, many other technology equipments (e.g., graphing calculators, internet) and sophisticated software have become readily available for teaching and learning school mathematics at all levels (Li et al., 2014). Chinese teachers, therefore, need to change their beliefs for the effective use of ICT to support constructivist-oriented mathematics teaching and learning as emphasized in the reformed mathematics curriculum. This change is a huge challenge for in-service and pre-service mathematics teachers in China, since most of them are used to the traditional ways of mathematics teaching dominated by work with pencil and paper, and their beliefs about mathematics teaching and learning are rather traditional (Ni et al., 2014). Moreover, since most pre-service mathematics teachers in China did not experience a technology-integrated K-12 mathematics curriculum, it should be quite difficult for them to value the role of technology in mathematics education (Funkhouser & Mouza, 2013). Under such background, it may be very possible that teachers' beliefs regarding ICT use identified in previous studies in developed countries do not necessarily reflect the situation in China. In view of this, this study aims to investigate the following research questions:

1. What are Chinese pre-service mathematics teachers' beliefs about the nature of mathematics and its learning and teaching, their attitudes towards ICT, and their beliefs about the use of ICT?
2. What are the relationships among Chinese pre-service mathematics teachers' mathematics beliefs, pedagogical beliefs, attitudes towards ICT, and their beliefs about ICT use?

LITERATURE REVIEW

Pre-service teachers' mathematics beliefs

One common trend in previous research is to refer to teachers' beliefs as "psychologically held understandings, premises, or propositions about the world that are thought to be true" (Philipp, 2007, p. 259). Belief is generally thought as a multifaceted construct and normally, teachers will have various beliefs (Charalambos et al., 2008; Cross, 2009). With respect to mathematics teachers, their key belief components include their beliefs in relation to the nature of mathematics and its learning and teaching (Ernest 1989; Speer, 2005; Thompson, 1992).

Teachers' beliefs about the nature of mathematics refer to teachers' "conscious or subconscious beliefs, concepts, meanings, rules, mental images, and preference concerning the discipline of mathematics" (Thompson, 1992, p. 132). Regarding the construct of the nature of mathematics, many researchers proposed different views, which more or less correspond to each other. One widely cited view is the one proposed by Ernest (1989). He differentiated between three views about the nature of mathematics, including: 1) the Platonist view, portraying mathematics as a static body of knowledge that is discovered, not created; 2) the instrumentalist view, viewing mathematics as a useful but unrelated collection of facts, rules, procedures, and skills; and 3) the problem-solving view, portraying mathematics as a continually expanding field of human inquiry. Grigutsch et al. (1998) proposed four fundamental views on the nature of mathematics: formalism-related view, schemerelated view, process-related view, and application-related view. The first two views generally characterize mathematics as being static, like accurate results and infallible procedures, or a procedure-driven body of facts and formulas (Charalambous et al., 2008; Thompson, 1992). The later two views, however, conceptualize mathematics as a dynamic and continually expanding domain of knowledge based on sense-making and pattern-seeking (Felbrich et al., 2012; Thompson, 1992).

Teachers' beliefs about the nature of mathematics will underpin their beliefs about mathematics learning and mathematics teaching (Cross, 2009; Ernest, 1989; Philipp, 2007). Teachers' beliefs about mathematics teaching and learning refer to their views on the preferred ways of teaching and learning, such as their mental imagery of prototypical classroom teaching activities and what constitute appropriate and prototypical mathematics learning activities (Chan & Elliott, 2004; Ernest, 1989; Thompson, 1992). It has been widely argued that teachers' beliefs about mathematics teaching and learning play an influential role in determining the nature of teachers' purposes of teaching and directly affect numerous aspects of their professional work (Cross, 2009; Philipp, 2007). In the literature, teachers' beliefs about mathematics teaching and learning are generally classified into two main categories: 1) knowledge transmission view or traditional view, that is, mathematics teaching is conceptualized as a process of knowledge transmission, and students receive knowledge from teachers passively, and 2) constructivist view, that is mathematics teaching is conceptualized as facilitating students' knowledge construction (Chan & Elliott, 2004; Lim & Chai, 2008; Speer, 2005). Previous research has identified that for teachers who hold dynamic views of mathematics, they tend to hold constructivist views of learning and teaching, and tend to encourage students' inquiry activities so as to enrich students' mathematics experience (Chan & Elliott, 2004; Teo et al., 2008). In contrast, for teachers who hold static views of mathematics, they will focus more on teachers' explanation and knowledge transmission, and will emphasis drill-and-practice with students following rules and procedures or memorizing facts (Charalambous et al., 2009; Cross, 2009).

Although teachers' mathematics beliefs have been classified into different views in the literature as reviewed above, in reality, for a certain belief, it is quite difficult to say that teachers only hold one specific view. Instead, previous studies have found that pre-service teachers tend to hold different views, even some contradictory ones, at the same time. For example, recently, researchers found that some pre-service mathematics teachers believe that the nature of mathematics is open and creative, but on the other hand, they also believe that essentially, it is conservative and rigorous (Felbrich et al., 2012, Tang & Hsieh, 2014). Similarly, the intermingling of the two beliefs about mathematics teaching and learning, namely traditional view and constructivist view, was also identified among pre-service teachers in various contexts. Chan and Elliott (2004) found that pre-service teachers did not exclusively believe in the traditional or constructivist conception about teaching and learning. Tang and Hsieh (2014) found that pre-service mathematics teachers believe that students can learn mathematics through their initiations and also by following teachers' instruction.

Pre-service mathematics teachers' attitudes and beliefs about ICT

It is believed in the mathematics education community that appropriate integration of ICT will impact every aspect of mathematics education: what kind of mathematics is to be presented and how mathematics is taught and learned (Leung, 2013). Effective use of ICT in mathematics education could lead to a more learner-centered teaching practice, since the integration of ICT fundamentally changes the teacher-student interaction and the ways mathematics content is being presented to students (Pierce & Ball, 2009; Ertmer, 2005). These changes have been commonly believed to have positive effect on mathematics teaching and learning. For example, the use of ICT can enrich students' mathematics learning experience and improve students' interests in learning mathematics, and change their attitudes towards mathematics (Goos & Bennison, 2008; Jimoyiannisa & Komis, 2007; Pierce & Ball, 2009). More importantly, the effective integration of ICT can make mathematics (e.g., abstract concepts) more accessible to students and further facilitate students' understanding of mathematics concepts, develop students' problem solving skills, improve students' higher levels of mathematical thinking, and even generally improve students' mathematics achievement (Goos & Bennison 2008; Li & Ma, 2010).

Although ICT is believed to have positive benefits on mathematics education, in reality, sometimes teachers do not use ICT at all or use it in a very traditional way, like using ICT to sustain direct teaching (Ertmer, 2005; Goos & Bennison, 2008). Teachers' attitudes towards and beliefs about the use of ICT have been argued as a critical barrier for teachers to adopt and make effective use of ICT in practice (Ertmer et al., 2012; Pierce & Ball, 2009; Prestridge, 2012). Teachers' attitudes toward ICT can be conceptualized as teachers like or dislike the use of ICT in practice (Hew & Brush, 2007), or teachers believe that ICT is beneficial for mathematics teaching and learning or not (Pierce & Ball, 2009). People's attitudes are primary indicators of their intent to perform a behavior (Ajzen, 2005). Researchers have found that teachers' attitudes toward ICT were a much greater indicator of their intention to the use of technology than their other beliefs, like self-efficacy beliefs (Prestridge, 2012; Sang et al., 2010). Generally, more favorable attitudes towards ICT will encourage higher classroom ICT integration while negative attitudes discourage the use of it (Jimoyiannis & Komis, 2007; Sang et al., 2010). In mathematics education, it was found that it is only when teachers believe that the use of ICT will enhance students' mathematics learning or increase students' motivation, enjoyment and confidence compared with other approaches that they will consider to use technology (Hennessy et al., 2005; Pierce & Ball, 2009). If teachers believe that in order to demonstrate understanding of mathematics, a student must be able to solve problems without the assistance of ICT, or even believe that the use of ICT will hinder the development of students' ability, such as the ability of calculation, they will not integrate ICT in mathematics education, or use it in a very traditional knowledge transmission way (Goos & Bennison, 2008; Pierce & Ball, 2009).

Furthermore, teachers' decision of whether and how to use ICT in mathematics teaching mostly depends on their beliefs about technology (Ertmer, 2005; Ertmer & Ottenbreit-Leftwich, 2010). Generally, there are two discrete categories of views about the use of ICT in practice: transmission-oriented view and constructivist-view (Gurcay et al., 2013; Teo et al., 2008). The transmission-oriented view refers to that teachers believe that ICT is used as teaching machines to present information, reinforce students' drill and practice, and track student progress (Niederhauser & Stoddart, 2001; Teo et al., 2008). In contrast, the constructivist-view of using ICT means using ICT to expand traditional classroom boundaries, such as promoting student learning through collaborative involvement in authentic, challenging, multidisciplinary tasks by providing realistic events for student inquiry, and guiding students to become independent learners (Ertmer et al., 2012; Funkhouser & Mouza, 2013; Teo et al., 2008).

As to attitudes towards the effects of ICT use in mathematics education, mathematics teachers were not found to always hold positive attitudes. Both in-service and pre-service mathematics teachers in previous studies (e.g., Dogan, 2012;

Goos & Bennison, 2008; Pierce & Ball, 2009) were found to believe that the use of ICT is useful for mathematics teaching and learning, such as helping students to understand concepts and motivating students. However, they were also found to believe that the use of ICT is time consuming and it is not effective for the learning of some mathematics topics such as algebra. As to beliefs about the integration of ICT in practice, previous studies also found that teachers tend to hold mixed views. For example, pre-service teachers were found to believe in both traditional and constructivist ways of integrating ICT in their future teaching (e.g., Gurcay et al., 2013; Teo et al., 2008).

Moreover, teachers' beliefs about the use of ICT and its actual integration in practice are associated with teachers' beliefs about the nature of knowledge and beliefs about learning and teaching. Generally, teachers with more sophisticated beliefs about the source of knowledge were found to hold more constructivist-oriented beliefs about learning and teaching and are more likely to use ICT in practice or hold constructivist beliefs about ICT use (e.g., Deng et al., 2014; Kim et al., 2013). On the other hand, teachers who hold strong constructivist beliefs about teaching and learning were generally found to be more likely to use technology in the classroom than teachers who hold traditional beliefs about learning and teaching (Ertmer, 2005; Ertmer et al., 2012; Hermans et al., 2008). For example, Sang et al. (2010) identified that teachers with stronger constructivist-oriented beliefs were more inclined to integrate technology into their future teaching. Similarly, Ertmer et al. (2012) found that teachers with constructivist beliefs tended to use technology to support student-centered teaching.

However, previous studies also found that due to the influence of social and cultural conditions, especially for teachers from Eastern countries, even though they hold constructivist-oriented beliefs about learning and teaching, they will not always use ICT in a constructivist way in practice. For example, although Singaporean teachers in Lim and Chai (2008)'s study were found to hold constructivist beliefs, their lessons were predominantly traditional teacher-centric in nature. Similarly, only 28% of teachers who held learner-centered beliefs in Liu (2011)'s study implemented constructivist-based activities while the others utilized ICT to support lecture-based teaching in Taiwan. Previous studies further found that teachers' constructivist pedagogical beliefs are correlated with both constructivist and traditional beliefs about the use of technology (Gurcay et al., 2013; Teo et al., 2008). For teachers who hold traditional beliefs about teaching and learning, they will either use technology in a traditional approach (Ertmer, 2005; Hermans et al., 2008) or do not hold constructivist beliefs about the use of technology (Deng et al., 2014; Gurcay et al., 2013). Also, Teo et al. (2008) found that teachers' traditional pedagogical beliefs are negatively correlated with their constructivist beliefs about the use of technology.

METHODOLOGY

Participants

A total of 787 pre-service mathematics teachers from three teacher education universities in two provinces of China (Chongqing and Zhejiang) participated in the study. For these participants, most of them will work as secondary school teachers after the completion of pre-service education. Chinese pre-service secondary school teachers undergo a 4-year program offered in teacher education (or normal) universities. Since Chinese mathematics teachers, including most of the elementary mathematics teachers, are content specialists, pre-service mathematics teachers study in mathematics departments in normal universities. Because of its highly centralized education system, China provides nationwide curriculum specifications for pre-service mathematics teachers education (see Li et al., 2008 for more information). As a result, the curricula offered by the mathematics departments in different normal universities are quite similar. Generally, around 60% of the total pre-service teacher education curriculum hours are devoted to mathematics subject courses (e.g., advanced algebra, analytical geometry, function analysis, topology, etc.), with relatively little time being devoted to teaching practicum (around 8 weeks of fieldwork in schools at the third year or the fourth year) and professionally oriented studies (Li et al., 2008).

Among the 787 participants, there were 406 Year 3 and 381 Year 4 pre-service teachers. 301 of them were males and 479 were females (7 did not indicate their gender information). At the time of the investigation, the Year 3 participants were having their teaching practicum in schools and the Year 4 participants already completed their teaching practicum around one year ago. Both Year 3 and Year 4 pre-service teachers finished a course on general ICT skills and knowledge for integrating ICT in mathematics teaching.

Instruments

A questionnaire was employed in this study and it includes the following four scales:

Beliefs about the Nature of Mathematics (BNM)

The Chinese version of the Beliefs about the Nature of Mathematics scale developed in the Teacher Education and Development Study in Mathematics (TEDS-M) was adopted in this study to assess future mathematics teachers' beliefs about the nature of mathematics, and satisfactory reliability has been indicated in various contexts (Wang & Hsieh, 2014). This scale has two dimensions: mathematics as a process of inquiry (6 items, sample item: "In mathematics many things can be discovered and tried out by oneself") and mathematics as a set of rules and procedures (6 items, sample item: "Fundamental to mathematics is its logical rigor and preciseness"), which represent two major perspectives on mathematics—dynamic and static.

Beliefs about Mathematics Teaching and Learning (BMTL)

To investigate pre-service mathematics teachers' beliefs about mathematics teaching and learning, items were chosen from the Teaching and Learning Conceptions Questionnaire developed by Chan and Elliot (2004) in Hong Kong. This scale has two dimensions: Traditional Teaching and Constructivist Teaching. In this study, 7 items for the Traditional Teaching subscale and 5 items for the Constructivist Teaching subscale were chosen. Sample items in the Traditional Teaching and Constructivist Teaching subscales are "learning mathematics means remembering what the teacher has taught" and "effective mathematics teaching encourages more discussion and hands on activities for students" respectively.

Attitudes towards ICT (AICT)

To measure pre-service mathematics teachers' attitudes towards technology, items were chosen from several previous studies (e.g., Goos & Bennison 2008; Jimoyiannisa & Komis, 2007; Pierce & Ball, 2009). This scale has the following four sub-scales: Positive Attitude on Mathematics Teaching, Negative Attitude on Mathematics Teaching, Positive Attitude on Mathematics Learning, and Negative Attitude on Mathematics Learning. The Positive Attitude on Mathematics Teaching subscale has 7 items (sample item: "using ICT in mathematics teaching improves student engagement in my teaching"), each of the Positive Attitude on Mathematics Learning and Negative Attitude on Mathematics Teaching subscales has 5 items (sample items: "the use of ICT can facilitate students' understanding of mathematics" and "using ICT in mathematics teaching results in students neglecting important traditional learning resources" respectively), and the Negative Attitude on Mathematics Learning has 4 items (sample item: "the use of ICT erodes students' basic mathematics skills").

Beliefs about the Use of Technology (BUT)

This scale represents two ways of using ICT in mathematics teaching: Traditional Use of Technology, such as using ICT to mainly present teaching content or providing more time for students to practice basic mathematics skills; and Constructivist Use of Technology, such as using ICT to help students construct their own representations of mathematics concepts or providing students with experience and opportunities for self-discovery. Each subscale has five items and they were chosen from previous studies (e.g., Niederhauser & Stoddart, 2001; Teo et al., 2008).

Items in Scales 2, 3, and 4 were further modified to meet the Chinese mathematics education situation by the first author and another mathematics education researcher with rich knowledge in ICT use in schools. The modified version of the questionnaire was translated into Chinese by the first author and was further checked by two mathematics educators with good knowledge in English and Chinese. Modifications were made according to their suggestions. Items on all the scales were presented in a six-point Likert scale with 1 = "strongly disagree" and 6 = "strongly agree".

To validate the scales, exploratory factor analysis with varimax rotation was performed with the items in each of the scales. All the factors as originally designed were recognized for each scale and the eigenvalue of each factor from the principal component analysis was larger than one. In each of the recognized subscales, items with a factor loading larger than 0.40 on its own subscale and less than 0.40 on other subscales were retained. The number of items remaining in each of the subscales were listed in Table 1 and the recognized factors in each scale explained more than 50% (varying from 51.76% to 55.36%) of the variance. The internal consistency of each modified subscale after factor analysis was estimated using the Cronbach alpha reliability coefficient, which ranged from 0.666 to 0.869 as shown in Table 1, indicating a satisfactory level of internal consistency for statistical consideration.

Data analysis

Besides the use of statistical techniques such as factor analysis to examine the quality of the four scales as mentioned above, descriptive statistics, simple correlation analysis, and step-wise regression analysis were further conducted to analyze participants' responses to each of the scales. To obtain a sample description of participants' mathematics beliefs, beliefs about mathematics teaching and

Table 1. Basic statistical results and internal consistency reliability of the four scales

Scale	Factors	No. of items	Item Mean ± SD	α reliability
Mathematics Belief	Static Belief	5	3.97±0.68	0.666
	Dynamic Belief	5	4.55±0.76	0.789
Teaching and Learning Belief	Traditional Teaching	6	3.36±0.91	0.864
	Constructivist Teaching	6	4.55±0.80	0.869
Attitude toward ICT	Positive on Teaching	7	4.18±0.70	0.848
	Negative on Teaching	5	3.71±0.79	0.787
	Positive on Learning	7	4.19±0.70	0.842
	Negative on Learning	4	3.46±0.91	0.799
ICT use Belief	Traditional Use	5	3.94±0.73	0.755
	Constructivist Use	5	4.27±0.70	0.812

learning, attitudes towards ICT, and beliefs about ICT use, item mean score of each scale with standard deviation of the chosen scales were computed. Next, Pearson correlation analysis was conducted to examine the interrelationships among pre-service mathematics teachers' beliefs about the nature of mathematics, mathematics learning and teaching, attitudes towards ICT, and beliefs about ICT use. Moreover, step-wise regression analysis was performed to examine the predictive power of mathematics beliefs, pedagogical beliefs, and attitudes towards ICT on pre-service mathematics teachers' beliefs about ICT use.

FINDINGS

General situation of pre-service mathematics teachers' beliefs and attitudes

In order to make a general description of Chinese pre-service mathematics teachers' beliefs about the nature of mathematics, mathematics teaching and learning, attitudes towards ICT, and beliefs about ICT use, item mean score of each subscale and its standard deviation were calculated (see Table 1). As shown in Table 1, for beliefs about the nature of mathematics, the mean scores of both the Static Belief subscale and Dynamic Belief subscale are close to 4, which indicates that the participants in this study tended to moderately believe that mathematics is an open, practical and creative field on the one hand, and mathematics is rigor and involve the application of a set of fixed procedures on the other hand. However, the item mean score of Dynamic Belief subscale is greater than the item mean score of Static Belief subscale, which illustrates that the surveyed pre-service mathematics teachers' dynamic mathematics beliefs are stronger than their static beliefs. With respect to beliefs about mathematics teaching and learning, the item mean score of Traditional Teaching subscale is close to 3 and the item mean score of Constructivist Teaching subscale is greater than 4. This means that the pre-service mathematics teachers in this study reflect low level of traditional beliefs about mathematics teaching and learning but they reflect relatively high level constructivist beliefs.

As seen in Table 1, for attitude towards ICT, the item mean scores of negative attitude subscales are both lower than 4, but the item mean scores of positive attitude subscales are both greater than 4. This indicates that the pre-service mathematics teachers tended to believe that ICT has a relatively stronger positive impact on mathematics teaching and learning. However, both Traditional Use and Constructivist Use subscale mean scores for the pre-service mathematics teachers are around 4, which indicates that they tended to hold constructivist and traditional beliefs about the use of ICT at the same time.

Relationships among Pre-service teachers' mathematics beliefs, pedagogical beliefs, attitudes towards ICT, and beliefs about ICT use

In order to understand the relationships among pre-service mathematics teachers' beliefs about the nature of mathematics, beliefs about mathematics teaching and learning, attitudes towards ICT, and their beliefs about ICT use, Pearson correlation analysis based on their responses to the four scales was performed. As shown in Table 2, both the Static Belief and Dynamic Belief were found to be significantly and positively correlated with Constructivist Use and Traditional Use of ICT (r-values range from 0.16 to 0.50). However, only the correlation between Dynamic Belief and Constructivist Use has a coefficient larger than 0.5, suggesting a moderate relationship (Cohen, 1992). For the relationships involving beliefs about mathematics learning and teaching, as seen in Table 2, Traditional Teaching was only significantly correlated with Traditional Use while Constructivist Teaching was significantly correlated with both Traditional Use and

Table 2. Correlations among the subscales in the four instruments: BNM, BMTL, AICT, and BUT

	Beliefs about ICT use (BUT)	
	Traditional Use	**Constructivist Use**
Beliefs about the nature of mathematics (BNM)		
Static Belief	0.30***	0.29***
Dynamic Belief	0.16***	0.51***
Beliefs about mathematics teaching and learning (BMTL)		
Traditional Teaching	0.40***	0.06
Constructivist Teaching	0.16***	0.57***
Attitude toward ICT (AICT)		
Positive attitude on mathematics teaching	0.52***	0.62***
Negative attitude on mathematics teaching	0.29***	0.05
Positive attitude on mathematics learning	0.42***	0.57***
Negative attitude on mathematics learning	0.25***	-0.02

*Note: ***p<0.001*

Constructivist Use. However, the relationship between Constructivist Teaching and Traditional Use is rather weak (r-value=0.16) and the relationship between Constructivist Teaching and Constructivist Use is relatively stronger (r-value=0.57).

For the relationships between attitudes towards ICT and beliefs about ICT use, as seen in Table 2, the results of the correlation analysis reveal that all the subscales of attitude are significantly correlated with Traditional Use (r-values range from 0.25 to 0.52). The subscales of positive attitudes are significantly correlated with Constructivist Use (r-values range from 0.57 to 0.62), but not the subscales of negative attitudes towards mathematics teaching and learning. In addition, there was a weak negative association (-.0.02) between Constructivist Use and negative attitudes towards mathematics learning. Moreover, as shown in Table 2, even though the two subscales of positive attitudes towards ICT tended to be positively correlated with both Traditional Use and Constructivist Use, the relationships between Constructivist Use and positive attitudes are stronger. In contrast, the relationships between Traditional Use and the two subscales of negative attitudes towards ICT are much stronger than the relationships between Constructivist Use and negative attitudes. This suggests that negative attitudes towards ICT are likely to have significantly positive correlations with traditional beliefs about ICT use; in contrast, positive attitudes towards ICT are more likely to have positive correlations with constructivist beliefs about ICT use.

Stepwise multiple regression estimates for predicting pre-service mathematics teachers' beliefs about ICT use

Stepwise multiple regression analyses were conducted to identify the predictive effects of the BNM, BMTL, and AICT scales on the scales of the BUT instrument. The subscales of BNM, BMTL, and AICT were used as predictive variables to construct two regression models of the subscales in the BUT. First, as shown in Table 3, the pre-service mathematics teachers' beliefs about traditional use of ICT could be significantly explained by three of the subscales (with the except of Negative Attitude on Mathematics Learning) in AICT and the subscale of traditional beliefs about mathematics learning and teaching (F=140.36, p<0.001). All of the four significant predictors of Traditional Use were positive (β ranges from 0.10 to 0.40 and t ranges from 2.72 to 12.10). Secondly, the pre-service mathematics teachers' beliefs about constructivist use of ICT could be significantly explained by two attitude subscales (Positive Affect on Mathematics Teaching and Positive Affect on Mathematics Learning), one mathematics belief subscale (Dynamic belief), and one mathematics learning and teaching subscale (Constructivist Teaching) (F=204.13, p<0.001). All these four significant predictors of Constructivist Use were positive (β ranges from 0.09 to 0.29 and t ranges from 2.90 to 8.57).

Table 3. Stepwise regression model of predicting pre-service teachers' BUT by BNM, BMTL, and AICT (n=787)

Beliefs about ICT use	Predictors	β	Adjusted R^2	t	F
Traditional Use	Constant		0.42	2.76**	140.36***
	Positive attitude on teaching	0.44		12.10***	
	Traditional teaching (TT)	0.25		10.93***	
	Negative attitude on teaching	0.10		3.70***	
	Positive attitude on learning	0.10		2.72**	
Constructivist Use	Constant		0.52	4.45***	204.13***
	Positive attitude on teaching	0.29		8.35***	
	Constructivist teaching (CT)	0.26		8.57***	
	Positive attitude on learning	0.21		6.29***	
	Dynamic belief (DB)	0.09		2.90**	

*Note: **p<0.05, ***p<0.001*

Some further information can be observed from Table 3. First, among the six significant predictors for the two ICT use belief subscales, three of them belong to the attitude scale. However, even though the two attitude subscales, Positive Affect on Mathematics Teaching and Positive Affect on Mathematics Learning, could both significantly predict Traditional Use and Constructivist Use, only Negative Attitude on Mathematics Teaching could significantly predict Traditional Use. Second, among the two subscales of mathematics learning and teaching belief, the Constructivist Teaching subscale could only significantly predict Constructivist Use while the Traditional Teaching Subscale could only predict Traditional Use. Moreover, among the two subscales of mathematics belief, only the Dynamic Belief subscale could significantly predict Constructivist Use. In general, the results of the stepwise regression analysis suggest that dynamic belief about mathematic, constructivist beliefs about mathematics teaching and learning, and positive attitudes towards ICT were more likely to positively explain the beliefs about constructivist use of ICT in practice. In contrast, negative attitudes towards ICT and traditional beliefs about mathematics teaching and learning were more likely to positively predict traditional beliefs about ICT use.

DISCUSSION

The main objective of the study is to investigate Chinese pre-service mathematics teachers' beliefs about the nature of mathematics, beliefs about learning and teaching, and beliefs about the use of ICT, and the relationships among them. Based on the item mean scores for the two subscales of nature of mathematics (BNM) as shown in Table 1, it seems that this sample of Chinese pre-service mathematics teachers both agree to the static and the dynamic perspective on mathematics. That is, they tend to see the nature of mathematics from a mixed perspective of Platonist views, instrumentalist views, and problem-solving views (Ernest, 1989). This finding is consistent with findings in previous studies (e.g., Felbrich et al., 2012; Tang & Hsieh, 2014) which found that pre-service mathematics teachers tend to hold intermingled beliefs about the nature of mathematics.

In addition, according to the item mean scores for the two subscales of beliefs about mathematics teaching and learning (BMTL), it seems that the sampled teachers are more inclined to hold constructivist rather than traditional view of mathematics teaching and learning. That is, they believe that to teach mathematics effectively, students should be actively involved and have opportunities for inquiry activities and discussion. In addition, it is also believed that teachers should act as facilitators rather than knowledge transmitters. These results are not consistent with earlier studies regarding pre-service teachers' beliefs about teaching and learning in other contexts (e.g., Chan & Elliott, 2004; Tang and Hsieh, 2014). As reviewed above, past studies found that pre-service teachers held both traditional and constructivist conceptions about teaching and learning. Chinese pre-service mathematics teachers' constructivist view of mathematics teaching and learning as identified in the present study, together with their views on the nature of mathematics, may be influenced by ideas as proposed in the current reformed national mathematics curriculum. Dynamic view of mathematics and learner-centered view about mathematics learning and teaching have been proposed in China for several years, and these views might have been integrated into the pre-service teacher education curriculum (Ni et al., 2014). This implies that like pre-service teachers in other contexts (e.g., Gurcay et al., 2013; Teo et al., 2008), the pre-service mathematics teachers in this study are not against the reformed ideas of mathematics education.

Similarly, results in this study indicate that the sampled pre-service mathematics teachers tend to hold positive attitudes towards the use of ICT in mathematics education. In other words, they agree that the use of ICT can improve students' interests and motivation, and can change students' attitudes towards mathematics and mathematics learning. However, to a certain degree, they also agree that the use of ICT in mathematics education is time-consuming, and students cannot completely depend on ICT for effective learning of mathematics. Similar findings were also identified in previous studies. Dogan (2012) found that pre-service mathematics teachers in Turkey emphasized that computer is helpful for mathematics teaching, but they also demonstrated negative feelings about computer-based mathematics education. As to pre-service mathematics teachers' beliefs about how to use ICT in teaching, findings in this study indicate that they believe in both traditional and constructivist use. However, unlike what has been found in previous studies (e.g., Teo et al., 2008), the surveyed pre-service mathematics teachers tend to hold a relatively stronger constructivist belief about ICT use.

Another main aim of this study is to examine the relationships between Chinese pre-service teachers' mathematics beliefs, attitudes toward ICT, and their beliefs about ICT use. Findings as reported above suggest that there is a significant association between pre-service mathematics teachers' beliefs about the nature of mathematics and their beliefs about ICT use. More specifically, the pre-service mathematics teachers' dynamic belief about mathematics, compared with static belief about mathematics, may be more associated with their constructivist belief about ICT use. This kind of association is consistent with arguments as proposed by previous researchers and the findings in previous research. For example, Olive et al. (2010) argued that if mathematics is considered as a fixed body of knowledge to be learned, the role of technology in mathematics teaching would be primarily an efficiency tool to help students practice mathematics more efficiently. Meanwhile, previous studies also found that teachers who hold more sophisticated epistemic beliefs about the nature of knowledge are more likely to hold constructivist beliefs about ICT use (Deng et al., 2014; Kim et al., 2013).

In addition, this study also identified that there is a significant correlation between pre-service mathematics teachers' beliefs about mathematics teaching and learning and their beliefs about the use of ICT. However, even though like what has been found in previous studies (e.g., Gurcay et al., 2013; Teo et al., 2008), pre-service mathematics teachers' constructivist pedagogical belief is positively correlated with both constructivist and traditional beliefs about ICT use, the association between constructivist pedagogical belief and constructivist belief about ICT use is much stronger than the association between constructivist pedagogical belief and traditional belief about ICT use. In addition, unlike what has been found in previous studies (e.g., Gurcay et al., 2013; Teo et al., 2008), this study found that pre-service mathematics teachers' traditional pedagogical belief is positively correlated with their traditional belief about ICT use. Moreover, it is worthy to note that constructivist pedagogical belief can only positively predict the constructivist belief about ICT use, and traditional pedagogical belief can only positively predict the traditional belief about ICT use. Results such as these support previous findings that teachers who hold constructivist beliefs tend to use technology to support student-centered teaching; while those with traditional beliefs tend to use ICT to support teacher-directed teaching (e.g., Ertmer 2005; Hermans et al., 2008).

Moreover, a significant correlation between pre-service mathematics teachers' attitudes towards ICT and their beliefs about ICT use was also identified in this study. Pre-service mathematics teachers' positive and negative attitudes towards ICT are both positively correlated with their traditional beliefs about ICT use. However, this study revealed that only positive attitudes toward ICT are more likely to be positively correlated with pre-service mathematics teachers' constructivist belief about ICT use. In addition, among the three predictors, namely beliefs about the nature of mathematics, beliefs about mathematics teaching and learning, and attitudes toward ICT, it is worthy to note that positive attitude toward ICT on teaching seems to be the strongest predictor of beliefs about ICT use. This finding is in accordance with previous studies involving pre-service teachers. For example, Sang et at. (2010) found that Chinese pre-service teachers with more favorable attitudes towards computer in education are more interested to integrate computers in their future teaching practice; and among teachers' thinking variables, attitudes towards computer use is the strongest predictor of prospective computer use.

CONCLUSIONS, LIMITATIONS AND SUGGESTIONS

This study is one of the very few studies that investigate the relationships among Chinese pre-service mathematics teachers' beliefs about the nature of mathematics and its learning and teaching, attitudes towards ICT, and their beliefs about ICT use. Generally, Chinese pre-service mathematics teachers in the present study were found to hold an intermingled dynamic and static view of mathematics, a relatively more constructivist belief about mathematics learning and teaching, relatively more positive attitudes towards ICT, and an intermingled traditional and constructivist view of ICT use. The findings indicated that pre-service mathematics teachers' dynamic belief about the nature of mathematics, constructivist belief about mathematics learning and teaching, and positive attitudes towards ICT are more likely to be correlated with their constructivist belief about the use of ICT. In contrast, pre-service mathematics teachers' traditional beliefs about the nature of mathematics and its learning and teaching are more likely to be associated with their traditional beliefs about the use of ICT. However, pre-service mathematics teachers' positive and negative attitudes towards ICT are both correlated with their traditional beliefs about ICT use.

There are a number of limitations with this study. This study only employed questionnaire to collect data; future studies may include more than one method of data collection, such as interviews and self-reports, to achieve greater validity of the data and a deeper understanding of the relationships among pre-service mathematics teachers' mathematics beliefs, attitudes towards ICT and their beliefs about ICT use. Future studies could also consider examining gender differences and grade differences for a deeper understanding of pre-service mathematics teachers' beliefs and the relationships among these beliefs. In addition, this study only focused on the investigation of pre-service secondary school mathematics teachers' mathematics beliefs, attitudes towards ICT, and their beliefs about ICT use. How they actually use ICT in classroom teaching is not studied. However, as reviewed above, teachers' beliefs and their classroom teaching practice are not always consistent (Lim & Chai, 2008; Liu, 2011). Future studies could consider exploring the relation between pre-service mathematics teachers' beliefs about ICT and how they integrate ICT in their teaching practicum. Findings such as this will not only contribute to deeper understanding of pre-service teachers' ICT beliefs, but will also provide useful information for the design of effective pre-service teacher education program.

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