

A Case Study of the Pedagogical Tensions in Teacher's Questioning Practices When Implementing Reform-Based Mathematics Curriculum in China

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This study examines a teacher's questioning strategies in mathematics classrooms in China when implementing reform-based mathematics curriculum. It explores teacher's strategies to deal with the tensions involved in the creation of opportunities for students to express and communicate mathematics ideas while ensuring the productivity of mathematics communication and the accomplishment of the lesson goals in a limited period of time. By doing so, this study has implications for teacher education and professional development in terms of how to strengthen the links between intended mathematics curriculum reforms and teacher's actual practices in mathematics classrooms.

Introduction

In current mathematics curriculum reform movement, not only the mathematics knowledge need to be upgraded to the most fundamental and useful in today's world, but also the pedagogical principles and should be improved so as to support the implementation of reform-based curriculum (Sullivan et al., 2013).

As an important pedagogical strategy in delivering mathematics curriculum, to provide students with sufficient opportunities in classroom interaction and communication has been well accepted by most nations. When implementing mathematics curriculum, teachers are encouraged to effectively use questioning strategies in classrooms to elicit students' mathematical ideas and to scaffold students' construction of mathematics knowledge. Although the use of questions in mathematics classrooms is not new for most nations, the effectiveness of this strategy has been challenging (Boaler & Brodie, 2004). This is not only because that question asking per se is a sophisticated art ((Boaler & Brodie, 2004), but also because that there are pedagogical tensions involved in teachers' strategies regarding the creation of opportunities for students to express and communicate mathematics ideas while ensuring the productivity of mathematics communication and the accomplishment of the lesson goals in a limited period of time (Sherin, 2002).

This study intends to investigate the ways in which a secondary school teacher employed questioning practices when implementing the reform-based curriculum. It explores the teacher's strategies to create opportunities for students to express and communicate mathematics ideas while ensuring the productivity of mathematics communication and the accomplishment of the lesson goals. By doing so, this study has implications for teacher education and professional development in terms of how to strengthen the links between intended mathematics curriculum reforms and teachers' actual practices in mathematics classrooms. Given that the challenges in employing effective questioning strategies are also experienced by mathematics teachers worldwide (Kosko, Rougee & Herbst, 2014), this case analysis of a Chinese teacher could also provide some implications for teachers in other countries to improve their instructional practices.

Methodology

A case study design was adopted in the present study so as to undertake a detailed analysis of mathematics lessons delivered by the participating teacher. Since this study aims to reveal the detailed and in-depth features of teacher questioning practices in mathematics classrooms, there is a need to utilise a case study design which could provide tools for researchers to explore complex phenomena within their contexts (Baxter & Jack, 2008).

Meanwhile, the IRF (Initiation-Response-Follow up) framework was utilised to analyse the teacher's discourse process of initiating questions and building up on student responses. Classroom lessons could be interpreted as a process of alternations between verbal and nonverbal behaviour that are jointly created by teachers and students and these alternations are characterised by interactional sequences of three interconnected parts: teacher initiation, student response and teacher follow up or IRF (Cazden, 2001). While the IRF structure has been criticised as limiting the potential of teacher-student dialogue in promoting students' conceptual learning in mathematics classrooms (i.e., Kyriacou & Issitt, 2007), more and more researchers have pointed out the IRF pattern includes more possible variations that could fulfil a diverse range of pedagogical purposes (Drageset, 2014, Franke, et al., 2009)

Considering the above analysis, the IRF structure in the classrooms was identified and then teacher questioning practices were examined within the IRF structure. It intended to develop a comprehensive framework with regard to teacher questioning and thereby to analyse what kinds of verbal questions were initiated by the teachers to elicit mathematical information and in what ways the teachers took students' verbal contributions into consideration so as to facilitate students' construction, acquisition and articulation of mathematical knowledge.

Setting and Participants

Data were drawn from video-recorded observations of one Chinese mathematics teachers' lessons in junior secondary level. The language of instruction is Mandarin Chinese. The participant is from the city of Nantong, Jiangsu Province in southeastern China and he is recognised as competent according to local criteria. As the teacher intended to implement the reform-based curriculum by providing more opportunities with students to express and communicate mathematics in classrooms, group learning was introduced into the classroom and the self-learning guide was also used. It includes three main sections in the self-learning guide, namely the review of mathematics knowledge relevant to the new topic, the construction or exploration of the new mathematics knowledge by problem solving, and the reflection and summary. In each section, the students are provided with some questions or tasks.

One day before a particular lesson, the teacher passed out the self-learning guide to every student, asking them to learn the new topic on their own and then to accomplish the tasks in the self-learning guide independently. On the next day, the students handed in the self-learning guide to be corrected by the teacher, who would leave written feedback in detail and then pass out the corrected self-learning guide to students before the lesson. It is worthwhile to point out that the teacher's feedback is not just simplistic evaluation of students' answers, but some detailed comments which could help students to reconsider their answers, encourage students to make connections with some previous mathematical knowledge, or challenge students to think more deeply.

For each lesson, the teacher had established a very regular structure, which consisted of four distinct parts. Firstly, at the beginning of the lesson, the teacher asked students to exchange ideas on the tasks in the self-learning guide in groups, as well as on the answers to the tasks. Secondly, after discussion and exchange in groups, one group was selected by the teacher to present in public the unanimously agreed ideas they had achieved on how to solve the tasks and each member of this selected group was responsible for one part of the whole group’s presentation. Thirdly, after each member had accomplished his/her part of the presentation, other students were encouraged to give comments and ask questions. The teacher would generally get involved in this part and direct the public discussion. Fourthly, when the whole group had completed the presentation, the teacher always gave a lecture to sum up the presentation and discussion, as well as the main mathematical points in this lesson. When the data were collected, the teacher had been teaching his class in this way for around two years. A whole unit of consecutive lessons was collected and the analysis of the first three lessons is presented in this study. The details of the lessons are listed in Table 1.

Table 1
Lesson Topics Delivered by the Participating Teacher

Teacher	Year level	Lesson content	Time
CHN	8	<i>Lesson1</i> An introduction to quadratic functions	45mins
		<i>Lesson2</i> Investigating the graph of $y=ax^2$	45mins
		<i>Lesson3</i> Investigating the graph $y=a(x-h)^2+k$	45mins

Data Analysis

The term “question” refers to what the teacher says to elicit students’ verbal responses related to mathematical content. Questions that were not mathematical were excluded unless they were associated with other mathematical “talk”. Questions immediately repeated using the same wording was counted only once.

Three types of occasions when the teacher interacted with students by using questions were identified initially. When the student/s replied to the teacher’s questions and the teacher did not respond the interactions were categorised as Question-Answer (Q&A) pairs. IRF (Teacher initiation-Student response-Teacher follow up) sequences (Cazden, 2001) were those where the teacher responded to students’ answers that were triggered by the teacher’s previous question. There are two types of IRF sequences: (1) IRF (single) in which the teacher asks a question and then gives a closed follow-up move (such as evaluation) to students so as to complete the current discussion, and (2) IRF (multiple) in which the teacher asks a question and then gives an open follow-up move (such as clarification or elaboration) to students so as to continue the current discussion. The episodes of Q&A pairs, the sequences of IRF (single) and IRF (multiple) were transcribed prior to the analysis.

When analysing the teacher’s questions, a distinction was highlighted between initiation questions and follow-up questions. Initiation questions are those questions asked by the teacher for initiating purposes, such as to start conversation or discussion. In contrast, follow-up questions are those questions asked for the purposes of following up, such as in response to students’ answers or contributions to the teacher’s previous questions. In this study, the Q&A pair contains teacher initiation questions and student responses and the IRF sequence includes the teacher initiation question, the student response, and the teacher follow-up question.

A coding system was developed to categorise the initiation questions and follow-up questions. Instead of inventing the name of each category in advance, those questions documented in our data were analysed first and then attempts were made to provide names to describe these different kinds of questions. The coding systems are presented in Table 2 and Table 3 where examples are shown in italics. Abbreviations for these categories are also provided.

Table 2
Sub-categories for Initiation Questions

Category	Description and Example
Understanding check (UND)	Questions used to check whether students can follow the teacher. “Is everyone OK with how I get from the 2nd line to the 3rd line?”
Evaluation (EVA)	Questioning requiring students’ comments. “Now let’s look at these two descriptions, which one do you agree with?”
Review (REV)	Questions used to elicit the previously learnt or mentioned mathematics knowledge. “Now what do I know about squares and their area?”
Information extraction (INF)	Questions requiring students to identify and select information from text descriptions, graphs, tables, or diagrams. “What is (b), what’s the mathematical word for what (b) is asking you to find?”
Link/ application (LIN)	Questions requiring students to provide examples or application of mathematical knowledge. “Could you list some examples?”
Result/product (RES)	Questions requiring results of mathematical operations or the final answer of the problem solving. “What is the square root of 80?”
Strategy/ procedure (STR)	Questions used to elicit the procedures or strategies of problem solving. “How can we solve this problem?”
Explanation (EXP)	Questions requiring students to provide explanations. “How would it be interpreted from the perspective of a function?”
Comparison (COM)	Questions requiring the comparison. “Is this different from the previous questions?”
Reflection (REC)	Questions requiring the reflection after mathematical activities. “What mathematics have we already used in solving triangles?”
Variation (VAR)	Questions requiring students to consider the variations of mathematical tasks. “So what if I got a hundred and twenty seven in that answer?”

The development of the coding system in this study was informed by coding systems proposed by some previous researchers (Boaler & Brodie, 2004; Hiebert & Wearne, 1993). Some categories’ names were borrowed from these studies, but because the distinction between initiation questions and follow-up questions was considered in this study, some new categories of questions were also identified and labelled. A test-retest method was used to check the reliability of the coding systems and the elapsed time between the first and second coding was two months.

Findings

The coding systems presented above were used to analyse the selected lessons taught by the participating teacher. In total, 121 initiation questions and 116 questions were asked by the Chinese teacher in the three lessons which cover 135 minutes altogether. On

average, the Chinese teacher raised approximately 1.8 (237/135) questions in every minute and for every initiation question, the Chinese teacher used approximately one (116/121) follow-up question.

Table 3
Sub-categories for Follow-up Questions

Category	Description & Example
Clarification (CLA)	Questions requiring a student to show more details about his/her answers or solutions. "How did you get this 16?"
Justification (JUS)	Questions requiring students to justify their answers "Why did you choose this method to solve this problem?"
Elaboration (ELA)	Questions requiring for additional information especially when the students fail to fully achieve the teacher's goals. "In other words, the green line becomes the what?"
Extension (EXT)	Questions used to extend the topics under discussion to other situations or to connect the knowledge under discussion with the previous knowledge. "Would this work with other numbers?"
Supplement (SUP)	Questions used to request for supplement. "Did anyone do this problem in a different way?"
Cueing (CUE)	Questions used to direct students to focus on key elements or aspects of the situation in order to enable problem-solving. "What is the problem asking you to find?"
Refocusing (REC)	Questions used to guides students to refocus on the key points, especially when students are off track. "But what was the question, if this was a textbook question, what would it look like?"
Repeat/rephrase (REP)	The teacher repeats or rephrases the question asked in the last turn.
Agreement request (AGG)	Questions used to check whether the rest of the class agrees with the student who gives the answer. "So would you agree that the height of this one is going to be a hundred and forty nine?"

The detailed information in terms of the breakdown of initiation questions and follow-up questions is shown separately in Figure 1, Figure 2 and Figure 3. For the abbreviations in these figures, please refer to Table 1 and Table 2.

Figure 1 shows the proportion of each type of initiation question that was asked in the three lessons and this outlines the teacher's initial purposes when asking initiation questions. As is shown in Figure 1, although 11 types of initiation questions were identified in the three lessons, several types of initiation questions are predominant in each lesson. For lesson 1, the teacher's initiation questions were mainly asked for understanding check (UND), review (REV), and explanation request (EXP).

For What Initiating Purposes did the Teacher Ask a Question?

There are more variations in Lesson 2 where the teacher asked initiation questions for understanding check (UND), review (REV), explanation request (EXP), evaluative comments request (EVA), and reflection request (REF). Two types of initiation questions, namely review (REV) and explanation request (EXP), take up more than 60 percent of all the initiation questions asked in Lesson 2. Among all three lessons, questions for review (REV) and explanation request (EXP) were the two common types of initiation questions

with significant proportions. Apart from these two common types, questions were also asked for understanding check (UND), evaluative comments request (EVA), and reflection request (REF) rather frequently, even though these types did not turn up with a significant proportion in every lesson.

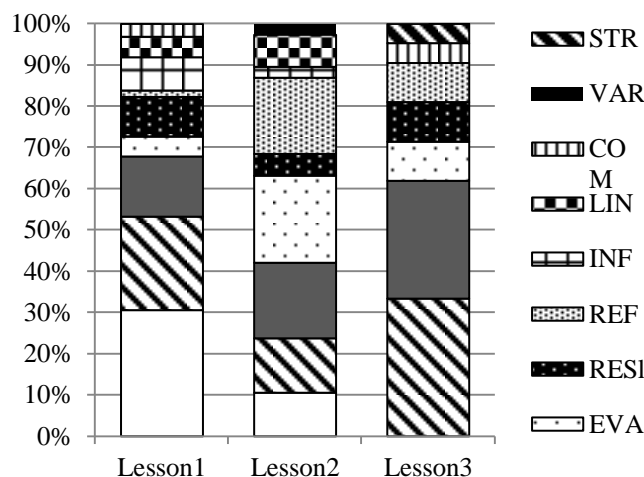


Figure 1. The breakdown of the teacher's initiation questions
 Note: Refer to Table 2 for the abbreviations.

Theoretically, all these types have the potential of allowing students to express mathematics except the questions for understanding check (UND) which usually request a yes or no answer. In particular, explanation requests (EXP), evaluative comments requests (EVA), and reflection requests (REF) are more likely to elicit students' mathematics ideas on the basis of which the teacher could thereby provide facilitation and request elaboration. In this way, mathematics communication could occur between the teacher and students. However, it would depend on this teacher's strategies whether the students' responses could be used to build up mathematics communication. To investigate how the teacher dealt with the students' responses is examined in next part as well as the extent to which the teacher built on students' responses after the asking initiation questions.

Figure 2 presents the proportion of initiation questions asked on three types of occasions and it shows to what extent the teacher's initiation questions lead to the sequences of teacher-student mathematics communication. Five types of initiation questions (EVA, EXP, COM, REF, and LIN) were asked with higher chances of leading to IRF (multiple) in which the teacher tended to build on students' responses and therefore create more opportunities for students to communicate mathematics. In Figure 1, it was shown that questions for review (REV) and explanation request (EXP) are the two common types of initiation questions with significant proportions.

To What Extent Did the Teacher Build on Students' Responses?

Figure 2 reveals almost 90 percent of the questions for review were asked by the teacher without giving follow-up moves that could lead to the sequences of mathematics communication. In other words, when the teacher asked initiation questions for review, instead of having opportunities to communicate mathematics in discourse sequences, the students normally just need to respond with answers to the questions. In contrast, the initiation questions for explanation requests were mostly asked by the teacher with the following support through which the students could communicate mathematics. As is shown in Figure 2, around 85 percent of questions for explanation requests were asked

within the IRF (multiple) structure in which the teacher tended to give open follow-up moves after initiation questions to students so as to continue the current discussion. The detailed approaches in terms of the follow-up moves used by the teacher to facilitate students to communicate mathematics are presented in Figure 3.

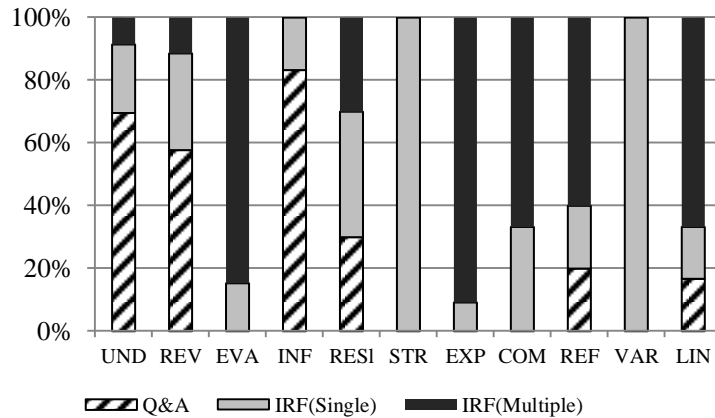


Figure 2. The teacher's initiation questions on three occasions
 Note: Refer to Table 2 for the abbreviations

In What Ways Did the Teacher Build on Students' Responses?

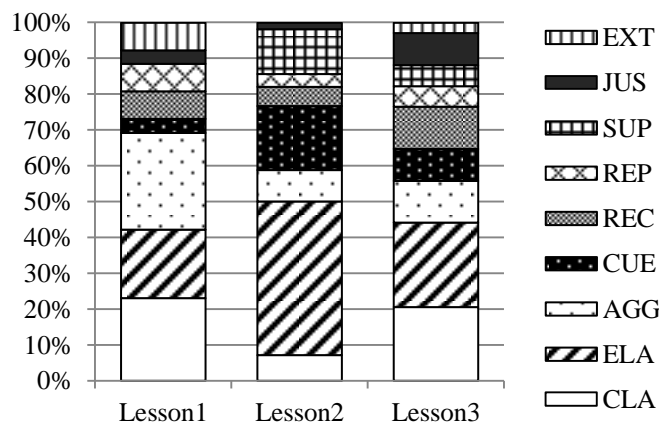


Figure 3. The breakdown of the teacher's follow-up questions
 Note: Refer to Table 3 for the abbreviations

Figure 3 shows the proportion of follow-up question types employed by the teacher in the three lessons. Nine types of follow-up questions were identified in the three lessons and once again the majority of the follow-up questions consist of several types of question. In Lesson 1, the follow-up questions were mainly asked for clarification (CLA), elaboration (ELA) and agreement requests (AGG). For Lesson 2, the teacher posed follow-up questions mainly for elaboration (ELA), giving cues (CUE), and supplement requests (SUP). And questions for clarification (CLA), elaboration (ELA), agreement requests (AGG) and refocusing (REC) constitute the main body of follow-up questions in Lesson 3. Among the three lessons, the teacher tended to choose elaboration questions as a tool to facilitate students' expression and communication of mathematics ideas.

Conclusion

Compared with the traditional mathematics curriculum, the reform-based mathematics

curriculum requires teachers to provide students with more opportunities to communicate mathematics. But it brings pedagogical tensions because teachers also need to control the flow of the communication to ensure the productivity of mathematics communication.

The participating teacher adopted a new way of delivering mathematics lessons by introducing the self-learning guide. The students had attempted to solve the tasks in the self-learning guide prior to the lessons, thus in the classroom the teacher and students had sufficient time to talk deeply about the corresponding strategies to solve these tasks. Meanwhile, students' discussion on these tasks also became the springboard on which the participating teacher could ask further questions to elicit students' deeper thinking and promote students' construction of mathematics knowledge. All of these made contributions to the creation of a discourse-rich classroom.

This study separately examined initiation questions and follow-up questions asked by the teacher. By exploring the proportion of these questions and the context in which these questions were used, it is possible to analyse the actual opportunities provided for the students to communicate mathematics. This helped understand more clearly the nature of the discourse-rich classroom. This study showed that a considerable proportion of elicitation and facilitation were used by the teacher to promote the communication and construction of mathematics. But it also reflected some suppression of learning when the teacher attempted to fulfil the lesson goals.

This has implications for mathematics teacher education in terms of supporting the implementation of intended mathematics curriculum. For one thing, the reform in terms of learning materials, such as the introduction of self-learning guide, could assist the shift from traditional classroom into inquiry-based classroom. The design of the tasks in the self-learning guide could help to ensure the depth and productivity of mathematics discussion and communication in classroom. Also, more assistance is needed to help the teacher use the self-learning guide more efficiently.

References

- Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The qualitative report*, 13(4), 544-559.
- Boaler, J., & Brodie, K. (2004). The importance, nature and impact of teacher questions. *Proceedings of the 26th annual meeting of the North American chapter of the International Group for the Psychology of Mathematics Education* Vol. 2, pp. 773-781.
- Brodie, K. (2011). Working with learners' mathematical thinking: Towards a language of description for changing pedagogy. *Teaching and Teacher Education*, 27(1), 174-186.
- Cazden, C. B. (2001). *Classroom discourse: The language of teaching and learning*. Portsmouth, NH: Heinemann.
- Drageset, O. (2014). How Students Explain and Teachers Respond. In J. Anderson, M. Cavanagh & A. Prescott (Eds.). *Curriculum in focus: Research guided practice* (Proceedings of the 37th annual conference of the Mathematics Education Research Group of Australasia pp. 191-198) Sydney: MERGA
- Franke, M. L., Webb, N. M., Chan, A. G., Ing, M., Freund, D., & Battey, D. (2009). Teacher questioning to elicit students' mathematical thinking in elementary school classrooms. *Journal of Teacher Education*, 60(4), 380-392.
- Hiebert, J. & Wearne, D. (1993). Instructional Tasks, Classroom Discourse, and Students' Learning in Second-Grade Arithmetic, *American Educational Research Journal*, 30(2), 393-425
- Kosko, K. W., Rougee, A., & Herbst, P. (2014). What actions do teachers envision when asked to facilitate mathematical argumentation in the classroom? *Mathematics Education Research Journal*, 26(3), 1-18
- Kyriacou, C., & Issitt, J. (2007). Teacher-pupil dialogue in mathematics lessons. *BSRLM Proceedings*, 61-65.
- Sullivan, P., Jorgensen, R., Boaler, J., & Lerman, S. (2013). Transposing reform pedagogy into new contexts: complex instruction in remote Australia. *Mathematics Education Research Journal*, 25(1), 173-184.
- Sherin, M.G. (2002). A balancing act: developing a discourse community in a mathematics classroom. *Journal of Mathematics Teacher Education*, 5(3), 205-33