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What Are You Doing in the Mathematics Classroom? Using a Drawing Task to Investigate Pre-service Teachers' Beliefs About Mathematics Teaching and Learning[1]

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Drawing-based methods are one of well-regarded alternative approaches to the study of teacher beliefs. However, they are seldom used to study mathematics teachers' beliefs. As such, this study aimed to investigate 90 Taiwanese pre-service primary teachers' beliefs about mathematics teaching and learning using a drawing task, specifically creating pictures of themselves as mathematics teachers at work and writing explanations of the content of those drawings. Data were analyzed via a scoring scheme and a coding framework revised from previous studies. The study found that: (a) the participants' drawings mainly represented a mix of traditional and constructivist beliefs, with rare uses of technology and manipulatives; (b) around 30% of the drawings presented teachers or students as having positive emotions or attitudes toward mathematics teaching and learning, while around 15% depicted negative student behaviors; (c) because the participants could have used a few figures to represent more, the number of students drawn per picture (M = 11.1) might not have any specific meaning, but might reflect their ideals about class size; (d) participants with different levels of educational degrees and different attitudes toward mathematics seem to have revealed differing beliefs about mathematics teaching; (e) these results imply that these pre-service teachers held somewhat less traditional beliefs than stereotypes of the younger generation of teachers tend to suggest. Practical implications and suggestions for follow-up studies were also discussed.

Keywords: *beliefs; drawing; mathematics; pre-service teachers; teacher education*

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Teachers' beliefs related to teaching and learning significantly influence their instructional practices, including how they design and plan learning activities for their classrooms (Leatham, 2006; Philipp, 2007). As such, teachers' beliefs also have an impact on learners' beliefs about learning mathematics (Y. C. Chan & Wong, 2014), and have been found to significantly influence their students' learning outcomes (Philipp, 2007).

Understanding pre-service primary teachers' beliefs is a very important aspect of mathematics teacher education. As compared to their in-service counterparts, these teachers usually hold more traditional beliefs, but their beliefs were also more easily changed (Wall, 2016), and such changes usually start during and because of their participation in university teacher-education programs (Jao, 2017). As such, teacher educators aiming to modify pre-service teachers' traditional beliefs via specific instructional strategies or learning materials should first seek to develop an understanding of such beliefs as comprehensive and detailed as possible. It should also be borne in mind that primary pre-service mathematics teachers usually have weaker mathematics knowledge than their secondary pre-service colleagues (Blömeke & Delaney, 2014), and this relative weakness tends to prevent them from developing constructivist beliefs (Beswick & Callingham, 2014). As such, primary pre-service teachers' beliefs are worthy of considerably more research attention.

Prior studies have also indicated that using traditional methods such as Likert scale questionnaires, interviews, and observations may not yield a rounded understanding of teachers' beliefs, and therefore have recommended the development of alternative research methods (Philipp, 2007; Speer, 2005). Specifically, many researchers have endorsed drawing-based methods (e.g., Chang et al., 2020; Minogue, 2010; Thomas et al., 2001), which can be considered a type of open-ended survey in which respondents provide rich data, including aspects of their beliefs that they may not be fully aware of.

Although drawing-based methods are common in the field of psychology, using them to study teacher beliefs may not have enough emphasis (Chang et al., 2020), particularly in the field of mathematics education. As such, educational scholars have not yet developed a sophisticated coding framework for analyzing such beliefs in mathematics teacher education. Additionally, although some studies have shown that participants' background differences (e.g., gender) relate to their beliefs (Devine et al., 2013), such relationships have not been examined using drawing-based methods, which might yield richer results or even different ones.

Thus, this study used a drawing task adapted from the famous Draw-a-Science-Teacher-Test Checklist (DASTT-C) (Thomas et al., 2001) to examine pre-service mathematics teachers' beliefs. By revising existing coding frameworks, this study developed a new version of the DASTT-C suitable to analyze the beliefs of mathematics teachers. The study also assessed the relationships between their beliefs as suggested by their drawings and captions on the one hand, and their background variables (including gender, degree level and attitude toward mathematics) on the other.

Literature Review

Definition of Beliefs

Research on teacher beliefs has been fraught with challenges due to differing definitions of the word "beliefs" (Nespor, 1987). For example, as Philipp (2007) reported, affect researchers have tended to regard beliefs as a component of affect, whereas most others interested in the topic have argued that beliefs are a distinct construct. A separate issue pointed out by Shilling-Traina and Stylianides (2013) is that beliefs, conceptions, and views are used almost interchangeably, rendering it very difficult to precisely discuss any one of them or the differences between them. As a consequence, the word "beliefs" is described as a messy construct by Pajares (1992) and as a sensible system (i.e., with no need to be coherent) by Leatham (2006).

Beliefs are similar to propositions or premises, in that they are mental constructs of what holds true in the world; usually, they are conceived of as a lens that influences one's view of some aspect of the world and/or disposes one toward certain behaviors (Philipp, 2007). However, in the absence of an agreed-upon definition of teacher beliefs, this article adopts a broader view of belief: as general mental structures, integrating both cognitive and affective components, that include views, conceptions, meanings, concepts, propositions, and mental images (Goldin et al., 2016), and that connect the domains of affect, identity, and knowledge (Pajares, 1992).

Pre-service Teachers' Beliefs

In general, pre-service teachers entering teacher education programs in university hold more traditional beliefs than when they leave (Jao, 2017). Also known as teacher-centered beliefs, these include the idea that the teacher should dominate the entire teaching process (Jao, 2017). In this view, students are passive receivers who obtain knowledge transmitted by their teachers and textbooks, and step-by-step learning processes are emphasized and highly valued. As such, one of the major goals of pre-service teacher education is to change these beliefs in a more student-centered direction (student-centered beliefs or reformed-based beliefs). In contrast to those who hold traditional beliefs, teachers with student-centered beliefs are inclined to perceive students as active learners who can construct their own knowledge via active investigation and meaningful exploration (Ren & Smith, 2018). Teachers, in this view, are facilitators: emphasizing students' prior knowledge during the learning process, and helping them to engage in active learning. A third type of teacher beliefs, referred to as mixed beliefs, is located between these two extremes (Thomas et al., 2001). It implies a mindset in which teachers still dominate the classroom, but allow some space for students to explore concepts on their own.

Various studies have outlined how these three types of beliefs might be revealed in teachers' drawings (e.g., Minogue, 2010; Thomas et al., 2001). For example, teacher-centered beliefs are frequently manifested in drawings that show the teacher standing at the front of the classroom, introducing or explaining a concept, while seated students listen. In contrast, drawings indicative of student-centered beliefs often show no teacher, or the teacher engaged in activities alongside the students in a classroom arranged for group work; the students in such pictures, meanwhile, tend to be exploring concepts, asking questions, or discussing ideas with others. Lastly, drawings with mixed beliefs contain both teacher-centered and student-centered elements. That is, the teacher might be standing in front of the class to introduce a concept, but the students are also exploring it in groups or by themselves.

Advantages of Using Drawings in Beliefs Research

Using drawings to study beliefs may trace to Mead and Métraux (1957). Their study on images of the scientist among high-school students seems to open the door to the extensive use of drawing as a research instrument. Researchers have indicated several advantages of using drawings in studying beliefs:

1. Not only can drawings provide a rich source of information about a person's mental images of a particular phenomenon, they can also provide insights on the place of objects within the phenomenon, including their arrangement in physical space and their actions (Hancock & Gallard, 2014).
2. Unlike Likert scale questionnaires, drawing tasks do not require research participants to take a stand regarding their agreement or disagreement with particular statements.

This lack of prompting can afford the researcher a more in-depth understanding of the phenomenon under study.

3. Additionally, the use of drawings can bypass the articulation difficulties of participants who may find it challenging to write or speak about abstract beliefs (e.g., Hsieh & Tsai, 2018). In particular, some of their beliefs are even implicit or unconscious (Buaraphan, 2011).
4. Finally, it may reduce participants' stress when compared to the traditional interview method, therefore allowing them to express ideas more freely (Lee & Zeppelin, 2014).

In sum, teacher beliefs are often abstract and complex and not easy to capture, but the drawing method has the advantages for exploring them.

Drawing-a-Science-Teacher-Test Checklist

Among the drawing-based instruments for studying teacher beliefs, DASTT-C by Thomas et al. (2001) is most frequently used, whether in its original or adapted form (e.g., Minogue, 2010). This instrument's popularity is ascribable not only due to its pioneering nature, but also because of its well-validated analysis framework and scoring scheme. More importantly, the core element of such instruments is usually fixed, that is, "to make a classroom teaching drawing." Variations can be found in their prompts, which might ask about participants' past experience versus their current thinking about a particular kind of teaching. However, researchers can easily change such prompts to fit their own research purpose.

The original DASTT-C asks the participant to draw a picture of himself or herself at work that reflected his or her self-perceptions as a science teacher. In order to facilitate a clearer understanding of the ideas in these drawings, as well as drawings made by individuals with less artistic skill, the instrument also asks for written descriptions of every drawing. As described in the Methods section of this article, the version in this study extends this written component via *written follow-up questions*, drafted after initial review of the image.

The analysis framework of the original DASTT-C is principally score-based. A score point is assigned to each of the 13 teacher-centered attributes in the drawings. As such, high total scores (10–13) for a given drawing indicate the participant's teacher-centered beliefs, while low total scores (0–4) reflect student-centered beliefs. Thomas et al. (2001) conducted a validation process on DASTT-C and reported a high degree of internal consistency (coefficient alpha .82 in KR20).

Obstacles to Using the Drawing Method

The validity of using drawings to study teacher beliefs has been confirmed, and many studies using it have been conducted (e.g., Minogue, 2010; Thomas et al., 2001).

However, like any other research approach, the drawing method is not perfect. Prior literature has indicated the following limitations. First, when participants have poor drawing skills or find the drawing method strange, their beliefs might not be accurately reflected in their drawings. To deal with this issue, and to avoid relying on drawings alone, researchers have usually required participants to write explanations of what they have depicted. Going beyond that, the current study asked its participants to write their responses to follow-up questions, as a further chance to clarify their thoughts. Second, as an open-ended approach, the drawing method is not easy to analyze (Ozden, 2009). To overcome this challenge, this study took great care when generating coding scheme, as described in the Methods section below.

Mental Images of Classroom Teaching

The pictures captured by the drawing task are generally participants' mental images (Tatar et al., 2012). They can arise either from memories or from reconstructions of the remembering process (Kosslyn, 1985). They are also components of mental models (Thomas et al., 2001), and such models serve as foundations for teachers' beliefs (Norman, 1983). Therefore, drawn mental images are usually thought to be a useful means of capturing teacher beliefs that cannot easily be assessed using traditional interview and survey methods (e.g., Tatar et al., 2012).

Calderhead and Robson (1991) summarized two general types of these images. They are "episode memories, relating to particular significant events or people" (p. 4), or more general images abstracted from their experiences (e.g., as students). However, no matter which type of images they generate, both could reflect teachers' implicit beliefs or feelings about teaching.

Research on Mathematics Teachers' Beliefs

Based on their respective reviews of relevant studies, Goldin et al. (2016) identified two major trends in research on mathematics teachers' beliefs: (a) inconsistency between such beliefs and actual instructional practices, and (b) change in beliefs over time. Those researching the first trend have mainly focused on methodology issues. For example, Speer (2005) thought that apparent inconsistency was, in fact, mainly due to a lack of shared understandings of the meanings of the terms used by teachers and researchers. To avoid this problem, Cross Francis (2014) encouraged researchers to study a broader set of beliefs, less directly related to teaching mathematics (i.e., beliefs about students, or beliefs about oneself). Beswick (2007), on the other hand, recommended a focus on contextually bounded beliefs (i.e., how beliefs, among other factors, interact with the teaching context) (see also Chen & Leung, 2015).

The second of the two research trends mentioned above has mainly focused on how to facilitate belief change within teacher-education programs. For example, Grootenboer (2008) reported that change in beliefs about mathematics teaching and learning could be facilitated by boosting pre-service teachers' awareness of their beliefs and encouraging them to reflect upon them. Liljedahl (2010) subsequently devised a five-part typology of paths to rapid and profound belief change. Among these paths, he emphasized conceptual change, a category rooted in conceptual-change theory. Also, Paolucci (2015) explored whether studying more advanced mathematics as part of their postsecondary education made teachers more likely to develop reformed teaching beliefs, concluding that it did not.

Goldin et al. (2016) further proposed that two research directions, currently under-emphasized by scholars, are ripe for further investigation. These are mathematics teachers' beliefs about (a) specific mathematics topics and (b) using technology in the mathematics classroom.

From the above discussion, it would seem that the most crucial issues confronting research on mathematics teachers' beliefs are methodological. To address those issues, researchers have recommended using batteries of disparate methods (e.g., surveys, interviews, and classroom observations). However, such recommendations have generally ignored drawing methods, despite the above-mentioned strong methodological potential. For example, the concreteness of a drawing of mathematics teaching could help to avoid participant-researcher misunderstandings arising from differences in their definitions of the same terms.

Due to the drawing method being so rarely used in studies of mathematics teachers' beliefs, the current study can be expected to make a useful contribution to that body of research, by comparing prior results derived from surveys against those arrived at using the drawing method adopted here. In particular, the researcher would like to revisit past research relying on surveys that reported pre-service teachers as generally holding traditional beliefs about mathematics teaching and learning (Philipp, 2007). Secondly, the researcher plans to explore whether a drawing-based approach to data collection will produce unexpected results vis-à-vis participants' backgrounds and self-reported beliefs. Thirdly, the researcher hopes that such an approach can yield important new insights about the hitherto under-studied beliefs about using technology that are held by mathematics teachers specifically.

Research Purpose and Questions

Accordingly, the purpose of this study is to investigate pre-service teachers' beliefs about mathematics teaching and learning via a drawing task. Its specific research questions are:

1. What are the beliefs about teaching and learning that can be detected in the drawings?
2. What are the key features (e.g., typical teacher image, teacher and student size differences, technology use) depicted in the drawings?
3. How do teachers' beliefs about teaching and learning approaches potentially relate to their genders, degree programs, and general mathematics attitudes?

The first question can be answered by using the scoring scheme; the second, by the coding framework of this study; and the third, by comparing the drawing results against the participants' background information.

Methods

Participants

The participants in this study comprised 90 pre-service primary teachers (20 males and 70 females). At the time of data collection, all were enrolled in one of two Taiwanese public universities. In their degree programs, they were training to teach all curriculum subjects in primary schools, but in the Taiwanese situation, most of them would likely be asked to teach mathematics and the Chinese language once they became in-service teachers. In terms of educational level, most were undergraduate students (*n* = 67), and the rest (*n* = 23) master's students.

Drawing Task

This study's drawing task was adapted from Thomas et al. (2001), and the only change to the prompt was to alter "science teacher" to "mathematics teacher." As such, each participant was asked to "draw a picture of himself or herself as a mathematics teacher at work" and to "write an explanation of what the teacher and the students are doing in the picture." Around two weeks later, after the preliminary analysis had been completed, the participants were also asked follow-up questions aiming at clarifying the researcher's impressions of their drawings.

Development of the Coding Framework (Coding Scheme)

To analyze the pre-service teacher beliefs that emerged from the drawing task, this study adapted a technique called emergent analytic coding (Haney et al., 2004). First, the study reviewed existing coding frameworks relevant to its research purpose (e.g., Hsieh & Tsai, 2018; Thomas et al., 2001) to form a preliminary coding framework. Based on that review, five most common categories in such frameworks were found:

1. *actors* (who was involved: teachers or students);
2. *actions* (what the actors were doing: e.g., a teacher is lecturing);
3. *emotions* (the actors' emotions or attitudes);
4. *positions* (the actors' positions or postures);
5. *environment* (objects in class or classroom arrangements: e.g., stationery, desks arranged in rows).

These five categories were used to create the preliminary version of the coding framework. Using it, two researchers worked independently to code an initial sample of 30 drawings. While coding, they also recorded features of the drawings that were not reflected in the coding framework. Then, both researchers compared and discussed their coding results and the out-of-framework features they had recorded. If they both agreed that a particular new feature should be added to the coding framework, it was added. In cases where one coder wanted to add a new feature and the other did not, the idea was discussed until an agreement to include or exclude it was reached. In the end, this process resulted in a second version of the coding framework. Then, two other researchers used this second version to code a second sample of 30 drawings. The percentages of their agreements were calculated and compared, and any features with an agreement of less than 80% were eliminated. This process yielded the final version of the coding framework used in this study.

Table 1 presents this study's final coding framework and coding results, which are divided into six dimensions: (a) tool, (b) teaching content, (c) teacher, (d) students, (e) environment, and (f) size difference. The focus of *tool* is whether the teacher is shown using any technology or manipulatives. *Teaching content* is an assessment of what is depicted as being taught, especially in terms of its relationship to grade level. The *teacher* and *students* dimensions both focus on the depicted figures' main activities and positions, but where discernible, their emotions or attitudes were also recorded. *Environment* records how the drawn classroom is arranged, and whether it contains any symbols of teaching or learning (e.g., a chalkboard or stationery). Finally, *size difference* looks at whether the relative sizes of the drawn teachers and their students reflect the participants' conceptions of teachers' authority. A coding example is shown in Figure 1.

Data Collection and Analysis

The data were collected during two 50-minute classes of education course at two different universities. At the beginning of the class, the participants were told that there was no pressure, and they could freely decide whether or not to participate in the study. In addition to completing the drawing task, the participants were asked to provide background information (i.e., gender, degree program, and attitude to mathematics). They had to complete all requirements of the task within 50 minutes and were told after submitting the drawings that they would not be allowed to revise them.

Preliminary analysis to produce follow-up questions

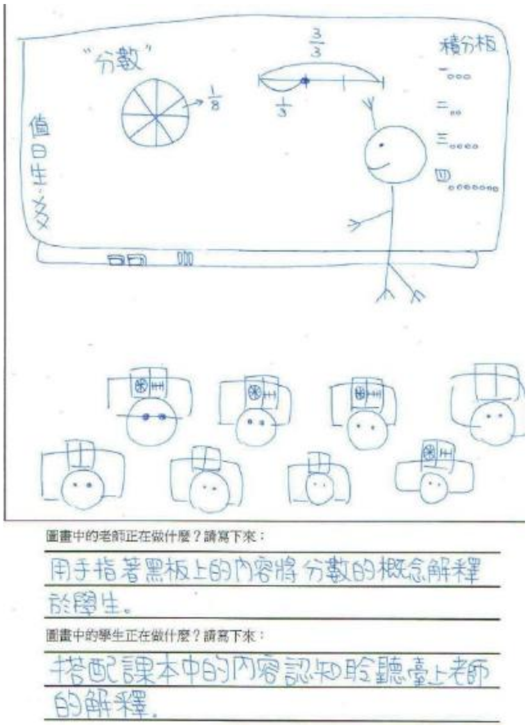
Around two weeks later, the researchers conducted a preliminary analysis to review the collected drawings and asked 32 participants, selected for the reasons explained in the next paragraph, follow-up questions aiming at clarifying the impressions of their drawings. During the preliminary phase of data analysis, three researchers worked together to quickly review these drawings, and proposed possible follow-up questions. The three researchers

Table 1: Coding and Scoring Scheme

Dimension	Category	Code		
Tool (O)	O1. Technology	(1) Present	(2) Not present	
	O2. Manipulatives	(1) Present	(2) Not present	
Teaching content (C)	C1. Maths domains	(1) Not indicated	(2) Algebra	(3) Geometry
		(4) Numbers and operations	(5) Statistics	(6) Others
	C2. School level	(1) Not indicated	(2) Primary school	
		(3) Secondary school	(4) Others	
Teacher (T)	T1. Teaching activity	(1) Lecturing*	(2) Guiding	(3) Doing maths
		(4) Mixed	(5) Others	
	T2. Teacher location	(1) At the front*	(2) Others	
	T3. Teacher posture	(1) Not indicated	(2) Standing up*	(3) Sitting down
	T4. Teacher emotion	(1) Not indicated	(2) Positive	(3) Negative
	T5. Teacher gender	(1) Not indicated	(2) Male	(3) Female
Students (S)	S1. Student activity	(1) Listening*	(2) Explaining	(3) Discussing
		(4) Doing maths	(5) Mixed	(6) Others
	S2. Student position	(1) Not indicated	(2) Standing up	
		(3) Seated*	(4) Mixed	
	S3. Number of students	(1) all students	(2) males	(3) females
	S4. Student attitude	(1) Not indicated	(2) Negative	
		(3) Positive	(4) Mixed	
Environment (E)	E1. Classroom arrangement	(1) Not indicated	(2) In traditional rows*	
		(3) In groups	(4) In a circle	
	E2. Classroom location	(1) Indoor	(2) Outdoor	
	E3. Chalkboard	(1) Present*	(2) Not present	
	E4. Student stationery	(1) Present*	(2) Not present	
	E5. Student textbooks	(1) Present*	(2) Not present	
	E6. Teacher lectern	(1) Present*	(2) Not present	
Size difference (D)		Too much: the teacher as more than doubling the size of the students	Normal: the teacher and his or her students are of realistic relative sizes	

* teacher-centered indicators for scoring (1 = present, 0 = not present), while score 0–4 indicate student-centered beliefs; score 5–7 indicate mixed beliefs; and score 8–10 indicate teacher-centered beliefs (Lin, 2021; Thomas et al., 2001).

Figure 1: An Example of a Coded Drawing



O1. Technology = not present
O2. Manipulative = not present
C1. Maths domain = numbers and operations (Fraction)
C2. School level = primary school
T1. Teaching activity = lecturing (1)
T2. Teacher location = at the front (1)
T3. Teacher posture = standing up (1)
T4. Teacher emotion = positive
T5. Teacher gender = not indicated
S1. Student activity = listening (1)
S2. Student position = seated (1)
S3. Number of students = 8 (gender unknown)
S4. Student attitude = not indicated
E1. Classroom arrangement = in traditional rows (1)
E2. Classroom location = inside the classroom
E3. Chalkboard = present (1)
E4. Student stationery = not present
E5. Student textbooks = present (1)
E6. Teacher lectern = not present
D = normal
Total score = 8, *teacher-centered beliefs*

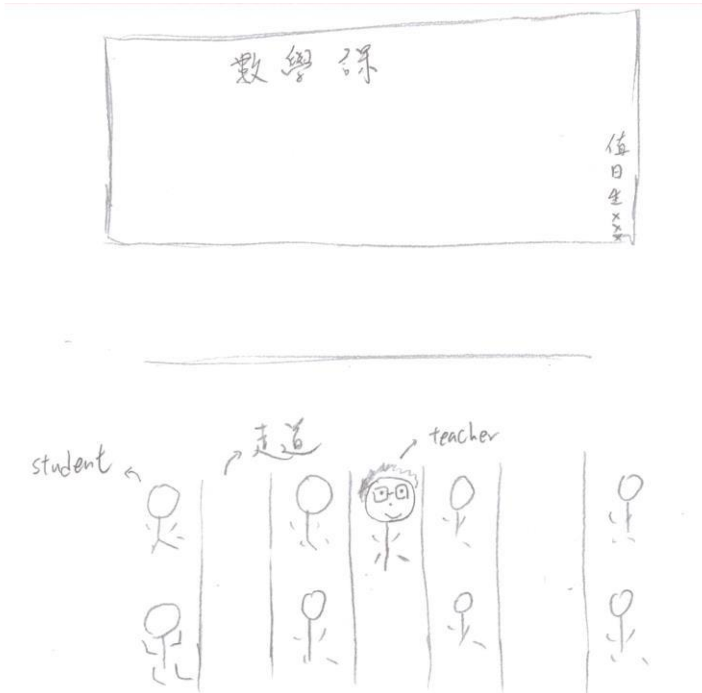
Note: Translation of the questions and answers in the figure as follows:
What is the teacher doing?
Pointing to the content on the board and explaining the concept of fractions to students
What are the students doing?
Reading their textbooks and listening to the teacher's explanation

discussed these possible questions and eliminated some on which agreement could not be reached, leaving a set of between three and five questions per participant that were agreed to be important. There was also one follow-up question common to all participants: "Why did you draw [number of] students in your classroom?"

These 32 participants were selected because they all were attending the same university and taking the same course, which helped to avoid possible confounding effects related to institutional affiliation, while also making it easier to distribute question papers and collect responses. It should also be noted here that the researchers did not conduct interviews during this process. Rather, follow-up questions were administered as paper attachments to photocopies of the 32 participants' own drawings. After they wrote down their responses to these questions, by the end of the same class session, they handed them back to the course instructor (the author of this article). For example, in Figure 2, the follow-up questions included: "Why did you draw eight students in your classroom?" (since a number-of-students question was asked of all 32 participants), "Were all the students seated?" and "Why was the student at the bottom left in a different position?" The strangeness of the mentioned student's position consisted of the curvature of the legs, the hands posed at a 90-degree angle to the arms, and the other depicted students' lack of these two characteristics. The participant who made the drawing said, in response to a follow-up question, that the student was stretching.

For more examples of the follow-up questions, the researchers also asked why a teacher (Figure 5b) was wearing a hat (to investigate typical teacher image), and why the participant decided to draw a teacher (Figure 5c) using an interactive whiteboard to teach calculation of the area of a leaf (to understand why technology and an interesting teaching topic were involved in her drawing).

Figure 2: A Drawing Showing a Student in a Strange Position at the Bottom Left



Formal analysis of data by the coding scheme

Then, a formal analysis was conducted using the coding framework (coding scheme) (see Table 1). It should be noted that this formal analysis was not only according to what the participants depicted but also according to *their written descriptions of them*, as well as their *explanations of picture content* that were offered in response to the follow-up questions.

Scoring drawings. In addition, based on the scoring sheet of Thomas et al. (2001), this study listed 10 indicators of teacher-centeredness in its coding framework (marked with * in Table 1), and scored each of them as 1 (indicated) or 0 (not indicated). As such, each drawing received a score from 0 (very student-centered beliefs) to 10 (very teacher-centered beliefs), with scores of 0−4 indicating student-centered beliefs; scores of 5−7 mixed beliefs; and scores of 8–10 teacher-centered beliefs. Notably, three indicators in Thomas et al. were removed due to their inappropriateness for mathematics teaching context (e.g., a laboratory classroom). Also, this revised scoring scheme was successfully applied in Lin (2021) to distinguish different types of teacher beliefs in the drawings.

Interrater reliability. To establish interrater reliability, two of the researchers separately analyzed 18 drawings using the coding framework and compared their coding results using Kappa values (Kraemer, 2014). These ranged from 0.61 to 1.00. After that, all the differences between coding were reconciled by the same two researchers, one of whom then coded the remaining 72 drawings.

Results

Scoring Results, Teacher Beliefs in the Drawings

Table 2 presents the results regarding the participants' beliefs as revealed in their drawings. It shows that a plurality of the participants expressed mixed beliefs (43.3%), while the percentages of teacher-centered beliefs and student-centered beliefs were similar to each other (28.9% vs. 27.8%). Figure 3b is a drawing of mixed-beliefs, in which the teacher is standing at the front of the classroom to introduce a concept while the students are engaging in hands-on activities. Figure 1 is a drawing of teacher-centered beliefs, and Figure 6 that of student-centered beliefs.

Table 2: Types of Participants' Beliefs Revealed in the Drawings (*N* = 90)

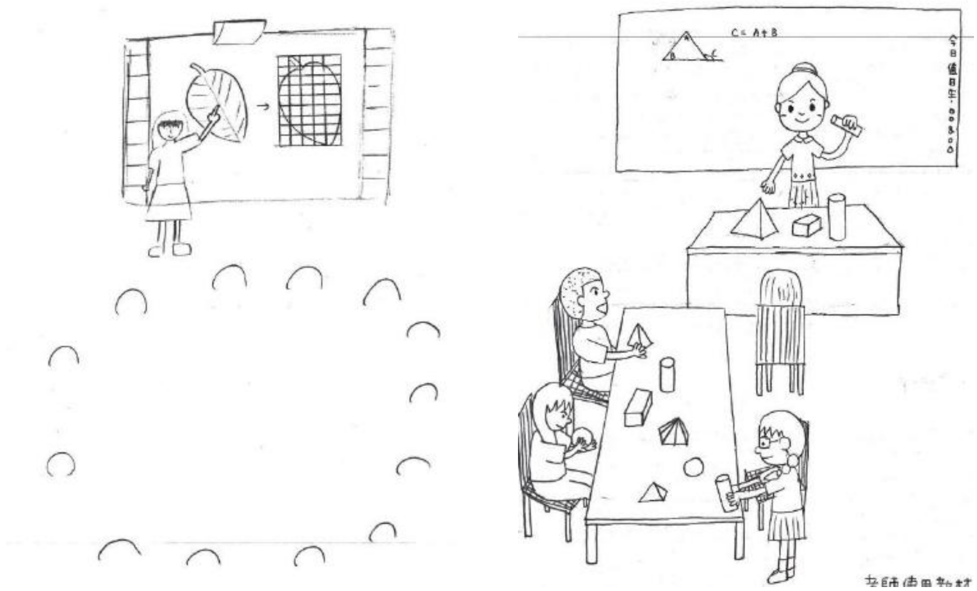
Teacher beliefs	*n*	%
Teacher-centered (score = 8–10)	26	28.9
Mixed (score = 5–7)	39	43.3
Student-centered (score = 0–4)	25	27.8

Note: The scoring scheme is based on Thomas et al. (2001) and was successfully applied in Lin (2021).

Use of Technology or Manipulatives

Only 6 of the 90 drawings depicted the use of technology (e.g., Figure 3), and in 4 of those 6 cases, such depiction was limited to the use of computers or projectors. One-fifth of the drawings (*n* = 18) involved the use of manipulatives for teaching and learning mathematics, mostly (*n* = 12) in group-work settings (e.g., Figure 3b), though 6 showed teachers using them to demonstrate concepts while their students mainly listened.

Figure 3: Drawings Containing Technology Use and Manipulatives



(a) Use of an interactive whiteboard to demonstrate how to calculate the area of a leaf

(b) Use of manipulatives to teach about prisms and pyramids

Teaching Content and School Levels

In Table 3, the most frequently depicted content was "numbers and operations" (46.7%). Notably, while geometry is an important topic in Taiwanese primary schools, making up 20% of Grade 1–6 mathematics textbooks (Hsu & Ko, 2014), it was rarely depicted in the participants' drawings (8.9%); and statistics was not depicted at all, despite being an important learning topic across Grades 1 through 6 in Taiwan (Ministry of Education, 2018). Notably, although the percentages of algebra (7.8%) and geometry (8.9%) in Table 3 are similar, the former makes up only around 4% of textbook content (Hsu & Hsu, 2009), so these figures represent an over-representation of algebra as much as an under-representation of geometry. The above findings could imply that geometry and statistics had not been emphasized enough in these pre-service teachers' training as of the time of the study.

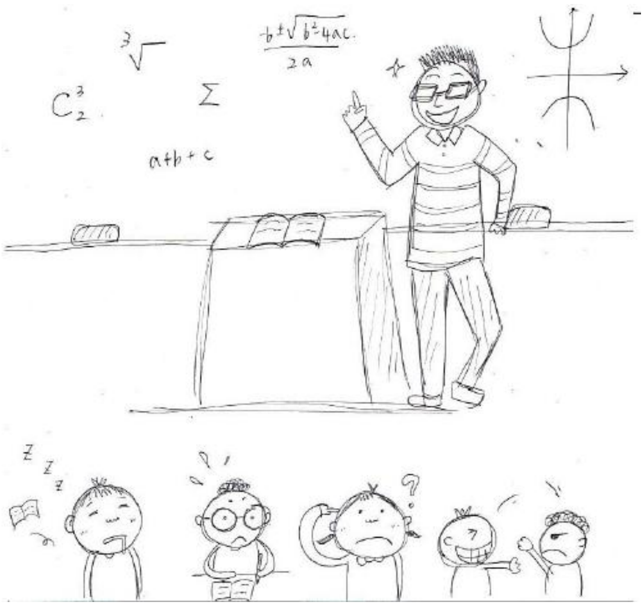
Unsurprisingly, the majority of the drawings (54.4%) depicted primary-school settings (i.e., Grades 1–6). However, 10% of the drawings showed secondary-school teaching (middle school = 8, high school = 1) (e.g., Figure 4), despite all the participants having declared an intention to work as primary teachers. One participant (#0921) explained that, in terms of mathematical subject matter, "I just wrote down what was coming into my mind." In this case, the participant did not seem to think of herself as a primary teacher but relied on a more generalized image of mathematics teaching when creating her drawing.

Table 3: Coding Results of the Teaching Content Dimension (*N* = 90)

Teaching Content (C) category	Code	*n*	%
C1. Maths domain	Not indicated	28	31.1
	Algebra	7	7.8
	Geometry	8	8.9
	Numbers and operations	**42**	**46.7**
	Statistics	0	0.0
	Others	5	5.6
C2. School level	Not indicated	29	32.2
	Primary school	**49**	**54.4**
	Secondary school	9	10.0
	Others	3	3.3

Note: The top one code in each category is marked in boldface.

Figure 4: Drawing in Which the Teaching Content is at a Secondary-school Level



Teachers' Main Teaching Activities

As shown in Table 4, around half of the 90 drawings appeared to show "lecturing" as their major teaching strategy. Roughly 40% were related to student-centered strategies, notably including "guiding" (25.6%), "doing maths" (7.8%) and "mixed" (4.4%).

Teachers' Emotions about Teaching Mathematics

More than two-fifths of the drawings (n = 38) depicted teachers' emotions or attitudes (Table 4). Of these, all but one seemed to reflect positive feelings about the teaching of mathematics (e.g., the teacher is smiling in Figure 5).

Common Images of the Teacher

As shown in Table 4, the most common teacher image created by the participants was a person of no clear gender (64.4%) standing up (93.3%) in front of the classroom (76.7%); and around two-fifths were holding a piece of chalk (n = 11) or a pointer (n = 9) or simply using their index fingers to point at mathematics content on the board (n = 17; e.g., Figure 5).

According to Thomas et al. (2001), the above types of images may represent the authority of teachers, conceived of in a traditional manner as knowledge holders or transmitters.

Table 4: Coding Results of the Teacher Dimension (*N* = 90)

Teacher (T) category	Code	*n*	%
T1. Teaching activity	**Lecturing**	**43**	**47.8**
	Guiding	23	25.6
	Doing maths	7	7.8
	Mixed	4	4.4
	Others	13	14.4
T2. Teacher location	**At the front**	**69**	**76.7**
T3. Teacher posture	Not indicated	4	4.4
	Standing up	**84**	**93.3**
	Sitting down	2	2.2
T4. Teacher emotion	**Not indicated**	**52**	**57.8**
	Positive	37	41.1
	Negative	1	1.1
T5. Teacher gender	**Not indicated**	**58**	**64.4**
	Male	12	13.3
	Female	20	22.2

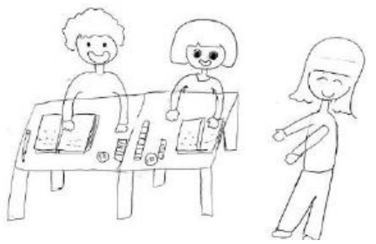
Note: The top one code in each category is marked in boldface.

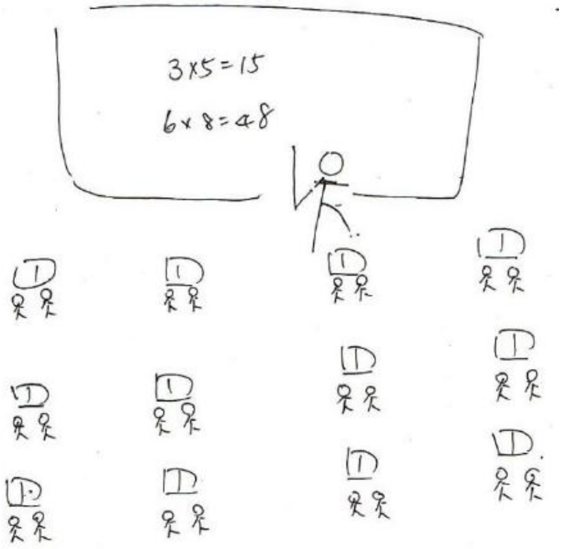
Figure 5: The Common Image of the Teacher Excerpted From Three Different Participants' Drawings

(a) Holding a pointer. (b) Holding a piece of chalk. (c) Using the index finger.

Size differences between the drawn teachers and their students could be related to participants' drawing skills, but could also reflect their conceptions about *teachers' authority*. As noted in family-drawing studies (e.g., Bland, 2012), figures that are drawn larger than others might imply that the depicted persons have more important roles within the family, while smaller ones might reflect weak authority. From this perspective, depictions in which the teacher and students are of a similar size could imply the participant's relative lack of interest in teachers as authority figures, whereas much larger teachers might implicitly emphasize teachers' power. In this study, 33 drawings (36.7%) depicted the teacher as more than double the size of the students (e.g., Figure 6b), while only 14 drawings (15.6%) showed the students and their teachers as being of a similar size (e.g., Figure 6a).

Figure 6: Extremes of Size Differences Between Students and Their Teacher





(a) Small difference (b) An overwhelming difference (students are seated)

Students' Attitudes Toward Learning Mathematics

In Table 5, nearly two-thirds of those 38 drawings showing student attitudes (25 out of 38) indicated a positive student attitude toward learning mathematics. The percentages of these 38 drawings that showed mixed or negative attitudes were 18.4% and 15.8%, respectively.

Student Activities and Positions

As Table 5 shows, the main student activities depicted in the drawings were discussing (43.3%) and listening (30.0%). This differs slightly from the main teacher activities (Table 4), within which teacher-centered teaching strategies (i.e., lecturing) were more prevalent than student-centered ones (e.g., guiding) (47.8% > 25.6%, see Table 4). In addition, two-thirds (66.7%) of the participants either depicted the students as seated or claimed that they were seated in their captions (Table 5). Interestingly, around half the participants used standing students to depict sitting ones (e.g., Figure 6b). In the follow-up question, one participant explained: "My drawing skills are limited [… so I] simplified the drawing" (#0955).

Table 5: Coding Results of the Student Dimension (*N* = 90)

Student (S) category	Code	*n*	%
S1. Student activity	Listening	27	30.0
	Explaining	6	6.7
	Discussing	**39**	**43.3**
	Doing maths	4	4.4
	Mixed	6	6.7
	Others	8	8.9
S2. Student position	Not indicated	11	12.2
	Standing up	3	3.3
	Seated	**60**	**66.7**
	Mixed	16	17.8
S3. Number of students	The mean number of students	11.1 (total *n* = 90)	
	The mean number of males	2.1 (total *n* = 15)	
	The mean number of females	2.3 (total *n* = 15)	
S4. Student attitude	**Not indicated**	**52**	**57.8**
	Negative	6	6.7
	Positive	25	27.8
	Mixed	7	7.8

Note: The top one code in each category is marked in boldface.

The Numbers and Genders of Students

Table 5 shows the mean number of students depicted in the participants' drawings was 11.1 (around one-third of the normal Taiwanese class size), with the smallest class shown consisting of zero students, and the highest, 30. Though only 15 of the 90 drawings specified the students' genders, their mean numbers of male and female students were almost the same (M_{male} = 2.1, M_{female} = 2.3). This could reflect the participants' beliefs about male and female students but needs further investigation.

Thirty-two of the 90 participants who had responded to follow-up questions provided four distinct explanations for the number of students they had drawn. These were: (a) the use of a few figures to represent larger numbers (37.5%); (b) no specific meaning (28.1%);

(c) a reflection of the participant's preference for smaller class sizes (25.0%), and (d) a sincere attempt at realistic depiction, based on the participant's past experience (9.4%). This seems to suggest that researchers should pay attention to the number of students drawn in the pictures when they want to conduct drawing research.

Teaching and Learning Environment

As shown in Table 6, almost all the drawings showed teaching and learning occurring inside classrooms (97.8%) equipped with chalkboards (93.3%). These rooms were mostly either arranged in groups (53.3%) or in traditional rows (44.4%); and teachers' lecterns (24.4%), students' textbooks (23.3%), and students' stationery (13.3%) sometimes appeared. According to Thomas et al. (2001) and Hsieh and Tsai (2018), chalkboards, stationery items, and textbooks are, respectively, *symbols of teaching, study, and knowledge*. As such, these three categories of images — along with teachers' lecterns — can be seen as indicators of a traditional teaching mindset. On the whole, however, the participants seemed much more concerned about teacher-controlled equipment (e.g., chalkboards) than about student-controlled equipment (e.g., textbooks) (93.3% > 23.3%).

Table 6: Coding Results of the Environment Dimension (*N* = 90)

Environment (E) category	Code	*n*	%
E1. Classroom arrangement	Not indicated	1	1.1
	In traditional rows	40	44.4
	In groups	**48**	**53.3**
	In a circle	1	1.1
E2. Classroom location	Inside the classroom	88	97.8
E3. Chalkboard	Present	84	93.3
E4. Student stationery	Present	12	13.3
E5. Student textbooks	Present	21	23.3
E6. Teacher lectern	Present	22	24.4

Note: The top one code in each category is marked in boldface.

Relationships Between Participants' Background Variables and the Types of Beliefs in the Drawings

Table 7 presents the participants' background variables (gender, degree type, and attitude toward mathematics) as these relate to the types of beliefs expressed in their drawings. The results indicated a broad similarity between the male and female participants:

both had higher percentages in mixed beliefs (55.0% vs. 57.1%), followed by teacher-centered (30.0% vs. 28.6%) and student-centered beliefs (15.0% vs. 14.3%). In terms of their educational backgrounds, the participants studying for master's degrees were inclined toward teacher-centered beliefs (47.8%), while those studying for undergraduate degrees held more mixed beliefs (64.2%). Lastly, there was some evidence, albeit rather weak, that the participants with more negative attitudes toward mathematics favored teacher-centered beliefs over student-centered ones; i.e., this effect is only discernible if considering the percentages of teacher-centered beliefs and student-centered beliefs across all three groups of the participants (positive: 14.3% in teacher-centered, 23.8% in student-centered; neutral: 28.6% in teacher-centered, 14.3% in student-centered; negative: 33.3% in teacher-centered, 8.3% in student-centered). As such, follow-up studies to further explore this issue should be considered.

Table 7: Cross-tabulation of Participants' Background Variables (Gender, Degree, Attitude) and Types of Beliefs

	Teacher-centered beliefs		Mixed beliefs		Student-centered beliefs	
	n	%	*n*	%	*n*	%
Gender						
Male (*n* = 20)	6	30.0	11	55.0	3	15.0
Female (*n* = 70)	20	28.6	40	57.1	10	14.3
Degree						
Master's (*n* = 23)	11	47.8	8	34.8	4	17.4
Undergraduate (*n* = 67)	15	22.4	43	64.2	9	13.4
Math attitude (*N* = 61)*						
Positive (*n* = 21)	3	14.3	13	61.9	5	23.8
Neutral (*n* = 28)	8	28.6	16	57.1	4	14.3
Negative (*n* = 12)	4	33.3	7	58.3	1	8.3

* Not all participants filled out this item, valid *N* = 61.

Discussion and Conclusion

Prevalence of Images of a Mixed Approach

In general, the majority of the pre-service primary teachers' drawings produced during this study depicted a mixed teaching approach (reflecting *mixed beliefs*), in which the teacher stands in front of the classroom to lecture, but students are allowed to discuss the lesson content with one another. Although many previous studies have asserted that pre-service teachers usually hold traditional beliefs (Shilling-Traina & Stylianides, 2013), the findings of this study echo those of a dissenting group (e.g., K. W. Chan & Elliott, 2004) that has reported such teachers as holding both traditional and constructivist views at the same time. It should also be noted in this context that the use of mixed teaching approaches is receiving increasing scholarly attention. For example, Preszler (2006) found that students improved the most under mixed teaching approaches, while Glogger-Frey et al. (2017) highlighted the importance of incorporating self-regulating activities into direct instruction, implying a kind of mixed teaching approach in which students are allowed to discuss class material before receiving the teacher's lecture on it.

Participants' Images of Mathematics Teaching and Learning

Past research has indicated how important emotion-packed experiences are to the formation of teacher beliefs (Pajares, 1992). As such, the results of the present study provided further confirmation that drawing methods are effective tools for capturing teachers' experiences and their related emotions (Hsieh & Tsai, 2018; Thomas et al., 2001).

According to the participants' explanations of the number of students they had depicted, their drawings could represent (a) their real experiences of mathematics teaching and learning, (b) their assumptions about it, or (c) their ideals of it. Moreover, this study also found that many of these images were emotionally laden (e.g., the smiling face of a teacher or a student). To an extent, this finding echoes Calderhead and Robson (1991) that pre-service teachers' images are memories or reconstructions, but also involve their feelings about teaching mathematics.

In addition, the author noticed that the participants' drawings were often very well-executed (e.g., Figure 3). This would imply the drawings were done very carefully. This is to be expected. Unlike school students, the participants of this study were more mature and in particular, 25% were even more mature as graduate students. Accordingly, the author believed they were quite aware of their responsibilities in their role as research participants. They also were completing the drawing task in a formal education class. The situation of being in a class might also have contributed to their careful work on their drawings.

Comparing the classroom images to those in science education studies

The drawing method used in this study was adapted from a widely used instrument that originated in a science education study (Thomas et al., 2001). As such, comparing the images of mathematics classrooms with those of science classrooms could be of interest in the study of how changes in context (mathematics teacher vs. science teacher) in the drawing task influence the results. Since most studies usually present only a few example drawings, the comparison is based on science education studies that have presented more drawings (Ambusaidi & Al-Balushi, 2012; Mensah, 2011; Tatar, 2015; Thomas et al., 2001). Comparing the two different contexts, the author found three major differences: (a) outdoor vs. indoor teaching, (b) science equipment vs. mathematics representations, (c) a variety of vs. traditional seating arrangements. The first notable difference is outdoor teaching. In the drawings of science classroom, several show outdoor teaching, but in the drawings of mathematics classroom (i.e., the current study), there is not any outdoor teaching. Second, in the drawings of science classroom, many show science equipment (e.g., beakers), whereas in the drawings of mathematics classroom, many show mathematics representations (e.g., mathematical symbols). Lastly, regarding seating arrangements, the drawings of science classroom show a greater variety than the drawings of mathematics classroom. In particular, some arrangements (e.g., stadium seating, see Tatar, 2015, p. 39) were not seen in the drawings of mathematics classroom.

Drawing conclusions from these differences, they are mainly due to the different contexts (mathematics vs. science classrooms) and reflect the different nature of mathematics teaching and science teaching (e.g., outdoor teaching being very unusual in a mathematics classroom). It seems that changing “science teacher” to “mathematics teacher” in the drawing task’s prompt did not result in a very different kind of response to the ones elicited in science education studies.

Potential Relationships among Types of Beliefs and Participants’ Background Variables

Owing to the small sample sizes of this study, the author will only report descriptive statistics about the scoring results (types of beliefs) and participants’ background variables. Nevertheless, because this information could help to reveal potential relationships between these variables, the results of this study will be compared against those of previous studies, and recommendations for follow-up studies using statistical tests will be made to further explore these possible relationships.

Gender differences

This study found no gender differences among the three types of beliefs. This echoes some prior studies (e.g., Blömeke et al., 2015) that found no gender differences in pre-service teachers' beliefs about mathematics teaching, though some others (e.g., Jacob et al., 2017) did report that female pre-service teachers held more student-centered beliefs about mathematics teaching than male ones did.

Differences across degree-program types

Those pre-service teachers in our sample studying for master's degrees seemed more inclined toward teacher-centered beliefs than those in bachelor's programs. This result is inconsistent with those of some previous large-scale studies that found no significant correlations between teachers' educational levels and their beliefs about mathematics teaching (Ren & Smith, 2018). On the other hand, as compared to the sampled undergraduate students, the master's students in the present study had taken fewer courses in the field of education. While it would be premature to argue that this was a key reason for their teacher-centered beliefs, it should be noted that Tigchelaar et al. (2014) found master's students to be more likely to express such traditional beliefs when they were just starting their program and had not yet taken many courses.

Differences in mathematics attitudes

Although this evidence could be considered fairly weak, the participants of this study who had neutral or negative attitudes toward teaching mathematics created a slightly higher number of drawings reflecting teacher-centered beliefs than student-centered ones. This is broadly similar to findings previously reported by Ren and Smith (2018) that pre-service teachers with more positive attitudes were more inclined to believe in the effectiveness of the reformed teaching approach (i.e., holding student-centered beliefs).

Suggestions for Follow-Up Studies

The validity and efficiency of the drawing task used in this study have been confirmed by many previous studies (e.g., Minogue, 2010; Thomas et al., 2001). Nevertheless, like any other method, it is not perfect and has its limitations. For example, as with questionnaires, participants may have differing interpretations of the task prompt, such as thinking that the phrase “at work” means “visibly performing a work-related task” versus simply “in the workplace.” To deal with this issue, it might be worthwhile in future studies to conduct interviews with participants after they have made their drawings. However, doing so would inevitably and dramatically reduce the maximum manageable number of participants. The strategy of asking written follow-up questions had the advantage of being less time-consuming than interviews, the tradeoff being that it generated less data. But it seemed to work well, and its use in future studies is recommended where interviewing everyone would be impractical. In any case, investigating small differences (if any) in how the participants understood the prompt was not part of our research purpose.

Drawing’s prompt is very critical to influencing participants’ creation of drawings (e.g., past experience vs. future plan in mathematics teaching). Therefore, the following suggestion is based on this assumption.

Prior drawing-based research has used different prompts to ours (e.g., Minogue, 2010). For example, some scholars have asked their participants to draw their past mathematics learning experience, or to imagine they are teaching mathematics. It would therefore be interesting to investigate how these different prompts influence the drawings that are produced. Likewise, given the same prompt, it is worth asking what proportion of respondents demonstrating their own beliefs versus their perceptions of typical others’ beliefs. By the same token, it might be worthwhile to ask participants to make two drawings: one showing their own beliefs about mathematics teaching, and the other, their perceptions of others’ beliefs about it.

Lastly, to make sure that some participants’ data is not misunderstood or ignored simply due to their weak drawing skills, researchers should integrate technology into drawing tasks. One potentially appropriate computer-based platform for this purpose, LessonSketch (Chazan et al., 2018), allows its users to complete drawings by dragging and dropping from a set of pre-drawn classroom objects.

Limitations

The drawing-based method is not perfect but serves as one of well-regarded alternative approaches in studying teachers’ beliefs. It is one way of collecting data and can be used in conjunction with other data to triangulate when different sources of data are in conflict. However, there are limitations in using a drawing method to study mathematics teachers’ beliefs, because of, among other things, the different interpretations respondents have of the task. For this reason, the findings should be interpreted and applied very carefully.

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你在數學教室做甚麼？使用繪圖任務探討職前教師關於數學教學與學習的信念

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摘 要

繪圖取向的方法被認為是研究教師信念的一種良好另類方式。然而，這種方法較少應用在數學教師上。有鑑於此，本研究目的在於透過繪圖任務，調查 90 位國小職前教師關於數學教學的信念。本研究的繪圖任務要求受試者想像他們正在學校課堂中教授數學，繪畫當時的情景，並使用文字輔助說明圖片中的內容。研究者參考先前文獻編制本研究的繪圖分析架構，分析資料後呈現五個重要結果：（1）本研究職前教師的信念繪圖以混合傳統和建構的信念為主，其中科技或教具的使用並不常見；（2）大約有 30% 的繪圖呈現教師或學生的正向情緒或態度，另有約 15% 的繪圖則呈現學生的負向行為；（3）繪圖中的學生人數平均為 11.1 人；據事後追問，繪圖裏學生人數的多寡可能是以少喻多、理想值或無意義；（4）職前教師的學歷或對數學的態度似乎影響其繪圖所呈現的信念類型；（5）整體而言，本研究的職前教師多數呈現混合的信念，與文獻中強調職前教師多為傳統信念的結果有別。本研究亦提出對教學的啟示，以及未來研究的建議。

關鍵詞：信念；繪圖；數學；職前教師；師資培育

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