

An Infiltrative Approach to Reform Mathematics Teaching: An Analysis of Chinese Middle School Teachers' Lessons

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Abstract

This study examines the changed and persistent characteristics of mathematics lesson structures, focuses, and activities that Chinese middle school teachers developed under the influences of mathematics teaching reform and the existing contexts of teaching. Drawing on lesson description and interview data, it found that most participants changed their lessons by infiltrating the ideas and activities as envisioned by the reform curriculum into their traditional lesson structure without revamping their lessons. Such an infiltrative approach to reforming their mathematics teaching supports the assumption that the nature of mathematics teaching is culturally scripted. Consequently, teaching change is inevitably gradual and incremental shaped by the existing curriculum, assessment, and teaching contexts in which teaching practices are situated.

Keywords: Teacher Change, Mathematics Education, Teaching Contexts, Chinese Teachers

Introduction

This study examines the ways in which Chinese middle school teachers reformed their mathematics lessons and the teaching contexts that influenced their reform efforts. Such an examination addresses some important issues emerging from the contexts of mathematics teaching reforms in many countries including China. These reforms, although different in the specific focuses and approaches, are developed to improve students' mathematics learning by engaging teachers in revamping their mathematics teaching practices and hold them accountable for their reform following several shared assumptions (Loomis, Rodriguez, & Tillman, 2008).

First, the emerging global economy presumably requires a country's work force to develop mathematics competencies, especially mathematics reasoning, problem solving, connection, and communication (Romberg, 1992). Second, teachers and their mathematics teaching quality are seen as the major influence on students' mathematics learning, which can be manipulated to produce the expected student learning outcomes (Wang, Lin, Spalding, Klecka, & Odell, 2011). Third, inquiry-oriented teaching is assumed to be central to helping students develop the expected mathematics competencies since it engages students actively in developing deep understandings about mathematical concepts (Romberg, Carpenter, & Kwako, 2005). In contrast, the popular teacher directed instruction is regarded as unable to meet these reform expectations.

These assumptions drive the establishment of mathematics curriculum standards and the relevant assessment systems to guide teachers to revamp their mathematics teaching practices and hold them accountable for the expected outcome of students' mathematics learning (Tatto, 2007). For example, in both the US and China, the mathematics standards and relevant curriculum materials were established and modified to meet this change (China's Ministry of Education, 2001; National Council of Teachers of Mathematics, 1989, 2006). Both reforms expect teachers to change their teaching to inquiry-oriented instruction to facilitate students in reasoning mathematically, making mathematics connections, and solving mathematics problems relevant to real life contexts through active communication and collaboration (Liu, Zhang, Lu, Yang, & Tao, 2001; Romberg et al., 2005).

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Such a reform meets a strong resistance from teachers (Hargreaves & Fullan, 2012) and yields little classroom change consistent with the reform goals in many countries (Hiebert, Gallimore, & Stigler, 2002). In China, mathematics teaching has been teacher directed consistently across urban and rural areas in spite of its mathematics teaching reform (An, Kulm, & Wu, 2004; Rao et al., 2009). However, their students demonstrated outstanding mathematics performances in international comparisons (Fleischman, Hopstock, Pelczar, Shelley, & Xie, 2010; Stevenson, Lee, & Stigler, 1986). Thus, it is important to understand what happened to teacher directed instruction in China under the pressure of reform and the role of such teaching in contributing to student performance.

Two theoretical assumptions frame the focus and design of this study. The first assumes that the reason for the failure of reform efforts to change teaching practice was a failure to consider teachers as learners who need not only relevant understanding and passion about the teaching reform, but also specific and sustained support for reforming their teaching (Cohen, 2011). The other assumes that the reform efforts failed to recognize teaching practice as culturally scripted and contextualized (Hiebert, Gallimore, & Stigler, 2002). Together, these assumptions suggest that teaching reform is difficult, and that any change is gradual and incremental in an *infiltrative* process instead of a rapid revamping transformation as expected by the teaching reforms (Kennedy, 2010; Sykes et al., 2010). Thus, an empirical examination of how teachers implement reforms and what influences their reform will help develop a knowledge base necessary for sound policy making and verifying these assumptions.

Two research questions guided this study:

- 1 What were the characteristics of Chinese teachers' mathematics lessons being developed for their reform teaching?
- 2 What were the influences of the reform curriculum standards and their teaching contexts on Chinese teachers' decisions to teach these lessons?

Methodology

We adopted the case comparison approach to collecting, analyzing, and comparing the mathematics lesson description and interview data from a number of Chinese middle teachers to understand their changed and persistent lesson characteristics under the influences of the mathematics teaching reform and the existing teaching contexts. Such a case comparison is assumed useful in providing deep insight into an issue through collecting, analyzing, and comparing the detailed, in-depth, and multiple data around different cases following the qualitative research tradition (Creswell, Hanson, Clark, & Morales, 2007).

Contexts and Participants

Participants of this study included 30 mathematics teachers from six middle schools in a provincial capital in Northern China. A local mathematics educator helped select the participants based on the following considerations necessary for the examination of this study.

First, they all taught under the contrived curriculum and teaching contexts presumably shaping teachers' teaching practices (Cohen & Spillane, 1992). For example, they all taught mathematics following the reformed centralized curriculum standards and materials, which prescribed the objectives and topics for their daily mathematics instruction and offered the relevant suggestions for pedagogical approaches (Ma, Lam, & Wong, 2006; Wang, 2001a). They also worked in a contrived subject-based teaching organization—the teaching research group—which organized them to plan lessons together, observe, and critique each other's lessons. This was the way that the curriculum-based teaching reform was implemented and supported (Han &

Paine, 2010; Wang & Paine, 2003). In addition, their teaching was held accountable for the regular district-level curriculum based tests and the provincial-level high school entrance examination (Eckstein, 1993).

Second, they presented the range of teachers' backgrounds and experiences assumed to shape their teaching practices differently (Darling-Hammond & Cobb, 1996). For example, they taught mathematics from six different middle schools including two schools having the higher, two having the average, and two having the lower student mathematics performances as measured by the provincial-level high school entrance examination. As shown in Table 1 below, the sample included 12 male and 18 female teachers who taught at different grade levels, such as eight teaching at the 9th, seven at the 8th, eleven at the 7th, and four at the 6th grade levels. In addition, they also had the range of experiences teaching in both the reform and traditional instruction contexts. Twenty-three of them had 6-7 years, six had 3-5 years, and one had fewer than 2 years of teaching experience in the reform contexts, while all but one had over 10 years of experience using teacher directed instruction.

Table 1: Background Information of Participants (N=30)

Gender		Grade Level				Years of Reform Teaching			Years of Traditional Teaching	
Male	Female	9th	8th	7th	6th	6-7	3-5	0-2	10 or more	0-2 years
12	18	8	7	11	4	23	6	1	29	1

Third, they developed certain understandings and experiences about the reformed mathematics teaching. They all had chances to observe and critique the demonstration lessons and then design and teach their own lessons following the reformed centralized curriculum. They also formed certain positive dispositions toward the reformed mathematics teaching as measured by the belief survey with the reliability of $\alpha = .74$, mean score of 73.97 out of 100, and a standard deviation of 6.95. This survey, developed by Ross, McDougall, and Hogaboam-Gray (2003), examined the relevance of teachers' teaching beliefs to the inquiry-oriented teaching envisioned by the reform curriculum standards in both U.S. and China (China's Ministry of Education, 2001; National Council of Teachers of Mathematics, 1989, 2006).

Data Sources and Analysis

Two kinds of data used for this study came from a larger study that examined how U.S. and Chinese middle school mathematics teachers interpreted their reform teaching. The first included a lesson description from each participant, in which they were asked to explain their roles, interaction with students, unexpected events, and thoughts about teaching as expected by the reformed curriculum based on one of their actual lessons. These lesson descriptions were used to generate the answers to our first research question about characteristics of participants' lessons and the extent to which these characteristics were consistent with the inquiry-oriented and teacher directed instruction.

The second data source was a one-hour interview with each of six participants on their mathematics teaching contexts, teaching decisions related to their lesson described, and teaching experiences. These interviews were analyzed to develop answers to our second research question about the influences of reform and teaching contexts on their lessons. These participants were selected for interviews because they were from the higher, average, and lower performing schools, two for each, and taught mathematics in both the reform and traditional contexts.

To understand the characteristics of their mathematics lessons developed, we conducted several levels of analysis. We first read and coded each lesson description for its structures, focuses, and activities as they

emerged following the suggested qualitative coding process (Strauss & Corbin, 1990). Then, using the constant comparison as suggested (Leech & Onwueghuzie, 2007), we compared coded lesson structures, focuses, and activities from each participant with the inquiry-oriented mathematics teaching encouraged by the teaching reform (Romberg, Carpenter, & Kwako, 2005) and the teacher directed teaching traditionally practiced by the Chinese teacher (Smith III, 1996; Rosenshine, 1985). Finally, we grouped all the lesson descriptions into different categories based on their similarities and differences.

To understand the influences of the reform curriculum standards and their teaching contexts on participants' decisions to teach their lessons, we conducted several steps of analysis. First, all interviews were audiotaped, transcribed, and translated into English and then translated back to Chinese so that any translation discrepancies could be identified and resolved. A US professor fluent in both English and Chinese helped check the translation accuracy. Then, we read and coded each interview transcript for participants' ideas behind lessons and the contextual information about curriculum, assessments, and professional development relevant to mathematics teaching reform as they emerged (Strauss & Corbin, 1990). Next, we compared the coded information across six participants to identify similarities and differences. In the end, we triangulated the results of the interview analysis with those from the lesson analysis to identify the ideas and contexts that influenced the participants' lesson characteristics.

Limitations of the Analysis

This study has two obvious limitations. The lesson descriptions cannot be used to represent exclusively all kinds of participants' teaching practices, in which they might develop different kinds of lesson structures, focuses, and activities for the reform purposes. In addition, our sample came from the large metropolitan area, which cannot be used to represent the reformed teaching in the small cities, suburban, and rural areas in China.

Results

Lesson Structure Characteristics

Our analysis led us to three kinds of lessons developed by the participants. The first kind was the most popular - *infiltrative lessons*. In such lessons, while all the phases of teacher directed instruction including introduction, instruction, practice, and summary phases were still maintained (Rosenhine, 1985), participants were able to incorporate their reform focuses and activities in one of the teacher directed teaching phases. As shown in Table 2 below, 21 out of 30 participants developed their lessons in this way to reflect reform expectations.

Among the infiltrative lessons, two differences emerged. One difference was that the participants in this group made their reform effects in different phases of teacher directed instruction structure. Table 2 showed that eleven participants infused the reformed focuses and activities in the instruction phase, nine in the introduction phase with one in the practice phase.

Another difference was that participants developed different kinds of reform focuses and activities in these infiltrative lessons. For example, seven participants tried to engage students in solving mathematics problems and five focused students on communicating and proving mathematics in the instruction phase. Then, two participants used stories and concrete activities to motivate students' learning, four connected the real world situations to mathematics concepts to be taught, and three used hints to inspire students to reason mathematically in the introduction phase. Finally, one participant helped his students understand mathematics ideas through writing poems in the practice phase.

Table 2: Characteristics of Participant Mathematics Lesson Structures

Types of Lessons	Phases of lesson reformed	Numbers of lessons	Kind of reform focuses and activities developed	Teachers who developed the focuses and activities
Infiltrated lessons	Introduction phase	9	Use manipulative and stories to motivate students' learning	T7, T18
			Connect real-world problems to mathematics concepts	T2, T17, T23, T28
			Use hints to engage students in mathematics reasoning	T13, T14, T29
	Instruction phase	11	Engage students in mathematics problem solving	T4, T8, T10, T16, T19, T20, T30
			Help students communicate and prove mathematics ideas	T12, T15, T25, T27
	Practice phase	1	Ask students to write poem to understand mathematics ideas	T3
Revamped lessons	Whole lesson	6	Develop mathematics communication in groups	T9, T21, T22, T24, T26
			Provoke and facilitate students' mathematics reasoning	T5
Unchanged lessons	No reform	3	Follow direct instruction without implementing any reform ideas	T1, T6, T11

T1, T2, T3... and T30 present different participants respectively.

The second kind was the *revamped lesson*. In these lessons, the participants developed new lesson structures to implement their reform focuses and activities throughout the whole lessons. As demonstrated in Table 2, six participants developed revamped lessons, among whom, five tried to engage students in communicating and proving each other's mathematics ideas in groups and one pressed students to reason mathematically throughout their lessons.

The third kind was the *unchanged lesson*. In such lessons, the participants did not develop any reformed ideas and activities. Instead, they taught following all the phases of teacher directed instruction. Three participants followed this lesson structure (See Table 2).

Reformed Focuses and Activities in Infiltrative Lessons

Our analysis of the reformed focuses and activities that participants developed in the introduction, instruction, and practice phase of their teacher directed lessons revealed several findings. For the eleven participants who infused reformed focuses and activities in the instruction phase, two characteristics of their focuses and activities can be identified.

First, the participants were able to engage students in developing and proving different solutions to various complex mathematics problems. This required students to connect what they had already learned to what

they were going to learn when they developed the problem solving focuses and activities. They often started their instruction phase with an easier problem and then move to one or a few more difficult problems to engage their students in problem solving. For example, T20 used visual representations and a number line together to help students identify the relationship between two circles. T19 used an open-ended problem that asked students to divide the area equally in an isosceles trapezoid in different ways. T16 first asked students to prove a square problem and then, changed the conditions of the problem to develop three problems more difficult for her students to solve. T8 helped his students develop multiple ways to prove the sum of interior angles in a triangle was 180 degrees.

Second, those participants who engaged students in mathematics communication and proof were able to help students demonstrate, share, and prove their mathematics ideas to each other using what they had already learned as a base. For example, T15 asked his students to use the ideas of exponents that they learned from the elementary school to find out what would happen to a^n when $a > 0$, $a = 0$, and $a < 0$. His students quickly proposed, if $a > 0$, a^n means to multiply a itself n times and the result is a positive number. They also saw, if $a = 0$, a^n means to multiply 0 n times, and the result is 0. Then, he asked his students, "If $a < 0$, what kind of number a^n would be?" and said, "Oh, this is easy. I can get the answer immediately, $a^n < 0$. Is this correct?" Some students said yes, some said no, and others were silent. He asked them to discuss in groups to see if they could reach a definite answer. After several minutes, the class came to the shared understanding about the following theorems of exponents, which he put on the board. (1) If base a is positive, then a^n is positive, (2) if base a is 0, then a is 0, and (3) if base a is negative, then a^n is negative when n is an odd number and a^n is positive when n is an even number.

In the above lesson, T15 first engaged students in discussing and proving what a^n would be when $a > 0$ and when $a = 0$ in the whole class format, to which his students quickly developed right answers using their knowledge about multiplication. Then, he asked his students to discuss and find answers in groups to a^n when $a < 0$, which involved the concepts of even and odd numbers in addition to their understanding multiplication. In the process, T15 facilitated their communications and organized ideas emerging from their communications that led students to the formal exponents theorems. These mathematics discourses echoed the vision of inquiry-oriented mathematics teaching that stress the development of active and public mathematics communication (Wong et al., 2004).

The other four participants in this group were able to develop similar mathematics communications and proof although each focused on a different mathematical topic. T27 engaged his students in discussing and proving whether any two triangles were congruent if three sides or two sides and the angles between the two sides of the two were equal. T12 asked her students to use different pieces of coloured paper to prove the Pythagorean theorem, while T25 asked students to develop the problems relevant to monomials and then demonstrate and justify their problems in small groups.

For the nine participants who infiltrated their reformed focuses and activities in the introduction phase, we captured two characteristics of their focuses and activities. First, those who stressed the role of real world connection and activities in supporting students' mathematics learning were able to use these situations and activities to connect their students to the mathematical ideas that they were going to learn. For example, T2 used the daily temperature to relate his students to positive and negative quantities and their representation. He started the lesson by writing the following on the board:

In December 3, 2005, a student, Xian, walked alone on the street. Guess what happened? There was heavy snow then! He wore a heavy jacket, heavy gloves, and heavy... Can any of you guess what temperature it was on the day?

Then, he asked his students to use various numbers to represent the temperature and students came up with 16^0 and 20^0 below zero, etc. He reminded them that the temperature could also be 1^0 and 2^0 above zero and stressed that “below” and “above” were opposite quantities. Next, he asked his students to think about other situations in which opposite quantities could be used. With a brief discussion in groups, his students showed examples of money, direction, altitude, or others. He finished the introduction section of his lesson by asking the class to represent each case using proper numbers.

In the above example, T2 used a real world situation that his students easily understood to introduce the term, opposite quantities. He then inspired students to come up with similar examples. He led the class to move from the ideas of opposite quantities to the concepts of positive and negative numbers. In this way, he was able to connect students’ mathematics learning to the real life context as encouraged by mathematics teaching reform in China (Wong et al., 2004).

The other participants in this group were also able to connect the real world situations and concrete activities to abstract mathematical ideas in a similar way as they introduced their lessons. For example, T23 showed a triangular-shaped land on the board and asked his students to draw, measure, and calculate the area of this land, from which he introduced the height-related properties of a triangle. T28 had his students fold a piece of paper into different three-dimension shapes to introduce the concepts of a cubic object. T17 used a word problem to derive an algebraic topic, how to calculate $(a + b)^2$.

Second, three participants in the group were able to use hints to engage their students in mathematics reasoning in the introduction phase. For example, both T14 and T13 were able to use two sets of problems to help their students understand the patterns for factoring quadratics.

Third, the last two participants were able to use poems and stories to help students connect what they were learning to the real world situation or activities. For instance, T18 used magic cubes to help students find the power of numbers while T7 adopted historical stories to help students develop the concepts of positive and negative numbers.

For the only participant who developed reformed focuses and activities in the practice phase of her lesson, T3, she was also able to engage her students in poem writing. Through this activity, she helped students practice the different methods for factorization in the practice phase.

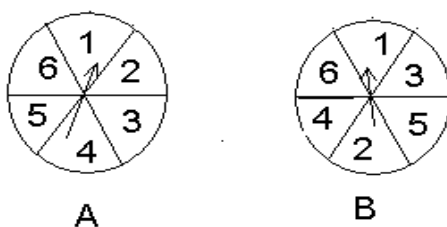
Reformed Focuses and Activities in Revamped Lessons

Our analysis demonstrated two characteristics of the lesson descriptions developed by the five participants using a *revamping approach*. First, unlike those participants in the infiltrative group who used mathematics communication to engage students in learning mathematics only in the instruction phase, the participants who used similar mathematics communication in the revamped lessons were all able to restructure their whole lesson around a meaningful mathematics task using different kinds of group discussions and activities.

For example, T21 engaged her students in two game competitions and the relevant group discussions to understand different probability concepts throughout his lesson. In Game 1, each student in a group took turns to roll two die 50 times to find the probabilities for 7 and 12 and then discuss with each other in their groups why the results might be different between the two situations. Through this game, students were expected to know that the probability of getting 7 is higher than that of 12 because of the underlying rule of this game.

In Game 2, students from each group took turns to select Spinner A or B shown in Figure 1 below and then to spin the needles on it 10 times. When the needle landed on a number, they had to move the needle across the number of regions on the spinner clockwise. If the needle reached an even number, the student won 1 point. If it ended up on an odd number, the student received 0 point. The group that accumulated the most points after 10 spins won the game. After the game, each group discussed why the results on different spinners were different. Through this discussion, they were expected to see the probability that for those who chose Spinner A to win was 1.0 given the unfair rules of the game. At the end of this lesson, T21 engaged students in comparing the results of two different games and discussed experimental probability and conceptual probability embedded in each game.

Figure 1



Through this revamped lesson, T21 was able to use game competitions to develop her students' interests and engagement and then, had group discussions to help her students develop a deeper understanding about the concepts of probability through mathematics communication and experiments. Such lesson characteristics resonate with the vision of inquiry-based teaching. Namely, teachers stressed students' interests and active participation in learning mathematics through mathematical communication and proving.

The above characteristics of a revamped lesson also reflected in the lessons designed by the other four participants in this group. For instance, T26 asked her class to use either array or tree diagrams to analyze probability in groups. T24 grouped students to discuss how to use regular polygons, equilateral triangles and hexagons to pave a room floor. T9 pushed his students to understand positive and negative numbers by having them walk two or three metres in opposite directions starting at a zero point physically. T22 asked his students to read textbooks critically in pairs and check if they understood concepts relevant to angles classification. Then, he asked each pair to share their understanding in class, had the class check each group's report for any misunderstandings, and then, helped each pair develop a reasonable classification of angles.

Contexts Shaping Reformed Lessons

Our analysis of interview data revealed three important teaching contexts that shaped participants' mathematics teaching reform. They were, (1) the centralized curriculum standards and the relevant materials that prescribed what the participants had to teach daily, (2) the curriculum based assessment that held them accountable for what they had to teach specifically, and (3) the professional supports that they received through their teaching research groups built in their school system. These contexts influenced the participants' lessons in three ways.

First, the centralized curriculum and assessment helped nurture their popular belief that mathematics lessons had to cover exclusively and efficiently the mathematics topics that they were required to teach. This belief limited many to infiltrate their reform efforts only in some phases of their existing lesson structure intentionally. For example, when implementing reform ideas, 21 out of 30 participants chose to infuse their

ideas in one of their lesson phases instead of revamping the whole lessons. Among six participants interviewed, five claimed that the teacher directed instruction allowed them to control the pace of the teaching so that they were able to cover the content that they had to teach. As T28 expressed:

I really care about efficiency in my teaching, I try to use every minute efficiently. This is the main reason I still use teacher-centered pedagogy in my teaching. To me, using a real world problem at the beginning of the class is very good. It helps me move to the next instructional phase quickly.

Other participants also expressed that the infiltrative approach to reforming their lessons helped them accomplish what they were required to teach effectively. T15 claimed in the interview that although he would like his students to discuss and develop their mathematics ideas themselves, he had to guide their discussion with hints and even interrupt their lengthy discussion so that these discussions became efficient as shown in his lesson on the theorems of exponents described earlier. Similarly, T30 also explained that his lesson on parallelogram shapes described earlier was designed to “contain three key parts: students’ presenting conditions, teacher providing difficult questions, and teaching-student discussion of the special case.” He intentionally went through the first and third parts quickly in the lesson introduction so that he could have more time on the instruction part for the efficiency purpose.

Some participants also chose to focus on the areas and topics in the reform curriculum that they had relevant understanding and experiences of, in teaching to implement their reform efforts. As T30 explained:

I combine the ideas from problem solving and open-ended problems to create a very condensing activity in my class [see his lesson described earlier for detail]. Although I used it before curriculum reform, I believe this meets the reform requirement since new mathematics standards ask us to develop students’ problem solving skills.

Second, the curriculum based accountability assessment system at the district-level and provincial-level also helped participants develop the popular belief that mathematics teaching should serve for the needs of accountability assessment and its changes effectively. T28 expressed how such an assessment pressed him to incorporate the idea of connecting real world situations to his students’ mathematics learning in daily lessons:

I collect the latest high-school entrance exams from the provinces where teachers have already taught the new curriculum. I found that these examinations changed toward a focus on math application. In other words, real-world problems appeared often in the tests. From then on, I tried to incorporate more real world problems in my lessons.

In the interviews, four participants expressed the influences of such an assessment system on their reform focuses and activities developed in their daily lessons. Such data suggest to us that changed focuses of the examination pushed many participants to choose the infiltrative approach to reforming their mathematics teaching.

Finally, the professional development activities built into the teaching research groups at different levels of school systems helped many participants develop some of the relevant experiences and understanding necessary for reforming their lessons in several ways. The training content in the professional development activities was based on the mathematics curriculum standards and the relevant textbooks that teachers were required to use. In these trainings, teachers had chances to observe and critique the demonstration lessons offered by those who were more experienced in teaching the reform curriculum materials. In addition, those who received training at the district level were also responsible for training their colleagues through the

regular activities of teaching research groups at the school level. T2 expressed how she developed her idea of connecting student mathematics learning to the real world situation in her lesson on positive and negative numbers based on the demonstration lessons that she observed in the professional development activities at district level:

I observed two demonstration lessons in other schools. I found the students are highly motivated by the real-world problems in these classes. Then, I decided to try this technique in my own class.

However, instead of following exactly the demonstration lesson to revamp her lessons, T2 chose to use the real world situation only in the introduction of her daily lessons. As she explained, “the demonstration lessons are not suitable for daily lesson practice” since she had to cover a range of contents efficiently in her daily instruction.

Discussion

This study contributes to several understandings about the two research questions we propose for our research. (1) What were the characteristics of Chinese teachers’ mathematics lessons being developed for their reform teaching? (2) What were the influences of the reform curriculum standards and their teaching contexts on Chinese teachers’ decisions to teach these lessons?

First, although committed to reforming their mathematics teaching, only a few participants were able to revamp their mathematics lessons to meet the expectations of mathematics teaching reform. Many were only able to infiltrate the reform focuses and activities in some of the phases of their teacher directed instruction without modifying its basic structure. As our analysis showed, 21 out of 30 participants chose to initiate their mathematics teaching reform in one of the phases of teacher directed instruction while six were able to revamp their lessons and three failed to initiate any changes.

This finding echoes the findings in the existing literature that Chinese mathematics teachers used teacher directed instruction popularly no matter if they taught in urban, semi-urban, or rural areas based on systematic observations (Rao et al., 2009) and anecdotal case documentation (Ma et al., 2006). It also confirms the assumption developed based on the observations that within the teacher directed instruction structure, chances can be created for students’ meaningful mathematics learning as envisioned by mathematics teaching reforms (Stigler & Stevenson, 1991; Wang, 2001b). Thus, the conception of inquiry-oriented teaching as the only approach to reforming mathematics teaching while teacher directed instruction is against the visions of mathematics teaching reform in the literature can be a false-dichotomy (Romberg, 1992; Smith III, 1996). This conceptual dichotomy may limit the space and chances for the potential mathematics teaching reform using the popular traditional teaching structure. However, to better understand its potentials, it is important to examine the relationship between the specific reforms within the teacher directed instruction structure and the expected student learning outcomes.

Second, participants’ reformed focuses and activities, whether using infiltrative or revamping approaches, were consistent with the visions of mathematics teaching reform standards in China. In this study, most participants in both infiltrated and revamped groups were able to support students to use what they have already learned and the real world contexts to help students reason mathematically, make mathematics connections, develop multiple solutions, or prove their mathematics ideas in whole classes or groups.

This finding is consistent with the finding of studies that Chinese teachers developed better understanding about mathematics teaching and learning (Ma, 1999; Zhou, Peverly, & Xin, 2006). It also mirrors the findings based on the anecdotal case and observations that Chinese teachers were able to develop meaningful

mathematics problems that involve the connection between what students learned and what they are going to learn (Wang & Paine, 2003; Yang & Cobb, 1995). However, whether and to what extent these characteristics of Chinese teachers' mathematics teaching are the sole or major factor influencing their students' higher mathematics performance is still an open question worth an empirical examination.

Third, the centralized curriculum contexts, contrived teaching organization and accountability assessment system shaped directly and indirectly participants' efforts in reforming their lesson structures, focuses, and activities. As shown in this study, the centralized reformed curriculum made it an obligation for many participants to develop reform focuses and activities for their lessons. The contrived organization of teaching offered a system of professional check and specific support for them to pursue their reform ideas. The curriculum based accountability assessment system shaped their choice of reform topics and activities for their lessons and made them choose the infiltrative approach to reforming teaching. This finding confirms the two assumptions. One is that the contrived curriculum and teaching contexts presumably shaped teacher's teaching practices (Cohen & Spillane, 1992). The other is that teaching change is a gradual and incremental process as it is culturally scripted (Kennedy, 2010; Sykes et al., 2010).

Conclusions and Implications

This study comes to three basic conclusions. The teacher directed mathematics instruction can be a host for teaching reform. Success of such a reform relies importantly on the reforms of curriculum and assessment as well as specific supports of professional training. Such teaching reform is inevitably incremental shaped by the curriculum, assessment, and teaching contexts in which teaching practices are situated.

The implications of this study for the policy makers and practitioners who are committed to transforming mathematics teaching practices are twofold. First, it is important to develop long-term policy initiatives and programs when they are trying to reform the existing teaching practice and be patient enough to sustain and adjust the influences of these policies and programs as teachers are reforming their teaching practices. Second, it is also necessary for them to develop an extensive and a deep understanding about the cultures and contexts of teaching. These understanding are necessary for them to identify the niches in these contexts to plant their reform policy initiatives and programs and expend their influences gradually, flexibly, and persistently (Hiebert et al., 2002; Kennedy, 2010).

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