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Teacher Questioning Practices over a Sequence of Consecutive Lessons: A Case Study of Two Mathematics Teachers

Lianchun Dong [1], David Clarke [2], Yiming Cao [3,4,*], Lidong Wang [5,*] and Wee Tiong Seah [2]

1 College of Science, Minzu University of China, No. 27 Zhongguancun South Avenue, Haidian District, Beijing 100081, China; lianchun.dong@muc.edu.cn
2 Melbourne Graduate School of Education, University of Melbourne, 234 Queensberry Street, Carlton 3053, Australia; d.clarke@unimelb.edu.au (D.C.); wt.seah@unimelb.edu.au (W.T.S.)
3 School of Mathematical Sciences, Beijing Normal University, No. 19 XinJieKouWai Street, HaiDian District, Beijing 100875, China
4 International Center for Research in Mathematics Education, Beijing Normal University, No. 19 XinJieKouWai Street, HaiDian District, Beijing 100875, China
5 Collaborative Innovation Center of Assessment for Basic Education Quality, Beijing Normal University, No. 19 XinJieKouWai Street, HaiDian District, Beijing 100875, China
* Correspondence: caoym@bnu.edu.cn (Y.C.); wanglidong@bnu.edu.cn (L.W.); Tel.: +86-10-5880-1986

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Abstract: This study examined teacher questioning practices over a sequence of consecutive lessons in China. Based on the IRF (initiation–response–follow-up) framework, a comprehensive coding system was developed to analyze what kinds of verbal questions were initiated by the teachers to elicit mathematical information and in what ways the teachers made use of students' verbal contributions. This study finds that all participating teachers' questioning practices showed both variations and consistencies over the lesson sequence. It is argued that the act of asking questions in classroom interaction not only includes the teachers' conscious planning so as to accomplish pedagogical goals, but also involves the teachers' unconscious routine in how to build up on students' thinking.

Keywords: teacher questioning; consecutive lessons; mathematics; China

1. Introduction

The ultimate goal of school education is to support and develop the sustainability of students' thinking and understanding. In the classroom, teacher questioning practices help to build an environment for students' sustainable learning and development. However, teachers' effective and efficient employment of questioning strategies in classrooms has been one of the most challenging techniques. Some researchers (e.g., Reference [1]) argued that expert teachers' questioning practices vary a lot to suit particular contexts and teaching purposes. In other words, effective questioning strategies do not represent a fixed set of techniques, but flexible adaptation, adjustment, and alteration of various questioning strategies according to actual teaching situations. However, very few empirical studies examined the ways in which teachers might vary their practices of asking questions according to different situations (e.g., in different lessons with different learning contents), which hindered our understanding of the instructional flexibility in classroom questioning. To find out how teachers might change their questioning practices in different lessons, this study conducted a detailed analysis of two mathematics teachers' employment of questioning strategies over a unit of consecutive lessons.

2. Literature Review

2.1. The Early Debate on Effective Question Types

Many attempts have been made to identify the effective question types that could improve student achievement. These attempts lead to the development of classification systems of teacher questions. One of the most influential criteria used to classify teacher questions was the adaptation of Bloom's taxonomy for question types: classifying teacher questions according to the level of cognitive process needed to achieve the answers [2]. In addition, the premise that certain types of question work better than others in classrooms sparks the debate regarding the superiority of higher-cognitive questions over lower-cognitive questions to influence student achievement (e.g., References [3,4]). Many researchers argued higher-cognitive questions contributed to students' high-order thinking and deep understanding. However, a great many studies reported that teachers asked predominantly lower-cognitive questions rather than higher-cognitive questions in classroom interaction [5]. It seems to be puzzling that many teachers do not prefer to ask questions that could promote students' better understanding.

One of the possible explanations might be that teachers' selection of question types is influenced by many other factors. For example, Gall pointed out that the effectiveness of teacher questions depends significantly on the student capabilities: lower-cognitive questions were more effective for students with low-level capabilities, whereas the students with average- or high-level capabilities could learn better from higher-cognitive questions [5].

In addition, the conceptions of questioning practices' effectiveness also go beyond preparing a list of effective question types. Wilen and Clegg concluded that effective questioning practices do not mean simply selecting certain types of questions, but rather involve the ways of posing questions and responding to student answers [6]. In other words, effective questioning is a dynamic process involving flexible strategies of asking questions and dealing with students' responses.

2.2. Sequences of Questions

Recent studies argued that no teacher question types should be glorified in classroom teaching because any question had a place in enhancing students' learning by interaction [7]. Some researchers claimed that more attention ought to be given to the sequence of discourse in which the teachers pose questions in classroom instruction [8,9]. Fine-grained analysis of the guiding process resulted in the identification of two different patterns of questioning: funneling and focusing [10–12]. In the funneling pattern, the teacher typically raises a sequence of questions as guidance towards the correct answers and students merely need to give the answers to each question without necessarily understanding the connections among the questions [10,12]. In contrast, the focusing pattern allows students to articulate their own mathematical thinking and to reflect on the meaning of teacher–student dialogues [11].

A prevalent structure in classroom discourse is referred to as the IRF sequence (teacher initiation—student response—teacher feedback; Sinclair and Coulthard [13]) or IRE, where E stands for evaluation [14], or "triadic dialogue" [15]. This triadic structure has been well-documented in the previous studies [16,17]. The initiation is typically enacted by the teacher questioning, followed by students' reply and subsequently the teacher's feedback or follow-up [18]. In recent years, the third move in IRF has attracted increasing attention from educational researchers in their attempts to investigate the value of IRF for teaching and learning. Some researchers [19,20] also pointed out that IRF proved to be productive in fostering collaborative work, during which the follow-up move plays a significant role.

2.3. Factors Influencing Teacher Questioning Practices

Recent research added evidence regarding the sophisticated nature of effective questioning by highlighting the changes of teacher questions in different contexts. Some researchers argued that teacher questioning practice is directly reflective of instructional goals. Hiebert and Wearne pointed

out the connections between instructional goals and teacher questions in mathematics classrooms, claiming that teachers raised questions with the intention to direct students' attention to interpret and solve mathematics problems in the expected ways according to the instructional goals [21]. Meanwhile, Nathan and Kim also highlighted the effects of teachers' curricular goals on classroom interactions [22]. They examined information flow and scaffolding in mathematics classrooms and demonstrated that classroom questioning practices could be shaped by teachers' interpretation of curricular goals. Shi argued that in mainland China the analysis of teacher questioning practices could be used as a framework to interpret the teachers' pedagogical goals in classroom instruction [23]. By examining five aspects of classrooms, namely, teachers' questions, student responses, teachers' responses to student answers, student activities, and teachers' balancing on student answering and student discussion, Shi found that teachers adjusted the cognitive requirements of classroom questions so as to ensure the completion of lesson goals [23].

In addition, Nathan and Kim reported that teacher questions in mathematics classrooms are highly responsive to the perceived state and current needs of students [21]. In the case of inaccurate or incomplete student responses, the teacher tended to reduce the level of cognitive complexity of a subsequent question, whereas teacher subsequent questions became more complex when students' responses were mathematically accurate.

2.4. Coding Teacher Questioning Practices

Some coding systems were developed in order to describe the complexity of teacher questioning in mathematics classrooms (e.g., References [21,23,24]). Instead of looking at the cognitive level of questions as is used by the earlier researchers, these coding systems focused on the teacher's intentions when asking questions. For example, Hiebert and Wearne grouped teacher questions into four broad categories, namely requesting recitation of previously taught facts or procedures, asking students to describe invented solution strategies, requesting students to generate problems, and asking students to explain why things work the way they do [21]. Similarly, in Boaler and Brodie's classification system [24], all the categories were named with verbs to describe teacher intentions when asking questions: (1) gathering information, leading students through a method; (2) inserting terminology; (3) exploring mathematical meanings and/or relationships; (4) probing, getting students to explain their thinking; (5) generating discussion; (6) linking and applying; (7) extending thinking; (8) orienting and focusing; and (9) establishing context.

When coding teacher questions, a distinction between initiation questions and follow-up questions is highlighted. As opposed to initiation questions which signal the opening of the teacher-student conversation, follow-up questions refer to those teacher questions asked in response to a student utterance, such as a student's answer or response to teacher questions posed earlier [25]. The investigation of follow-up questions is significant because teachers were reported to experience more challenges when properly following up students' responses than posing proper initiation questions [8].

2.5. The New Lens: A Unit of Consecutive Lessons

In recent years, researchers highlighted the necessity of examining mathematics teachers' practices over a unit of consecutive lessons rather than a single lesson (see, for example, References [24,26,27]). In particular, Koizumi pointed out teachers might prepare each lesson as one part of a sequence of lessons which could be regarded as a unit and thus different lesson within one unit usually had different instructional goals and structures which would influence classroom questioning practices [28]. However, much previous research has focused on single lessons, leading to an inability to comprehensively consider the lesson context as a factor in understanding teacher questioning. In one of the few studies investigating teacher questioning in consecutive lessons, Koizumi focused on teacher questioning strategies in introductory stages in mathematics lesson sequences in Japan and

Germany, concluding that the context of consecutive lessons enables the better observation of cultural specificity in teacher questioning practices [28].

2.6. Purpose of this Study

Despite the fruitful findings mentioned above, there is still a lack of comprehensive understanding of teacher questioning in mathematics classrooms. Especially, the instructional flexibility in teacher questioning practices is rarely investigated. Very little is known about the ways in which teachers flexibly vary their questioning practices in response to instructional contexts. Very few studies have been conducted to investigate how teachers change their ways of asking follow-up questions to probe or facilitate students' learning.

However, the previous studies demonstrated that a sequence of consecutive lessons could show more variation in teachers' teaching practices and also offer greater insight into the teachers' purposeful deployment of particular question types, reflective of their changing instructional purposes over the course of a lesson sequence. In other words, only in the sequence of consecutive lessons can we do justice to the situated nature of teacher questioning and give appropriate recognition to the strategic adjustment that teachers make in their questioning practices in response to changing classroom conditions.

This current study has been designed to investigate the flexibility in teacher questioning practices through the new lens: a unit of consecutive lessons. It aims to address the following research questions: (1) In each participating teacher's classroom, what variations in teacher questioning practices were evident across a sequence of consecutive lessons? (2) In each participating teacher's classroom, what consistencies in teacher questioning practices were evident across a sequence of consecutive lessons?

3. Methodology

This study aims to reveal detailed and in-depth features of teacher questioning practices in mathematics classrooms. Such a detailed investigation required the employment of a case study approach [29]. Each case concerns a single mathematics teacher and their class.

3.1. Participants

Two mathematics teachers from China participated in this study. One of them is from Beijing in the northern region of China, while the other one is from the Jiangsu Province, the southern part of China. Both participating teachers were considered competent by local standards, and were both experienced in teaching the respective grade levels being studied. The information about the participants is shown in the Table 1.

Table 1. Details of the participating teachers and the classes.

Teacher	Gender	Year of Experience	Site	School/Class
CHN1	Female	More than 5 years	Beijing	Urban public school, 36 students
CHN2	Male	More than 10 years	Haimen, Jiangsu Province	Urban public school, 46 students

3.2. Data Collection

For each teacher, one unit of consecutive lessons was videotaped through three cameras, separately focusing on the teacher, the whole class, and a group of focus students. The three-camera video recordings increased the possibility of continuously documenting all teacher–student interaction in classrooms, contributing to a better observation of teacher questioning practices in the classrooms. The details of the video-recorded lessons for each participating teacher are listed in the Table 2.

Table 2. Lesson topics delivered by the participating teachers.

	Lesson Topics
CHN1: Solving right triangles	L1: Solving right triangles; L2: Solving non-right triangles; L3: Applications: measurements of height and distance; L4: Applications: slope angles and marine navigation; L5: Mixed application problems; L6: Chapter review
CHN2: Quadratic functions	L1: Introduction to quadratic functions; L2: The graph and properties of $y = ax^2$; L3: The graph and properties of $y = ax^2 + k$; L4: The graph and properties of $y = a(x - h)^2$; L5: The graph and properties of $y = a(x - h)^2 + k$; L6: The graph and properties of $y = ax^2 + bx + c$; L7: Finding the equation of quadratic functions; L8: Quadratic functions and quadratic equations; L9: Quadratic functions and real-world problems; L10: Chapter review

3.3. Data Analysis

3.3.1. The Definition of the Teacher Questions

Three types of occasions when the teacher interacted with students by using questions were identified first. Where the student/s replied to teacher questions and the teacher did not respond, these interactions were categorized as question–answer (Q&A) pairs. There are two types of IRF (teacher initiation—student response—teacher follow up) sequences: (1) IRF (single) in which the teacher asks a question and then gives closed follow-up moves (such as evaluation) to students so as to accomplish the current discussion, and (2) IRF (multiple) in which the teacher asks a question and then gives open follow-up moves such as clarification or elaborations that require a further student response. The second type could potentially extend the discussion and the associated IRF sequence.

When analyzing teacher questions, a distinction was made between initiation questions and follow-up questions. Initiation questions are those questions asked by teachers for the purpose of starting a conversation or discussion. In contrast, follow-up questions are those questions asked for the purposes of responding to a student utterance, such as a student's answer or response to the teacher's previous question. In some cases, students stayed silent for 2 seconds or longer after the teacher posed a question and afterwards the teacher gave some clues by asking further questions. The latter questions are also categorized as follow-up questions, because a silent period of 2 seconds or longer could be recognized as a special type of student responses. In such cases, student responses will be shown as "[silent]" in the transcriptions.

In this study, the Q&A pair and IRF (single) sequence contain teacher initiation questions only and the IRF sequence includes the teacher initiation question, student response, and teacher follow-up question, as is shown in the Figure 1.

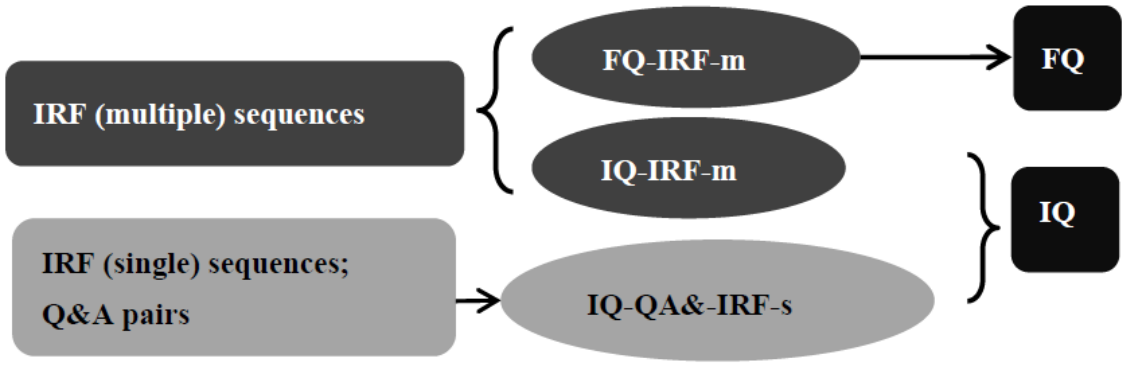


Figure 1. The framework to categorize teacher questions. Note: FQ-IRF-m = follow-up questions in IRF (multiple) sequences; FQ = follow-up questions; IQ-IRF-m = initiation questions in IRF (multiple) sequences; IQ-QA&IRF-s = initiation questions in Q&A question pairs and IRF (single) sequences; IQ = initiation questions.

3.3.2. Coding Systems

A coding system was developed to categorize the initiation questions and follow-up questions. Instead of inventing the name of each possible category in advance, those questions documented in our data were analyzed first and then attempts were made to provide names to describe these different kinds of questions. The naming of some question categories in this study was also informed by the research of Boaler and Brodie [24] and Hiebert and Wearne [21], whose classification schemes included question categories closely aligned with some of the question types identified in this study. The categories developed in the above to studies were introduced in the section of literature review.

However, because the coding systems developed by these researchers did not explicitly distinguish the initiation questions from the follow-up questions, new coding systems were developed in this study. For example, the category of *Information extraction* (see Table 3) was mentioned by Boaler and Brodie [24] who used the category of *Gathering information*, though in this study *Information extraction* questions only cover questions asked in the initiation stage of teacher–student interaction. In other words, the *Gathering information* questions by the definition of Boaler and Brodie [24] might be asked in both the initiation and follow-up stages of teacher–student interaction, whereas in the current study, the category *Information extraction* question only referred to the questions asked in the initiation stage. Those *Gathering information* questions asked in the follow-up stage would be coded with follow-up question categories depending on the actual purpose of the follow-up questions. The coding systems are presented in Table 3, in which each question category is associated with a three-letter code, accompanied by a description. Each three-letter code is used in the following sections.

3.3.3. Interrater Reliability

One lesson was selected separately from teacher CHN1's class and CHN2's class for a reliability check, in which three coders (one of whom was the first author) in the field of education research independently coded the questions in the transcripts of the selected lessons. Due to the ethical requirement restricting video access to the researcher, the classroom videos could not be watched by any coders other than the first author. However, coding of teacher questioning could be conducted using the lesson transcripts and also all teaching and learning materials including lesson plans, PowerPoint slides, and copies of student worksheets were available to both coders. Also, teacher questionnaires and classroom observation tables were also given to both coders so as to allow each coder the best possible basis on which to make sense of the instructional settings.

An agreement of 80% was achieved between the three coders' coding results. Any inconsistent coding results were discussed, and a consensus coding result was determined by all the coders and the authors of this paper. Where coding differences arose from differences in the interpretations of the coding scheme, rather than differences in the interpretation of the data, these differences were resolved by refining the categories' descriptions to achieve consensus as to the meaning of the code/category. Afterwards, the first author coded all the remaining lessons with the revised coding systems. The questions identified within the lesson transcripts were not coded in isolation, disconnected from the interactions of which they were a part. They were instead all coded within the classroom transcripts, where the teacher and students engaged in questioning and answering practices, such that the social context of each exchange could be taken into account, together with actions that immediately preceded or followed the coded exchange. The classroom videos were revisited and checked whenever there was ambiguity.

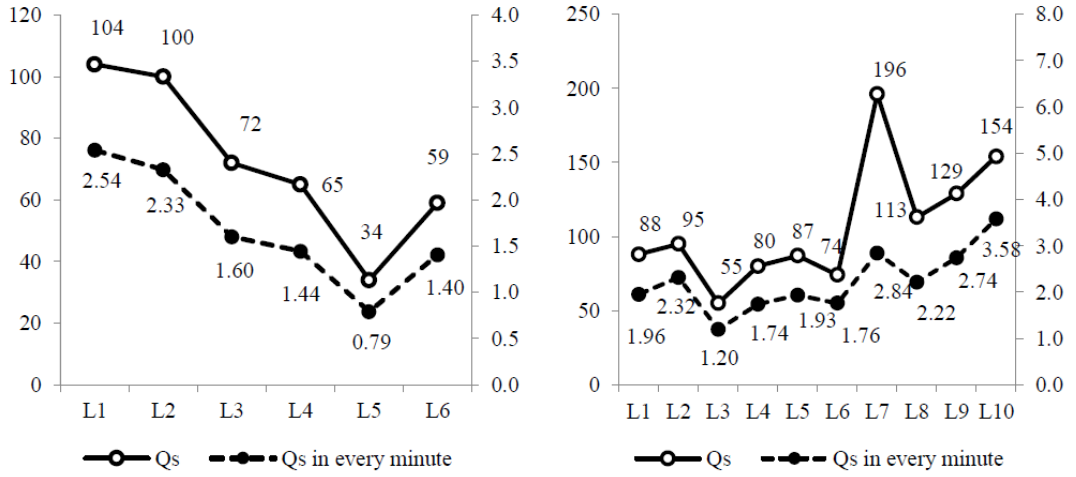
Table 3. Sub-categories for initiation questions and follow-up questions.

Regrouped Codes	Initial Codes and Descriptions
	Initiation Questions
Reflection (Ref.)	Initiation questions requiring students' reflection after mathematical activities.
Build-up (Bui.)	*Conjecture*: Initiation questions requiring students to come up with suppositions or presumptions about patterns. *Variations*: Initiation questions requiring students to consider a problem for which certain aspects vary while the other aspects are kept the same as a previous problem. *Link/application*: Initiation questions requiring students to provide examples of mathematics knowledge, or to apply mathematical knowledge. *Comparison*: Initiation questions requiring students to make comparisons between descriptions, graphs, etc. *Evaluation*: Initiation questions used to elicit students' opinions.
Open-up (Ope.)	*Explanation*: Initiation questions used to elicit students' thinking or interpretation. *Strategy/procedure*: Initiation questions requiring students to describe their strategies, procedures or the process of solving problems.
Result (Res.)	Initiation questions requiring the results of mathematical operation.
Tracking (Tra.)	*Understanding check*: Initiation questions used to check whether students understand the teacher's or students' statements. *Progress monitoring*: Initiation questions requiring students to monitor and regulate the process of reasoning and problem solving.
Information processing (Inf.)	*Information extraction*: Initiation questions requiring students to identify and select information from text descriptions, graphs, etc. *Generation*: Initiation questions asking students to generate a problem/scenario to satisfy given requirements.
Review (Rev.)	Initiation questions used to elicit the previously learnt knowledge.
	Follow-up Questions
Inviting comments (Inv.)	*Agreement request*: Follow-up questions that are used to elicit students' agreement on comments given by some students. *Supplement*: Follow-up questions used to request for a larger variety of opinions or comments.
Probing (Pro.)	*Clarification*: Follow-up questions requiring students to show more details about their answers, solutions, or comments. *Justification*: Follow-up questions requiring students to justify their answers, where the answers are responses to the teacher's initiation question or follow-up question in the last turn. *Elaboration*: Follow-up questions used to guide students towards a more comprehensive response by building on students' existing responses.
Redirecting (Dir.)	*Cueing*: Follow-up questions used to redirect students to focus on key elements or aspects of the problem situation so as to enable students' problem-solving. *Refocusing*: Follow-up questions used to redirect students to refocus on the essential points of the problem under discussion, especially when students' thinking is off the right track.
Extension (Ext.)	Follow-up questions used to extend the topics under discussion to other topics.
Reformulation request (Rer.)	Follow-up questions requiring one student to reformulate his or her answer.
Repeat (Rep.)	Follow-up questions where the teacher repeats or rephrases the question asked in the last turn.

4. Findings

4.1. The Variations in the Number of Teacher Questions

The number of questions asked by both teachers varied substantially from one lesson to another across the lesson sequence. Figure 2a,b show the total number of teacher questions in one lesson and the average number of teacher questions in each minute in the classes of the teacher CHN1 and CHN2. Both numbers experienced an overall falling trend across the lesson sequence taught by the teacher CHN1. Over the lesson sequence, she tended to ask fewer questions in the later lessons than in the earlier ones.



(**a**) Teacher CHN1 (**b**) Teacher CHN2

Figure 2. The total number of questions asked by the teacher CHN1 and CHN2 in each lesson. Note: Qs = the total number of questions; Qs in every minute = the average number of questions asked in each IRF (multiple) sequence; QA&IRF-s = the total number of Q&A pairs and the IRF (single) sequences; IRF-m = the number of the IRF (multiple) sequences.

For the teacher CHN2, the total number of teacher questions in one lesson and the average number of teacher questions in each minute both remained stable in the first six lessons, except lesson 3 where there was an obvious drop. The last four lessons saw a significant increase in the number of teacher questions. Compared with the teacher CHN1, teacher CHN2 preferred to ask more questions in the second half of the teaching unit than the first half.

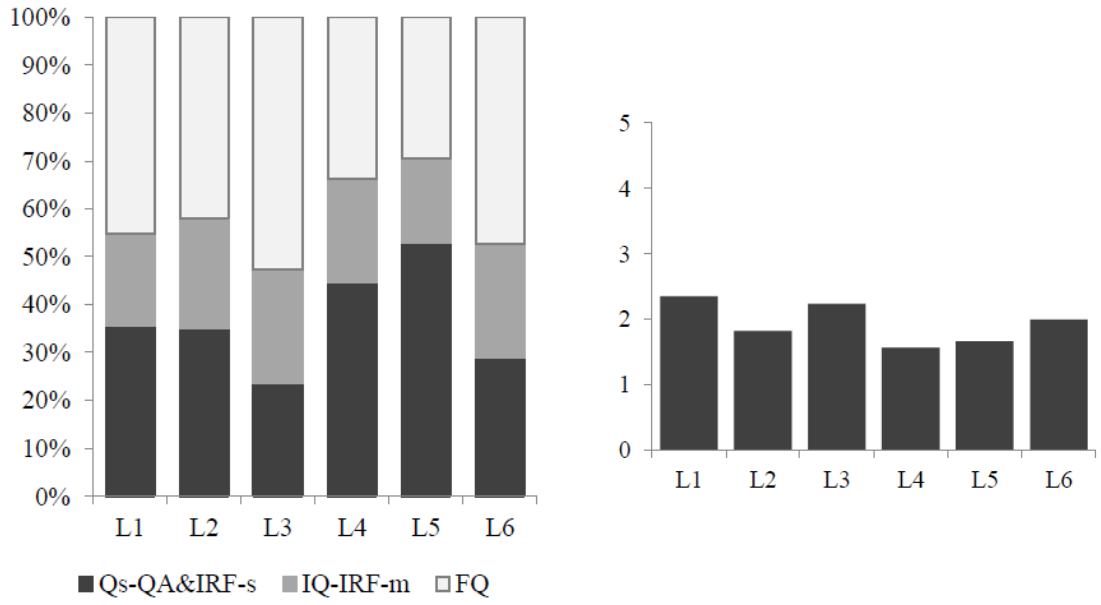
4.2. The Consistencies in the Distribution of Questions

For each participating teacher, the questions asked to initiate the IRF (multiple) sequences consistently took up a regular proportion of the total number of questions in a lesson. This means both participating teachers used questions to start the IRF (multiple) sequences in a consistent way across the unit of consecutive lessons.

Besides, each IRF (multiple) sequence on average includes one initiation question and two follow-up questions on average for each participating teacher. This means both participating teachers tended to maintain the length of IRF (multiple) sequences in different lessons.

4.2.1. The Case of Teacher CHN1

Figure 3a shows the distribution of questions in three occasions, namely, (1) Q&A pairs and IRF (single) sequences, (2) an initiation phase of the IRF (multiple) sequences, and (3) a follow-up phase of the IRF (multiple) sequences.



(**a**) Three types of questions

(**b**) The average number of follow-up questions in each IRF (multiple) sequence

Figure 3. The distribution of questions in the class of teacher CHN1. Note: Qs-QA&IRF-s = all questions in Q&A pairs and IRF (single) sequences; Qs-IRF-m = all questions in IRF (multiple) sequences; FQ = follow-up questions.

This illustrated that the proportion occupied by the initiation questions in the IRF (multiple) sequences, in relation to the total number of the questions in one lesson, stayed stable at 20% across all the lessons, regardless of how many questions were recorded in the lesson. A typical IRF (multiple) sequence recorded in this study included an initiation question followed by a couple of follow-up questions.

Figure 3b presents the average number of follow-up questions asked in each IRF (multiple) sequence. Across the lesson sequence, the average number of follow-up questions recorded in each IRF (multiple) sequence stayed relatively stable at around 2. In other words, in the IRF (multiple) sequence, teacher CHN1 tended to ask two follow-up questions after every initiation question. An episode was selected to show how the teacher asked two follow-up questions after an initiation question.

Episode 1: CHN1-Lesson 6, 0:02:49-0:04:04

T: For solving right triangles, there are two cases depending on what are given. ***What are the two cases?*** ***Initiation question***

Ss: [silent]

T: ***Given . . . ?*** ***Follow-up question***

Ss: Two side lengths.

T: ***Given two side lengths and . . . ?*** ***Follow-up question***

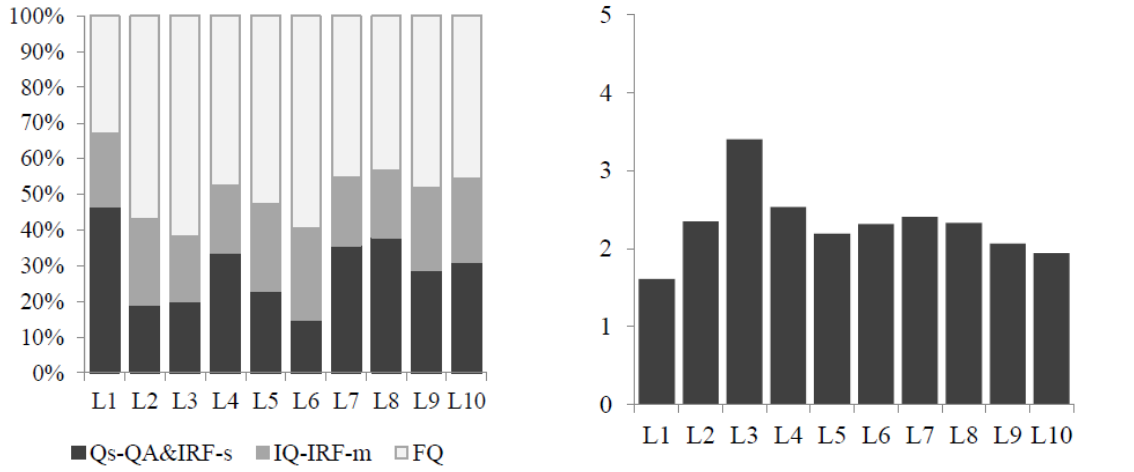
Ss: Given one side length and one angle size.

T: Given one side length and one angle size.

In this episode, the teacher led the whole class to recall the cases of problems in solving right triangles. After the teacher had initiated the first question, the whole class seemed to be a bit reluctant to respond. Therefore, the teacher repeated the question and the choral response was elicited but the responses were not complete. Then the teacher requested for a supplement from the whole class whose responses achieved the teacher's eventual expectations.

4.2.2. The Case of Teacher CHN2

In Figure 4a, it can be seen that that the proportion occupied by the initiation questions in the IRF (multiple) sequences, in relation to the total number of the questions in one lesson, stayed stable at around 20% across all the lessons.



(**a**) Three types of questions

(**b**) The average number of follow-up questions in each IRF (multiple) sequence

Figure 4. The distribution of questions in the class of teacher CHN2. Note: Qs-QA&IRF-s = all questions in Q&A pairs and IRF (single) sequences; Qs-IRF-m = all questions in IRF (multiple) sequences; FQ = follow-up questions; FQs in each IRF (multiple) = the average number of follow-up questions in each IRF (multiple) sequence.

In addition, for all the lessons except lesson 3, teacher CHN2 asked about two follow-up questions on average in each IRF (multiple) sequence (as is shown in Figure 4b). In lesson 3, an average of 3.4 questions was recorded in each IRF (multiple) sequence. Given that the fewest questions were observed in lesson 3 (as is shown in Figure 2), it can be inferred that the teacher CHN2 might ask fewer questions in lesson 3 but engaged students in longer IRF (multiple) sequences.

4.3. A Mixture of Variations and Consistencies in the Functions of Teacher Questions

In each participating teacher's class, the question types recorded in the Q&A question pairs and the IRF (single) sequences changed from one lesson to another and a similar change was identified regarding the questions types in the initiation questions of the IRF (multiple) sequences. In contrast, the question types documented in the follow-up questions of the IRF (multiple) sequences were relatively consistent across the lesson sequence.

4.3.1. The Case of Teacher CHN1

In Figure 5, the left graph shows the coding of questions asked in the Q&A question pairs and the IRF (single) sequences, with the middle and the right graphs separately for the coding of initiation questions in the IRF (multiple) sequences, and the coding of follow-up questions in the IRF (multiple) sequences. Please refer to Table 3 for the explanation of three-letter codes in the graphs.

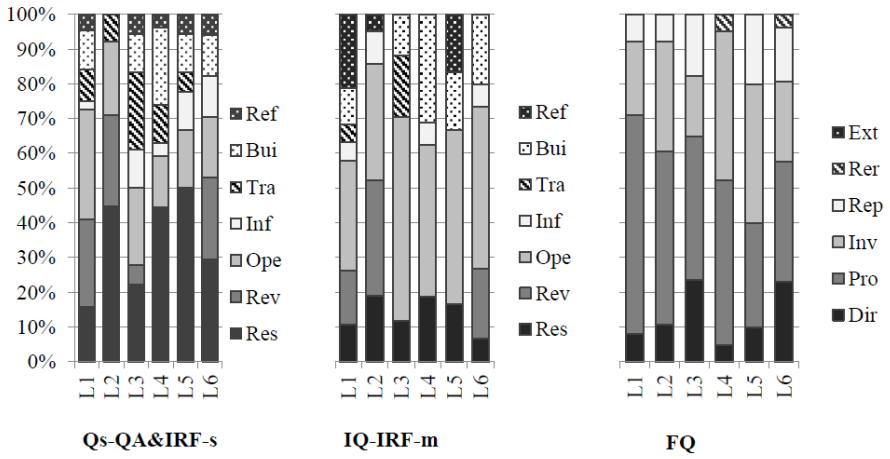


Figure 5. The categorization of questions asked by the teacher CHN1 over the lesson sequence. Note: Qs-QA&IRF-s = the categorization of questions asked in Q&A pairs and IRF (single) sequences; IQ-IRF-m = the categorization of initiation questions asked in IRF (multiple) sequences; FQ = the categorization of follow-up questions asked in IRF (multiple) sequences.

As is shown in Figure 5, the employment of initiation questions varied greatly in the constitution of subcategories and these categories' proportions across the consecutive lessons. For example, in lessons 1, 2, and 6, the *Review* questions were observed to take up significant proportions (about 25%) of all the teacher questions in Q&A question pairs and IRF (single) sequences (shown in the left graph of Figure 8), but in the lessons 4 and 5 this question type was not observed at all in Q&A question pairs and IRF (single) sequences. Similarly, as is shown in the middle graph of Figure 5, the *Build-up* questions occupied more than 30% of all the initiation questions in IRF (multiple) sequences in lesson 4, while this question type was not observed in IRF (multiple) sequences in lesson 1.

By contrast, the employment of the follow-up question types was relatively consistent across the consecutive lessons, regardless of where the lesson is located in the teaching sequence. In all lessons taught by the teacher CHN1, the follow-up questions consisted of mainly *Probing* questions and *Inviting comments* questions. In other words, during extended questioning exchanges in the IRF (multiple) sequences, the participating teachers tended to ask a particular group of follow-up question types to build on students' responses. Although each teacher employed some question types more frequently than others, the whole sequence of consecutive lessons shared these frequently used questions in common. This might suggest that each teacher might employ follow-up questions habitually with certain strategies, less dependent on where the lessons are located in the teaching sequence. An episode is provided in the following paragraphs to demonstrate the regular use of some particular follow-up questions types.

In Episode 2, the teacher was leading the whole class to analyze how to solve the second part of the task (as is shown in Figure 6), namely to find the tangent of angle EDC, which was not in any right triangle in the given diagram. Before this example, the ideas of constructing and converting had been introduced as two main directions for solving similar questions involving non-right (or oblique) triangles. Based on these two ideas, here the teacher asked the students to think about the possible strategies. She did not select any individual student or ask volunteers to answer the questions, but posed the questions to the whole class and elicited the choral responses. In the follow-up phase of the conversation, the teacher consistently employed two types of questions, namely *Probing* and *Inviting comments* questions.

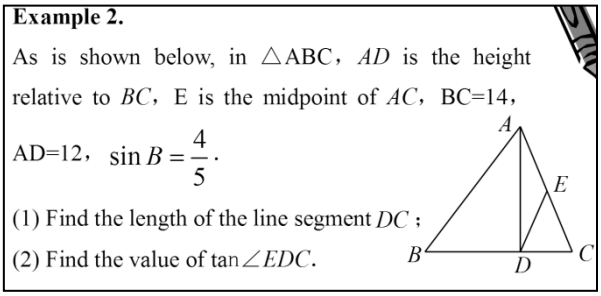


Figure 6. Teacher CHN1's PowerPoint slide used for example 2 in lesson 2.

Episode 2: CHN1-Lesson 2, 0:13:19-0:14:35

T: *So what should you do? There are two options. One is what?* ***IQ: Open-up (Strategy/procedure)***

Ss: Constructing.

T: Constructing. *If you like the constructing way, will you have to construct a perpendicular line?* ***FQ: Probing (Clarification)***

Ss: Yes.

T: Then we can put it [the angle EDC] into a right triangle. *What if you don't want to construct the perpendicular line? What could you do?* ***FQ: Inviting comments (Supplement)***

Ss: Converting.

T: Converting. We can also convert it to an equivalent, right? *Do we have the equivalent of that angle [angle EDC] here in the diagram?* ***FQ: Probing (Clarification)***

Ss: Angle C.

T: Good. Is angle C the equivalent? Why? Is the side length of DE equal to that of EC? *Reason? What is the reason?* ***FQ: Probing (Justification)***

Ss: The median on the hypotenuse of a right triangle equals one-half the hypotenuse.

T: Good. The median on the hypotenuse of a right triangle equals one-half the hypotenuse. In this way, we can find it [tan∠DEC] by converting it to tanC.

4.3.2. The Case of Teacher CHN2

As is shown in Figure 7, the employment of initiation questions varied greatly in the constitution of subcategories and these categories' proportions across the consecutive lessons. For example, in lesson 5, the *Result* questions were observed to take up significant proportions (about 30%) of all the teacher questions in Q&A question pairs and IRF (single) sequences (shown in the left graph of Figure 7), but in lessons 4 and 6 this question type was not observed at all in Q&A question pairs and IRF (single) sequences. Similarly, as is shown in the middle graph of Figure 7, the *Reflection* questions occupied more than 20% of all the initiation questions in IRF (multiple) sequences in lessons 4 and 5, while this question type was not observed in IRF (multiple) sequences in lesson 1.

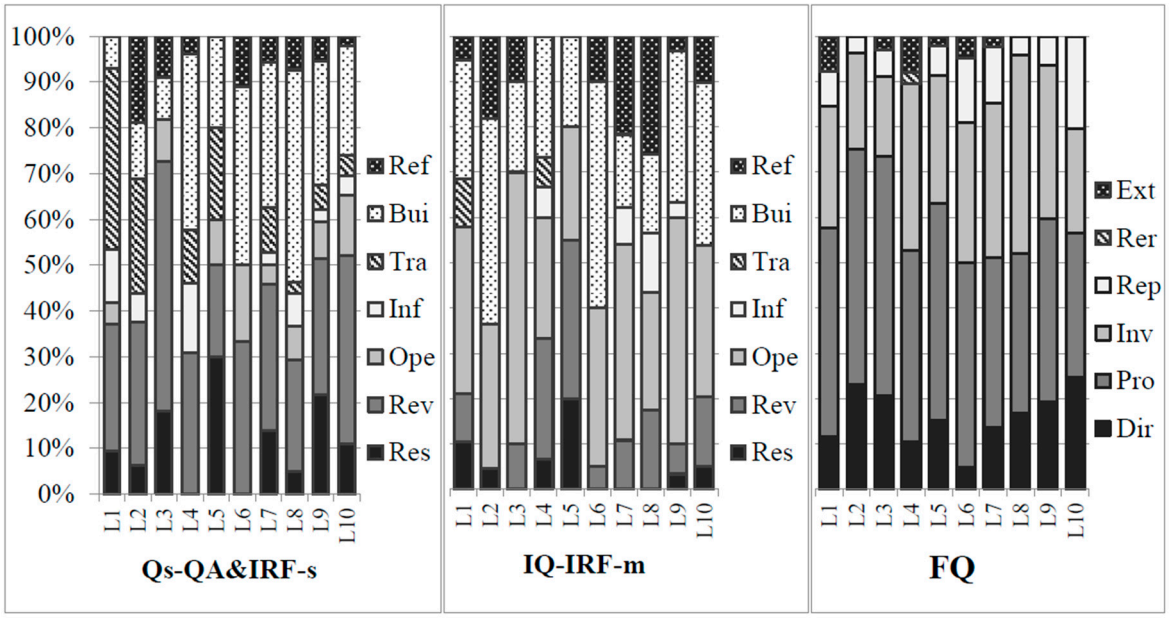


Figure 7. The categorization of questions asked by the teacher CHN2 over the lesson sequence. Note: Qs-QA&IRF-s = the categorization of questions asked in Q&A pairs and IRF (single) sequences; IQ-IRF-m = the categorization of initiation questions asked in IRF (multiple) sequences; FQ = the categorization of follow-up questions asked in IRF (multiple) sequences.

By contrast, the employment of the follow-up question types was relatively consistent across the consecutive lessons, regardless of where the lesson is located in the teaching sequence. In all lessons taught by the teacher CHN2, the follow-up questions consisted of mainly *Redirecting* questions, *probing* questions, and *Inviting comments* questions. An episode is provided in the following paragraphs to demonstrate the regular use of some particular follow-up questions types.

In this episode, the teacher asked the student to recall the conclusions that had been achieved in the last few lessons and to put these conclusions together in the task sheet (as is shown in Figure 8). The student (Li) answered the question from the perspective of graph translation. The teacher interrupted this student's talk and redirected the student to the right track. On the right track, the student described the direction of opening independently and then the vertex with the teacher's assistance. Then the teacher asked a further question to request for the description of the parabolas' vertices by looking at the coordinates. Although the student failed to give answers to the teacher's last question, the teacher had made a lot of efforts in facilitating this student's articulation of mathematical knowledge. In this episode, all the follow-up questions fell into three categories, namely *Redirecting* questions, *Probing* questions, and *Inviting comments* questions.

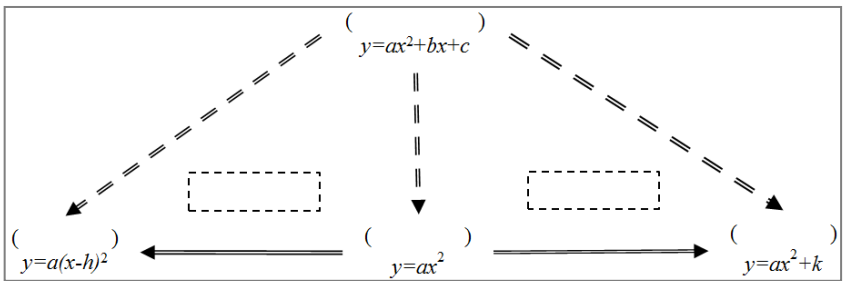


Figure 8. The mind map used in teacher CHN2's lesson 5.

Episode 3: CHN2-Lesson 5, 0:05:06-0:06:31

T: The question is, for these three special types of parabolas, if we look at the direction of opening, the vertex, and the axis of symmetry, and then think about the effects that the values of a, h, and k have on the parabolas. ***What are the corresponding relationships? Li?*** ***IQ: Review***

S: When h is greater than 0, shift h units to the left, we will have the parabola $y = a(x - h)^2$.

T: ***What question did I ask you?*** ***FQ: Redirecting (Refocusing)***

S: [silent]

T: ***What I asked is, the direction of opening, vertex, and the axis of symmetry, the relationship between them and the values of a, h, and k.*** ***FQ: Redirecting (Cueing)***

S: The open directions [of the three parabolas] are all related to the value of a.

T: Yes, good.

S: Then their . . . hum . . .

T: ***What about the vertex?*** ***FQ: Redirecting (Cueing)***

S: The vertex, their vertices are related to the value of h. The vertices are shifted h units to the left or right.

T: ***Does it have to be left or right?*** ***FQ: Probing (Clarification)***

S: Or, upwards or downwards.

T: So, the vertex, it has coordinates. That is an ordered pair. What you have said is about its position. ***Now, what if we look at its coordinates?*** ***FQ: Inviting comments (Supplement)***

S: Y-coordinate.

T: Okay. Please be seated. Let's have a look at this.

In summary, the initiation questions asked in the IRF (multiple) sequences were reported to take up a regular proportion of the total number of questions in each lesson of the whole unit. Here it was found that the breakdown of the initiation questions in IRF (multiple) sequences demonstrated various characteristics across the whole unit. In other words, the teachers tended to use a regular proportion of all the questions in each lesson as initiation questions to start IRF (multiple) sequences, but the purposes of starting IRF (multiple) sequences were different, which might reflect the teachers' stable and flexible strategies in using IRF (multiple) sequences.

5. Discussion

5.1. Adjustment of Teacher Questioning in the Sequence of Consecutive Lessons

This study contributes in demonstrating and exemplifying how the teachers adjusted and regulated their questioning strategies in different lessons of a teaching unit. It was shown in the previous studies (e.g., Reference [21]) that one teacher tended to change the ways of asking questions in a lesson in order to scaffold different students' needs. This study reports that one teacher also changed the ways of asking questions in different lessons. The two participating teachers both asked a substantially different number of questions in different lessons. In addition, the question types used in the initiation stages of IRF sequences also changed from one lesson to another over the lesson sequence.

In the unit of consecutive lessons, the pedagogical goal of one lesson is related to but different from another lesson. In order to fulfill the changing pedagogical goals, the teachers can approximately plan how many questions he or she can ask and determine when to start the IRF sequences in order to direct students in the ways aligned with the teachers' expectations to fulfill the pedagogical goals. Therefore, the evidence of the changes in the number of questions and in the use of initiation questions

across the unit of consecutive lessons might reflect the teachers' changes in his or her questioning practices in order to satisfy the different pedagogical goals of different lessons.

For example, in the case of the teacher CHN1, the earlier lessons involved the investigation of the methods to solve right triangles whereas the later lessons asked students to solve mathematics tasks by applying the methods of solving right triangles. In this regard, the later lessons in the unit were less investigation-based but more practice-based than the earlier lessons. To scaffold the students' investigations of the new methods, the teacher CHN1 asked a larger number of questions in the earlier lessons. However, she reduced the number of questions in the later lessons of the unit so that the students could have more time practicing the methods of solving right triangles.

The changes of questioning practices across consecutive lessons extend our understanding of how teachers employ questioning strategies to cope with different pedagogical goals in different lessons. The findings in this study lead us to the argument that teacher questioning can be seen as the implementation of the teacher's pedagogical strategies to cope with adjustments to the teacher's instructional goals in order to accommodate changing circumstances as the instruction proceeds in a teaching unit.

5.2. Consistencies of Teacher Questioning Practices across the Lessons

This study reported the consistencies regarding teacher questioning practices over the lesson sequences. Each participating teacher was inclined to use a consistent proportion of all the questions in each lesson to initiate IRF (multiple) sequences. For each initiation question in the IRF (multiple) sequences, each participating teacher tended to ask about two follow-up questions.

These consistencies might be interpreted as the routinized and habitual aspects of teaching practices in the participating teacher's classes. According to some researchers (e.g., Reference [1]), the teaching profession required teachers to continually make decisions on a daily basis in classrooms about how to interact with students, and such decision-making processes, regardless of teachers' awareness, become routinized over time. Although the teachers could plan how to initiate a questioning sequence, it is impossible for teachers to accurately prepare for what students could respond to teachers' initiation. Therefore, the teachers might have to make instant decisions to determine when to elicit students' longer responses and how to build up on students' responses. In this regard, the consistencies in the use of follow-up questions in IRF sequences could be interpreted as the teachers' routine and habitus developed in the teaching experiences.

5.3. The Complexity of Teaching and Classroom Observation Research

In this study, the act of asking questions in classroom interaction not only includes the teachers' conscious planning so as to accomplish pedagogical goals, but also involves the teachers' unconscious routine in how to build up on students' thinking.

The above results added evidence regarding the complicated process of how teachers' classroom practices could be shaped by various potential factors arising from teaching planning and implementation. By presenting both of these variations and consistencies evident in the questioning practices across the consecutive lessons, this study supports other researcher's arguments about the complexity of teaching [30–32].

The complexity documented in one teacher's teaching unit in this study suggests that it is also hard to represent one teacher's instructional practices by observing a limited number of his or her lessons. Therefore, the results in this study support the claim that there is a further complexity with regard to the reliability of classroom observations for generalizing results [33–35]. Schlesinger and Jentsch argued that it is challenging to determine the number of lessons in order to obtain enough information for one teacher's instructional quality [35]. This study reminds us that it is very easy to draw inaccurate or even misleading conclusions by examining a teacher's practices in one or two lessons. Instead, a unit of consecutive lessons might be a better lens through which the complexity of one teacher's teaching practices could be investigated and understood in better ways.

6. Conclusions

Teacher questioning is one the most frequently used and significant ways of orchestrating students' thinking and reasoning [7]. A better documentation and fine-grained analysis of teacher questioning practices could help to understand how classroom interaction could be initiated and sustained, which thereby contributes to the construction of the desirable environment for constructive and rich classroom talk and to the cultivation of positive learning attitudes [36].

This study contributes to the research community by utilizing the IRF framework to examine two Chinese teachers' questioning practices in a unit of consecutive lessons. Both participating teachers' questioning practices showed variations and consistencies over the lesson sequence. It implies the potential influences that the changing instructional objectives and teaching routines might exert on teacher questioning practices.

The explicit observation of the complicated nature of teacher questioning practices was enabled by adopting the IRF framework and the lens of consecutive lessons. It can be argued that the IRF framework and the context of consecutive lessons made the functions of teacher questioning more visible and explicit. Therefore, the challenges of determining the number of selected lessons when conducting classroom observation research might be partially resolved by choosing the lesson sequence as the analytical unit.

There are some limitations in this study. First, this study examined teacher questioning practices in one single culture, and therefore this study could not provide information about the potential influences that cultural differences might exert on teacher questioning practices. Second, the unit topics in the selected classrooms in two Chinese classrooms were rather limited to algebra and functions. We did not videotape classroom teaching of other topics such as statistics and probability. Therefore, this study could not conclude whether the unit topic could have significant impacts on the teachers' employment of questioning practices.

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References

1. Loughran, J. *What Expert Teachers Do: Teachers' Professional Knowledge of Classroom Practice*; Routledge: London, UK; New York, NY, USA, 2010.
2. Sanders, N.M. *Classroom Questions: What Kinds?* Harper & Row: New York, NY, USA, 1966.
3. Redfield, D.L.; Rousseau, E.W. A meta-analysis of experimental research on teacher questioning behavior. *Rev. Educ. Res.* **1981**, *51*, 237–245. [CrossRef]
4. Winne, P.H. Experiments relating teachers' use of higher cognitive questions to student achievement. *Rev. Educ. Res.* **1979**, *49*, 13–50. [CrossRef]
5. Gall, M.D. Synthesis of research on teachers' questioning. *Educ. Leadersh.* **1984**, *42*, 40–47.
6. Wilen, W.; Clegg, A. Effective questions and questioning: A research review. *Theory Res. Soc. Educ.* **1986**, *14*, 153–161. [CrossRef]
7. Marzano, R.J.; Simms, J.A. *Questioning Sequences in the Classroom*; Solution Tree Press: Bloomington, IN, USA, 2012.
8. Franke, M.L.; Webb, N.M.; Chan, A.G.; Ing, M.; Freund, D.; Battey, D. Teacher questioning to elicit students' mathematical thinking in elementary school classrooms. *J. Teach. Educ.* **2009**, *60*, 380–392. [CrossRef]

9. Goos, M.; Vale, C.; Stillman, G. *Teaching Secondary School Mathematics: Research and Practice for the 21st Century*; Allen & Unwin: Sydney, Australia, 2007.
10. Herbal-Eisenmann, B.A.; Breyfogle, M.L. Questioning Our Patterns of Questioning. *Math. Teach. Middle Sch.* **2005**, *10*, 484–489.
11. Wood, T. Patterns of interaction and the culture of mathematics classrooms. In *Cultural Perspectives on the Mathematics Classroom*; Lerman, S., Ed.; Kluwer: Dordrecht, The Netherlands, 1994; pp. 149–168.
12. Wood, T. Alternative patterns of communication in mathematics classes: Funneling or focusing. In *Language and Communication in the Mathematics Classroom*; Steinbring, H., Bartolini-Bussi, M., Sierpinska, A., Eds.; NCTM: Reston, VA, USA, 1998; pp. 167–178.
13. Sinclair, J.M.; Coulthard, R.M. *Towards an Analysis of Discourse: The English Used by Teachers and Pupils*; Oxford University Press: London, UK, 1975.
14. Mehan, H. *Learning Lessons: Social Organisation in the Classroom*; Harvard University Press: Cambridge, MA, USA, 1979.
15. Lemke, J.L. *Talking Science: Language, Learning, and Values*; Ablex Publishing Corporation: New York, NY, USA, 1990.
16. Atkins, A. Sinclair and Coulthard's "IRF" Model in a One-to-One Classroom: An Analysis. 2001. Available online: https://www.birmingham.ac.uk/documents/college-artslaw/cels/essays/csdp/atkins4.pdf (accessed on 28 November 2018).
17. Cazden, C.B. *Classroom Discourse: The Language of Teaching and Learning*; Heinemann: Portsmouth, NH, USA, 2001.
18. Nassaji, H.; Wells, G. What's the use of triadic dialogue? An investigation of teacher-student interaction. *Appl. Linguist.* **2000**, *21*, 376–406. [CrossRef]
19. Drageset, O.G. How Students Explain and Teachers Respond. In *Curriculum in Focus: Research Guided Practice-Proceedings of the 37th Annual Conference of the Mathematics Education Research Group of Australasia*; Anderson, J., Cavanagh, M., Prescott, A., Eds.; MERGA: Sydney, Australia, 2014; pp. 191–198.
20. Radford, J.; Ireson, J.; Mahon, M. Triadic dialogue in oral communication tasks: What are the implications for language learning? *Lang. Educ.* **2006**, *20*, 191–210. [CrossRef]
21. Hiebert, J.; Wearne, D. Instructional tasks, classroom discourse, and students' learning in second-grade arithmetic. *Am. Educ. Res. J.* **1993**, *30*, 393–425. [CrossRef]
22. Nathan, M.J.; Kim, S. Regulation of teacher elicitations in the mathematics classroom. *Cogn. Instr.* **2009**, *27*, 91–120. [CrossRef]
23. Shi, J. Classroom analysis based on examination of teacher questioning strategies. *Shanghai Res. Educ.* **2011**, *9*, 67–69. (In Chinese)
24. Boaler, J.; Brodie, K. The importance, nature and impact of teacher questions. In *Proceedings of the Twenty-Sixth Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*; McDougall, D.E., Ross, J.A., Eds.; Ontario Institute for Studies in Education/University of Toronto: Toronto, ON, Canada, 2004; Volume 2, pp. 773–781.
25. Dong, L.; Seah, W.T.; Clarke, D. Pedagogical Tensions in Teacher's Questioning Practices in the Mathematics Classroom: A Case in Mainland China. *Eurasia J. Math. Sci. Technol. Educ.* **2017**, *14*, 167–181. [CrossRef]
26. Clarke, D.J.; Mesiti, C.; Jablonka, E.; Shimizu, Y. Addressing the challenge of legitimate international comparisons: Lesson structure in the USA, Germany and Japan. In *Making Connections: Comparing Mathematics Classrooms around the World*; Clarke, D.J., Emanuelsson, J., Jablonka, E., Mok, I.A.C., Eds.; Sense Publications: Rotterdam, The Netherlands, 2006; pp. 23–45.
27. Lopez-Real, F.; Mok, A.C.I.; Leung, K.S.F.; Marton, F. Identifying a pattern of teaching: An analysis of a Shanghai Teacher's Lessons. In *How Chinese Learn Mathematics: Perspectives from Insiders*; Fan, L., Wong, N.Y., Cai, J., Li, S., Eds.; World Scientific: Singapore, 2004; pp. 383–412.
28. Koizumi, Y. Similarities and differences in teachers' questioning in German and Japanese mathematics classrooms. *ZDM Int. J. Math. Educ.* **2013**, *45*, 47–59. [CrossRef]
29. Stake, R.E. *The Art of Case Study Research*; SAGE Publications, Inc.: Thousand Oaks, CA, USA, 1995.
30. Cheng, L.; Xu, N. The complexity of Chinese pedagogic discourse. *J. Curric. Stud.* **2011**, *43*, 606–614. [CrossRef]
31. Koedinger, K.R.; Booth, J.L.; Klahr, D. Instructional complexity and the science to constrain it. *Science* **2013**, *342*, 935–937. [CrossRef] [PubMed]

32. Wood, T.; McNeal, B. Complexity in teaching and children's mathematical thinking. In *Proceedings of the 27th Conference of the International Group for the Psychology of Mathematics Education*; Pateman, N., Dougherty, B., Zilliox, J., Eds.; PME & PMENA: Honolulu, HI, USA, 2003; Volume 4, pp. 435–441.
33. Hill, H.C.; Laura, K.; Kristin, U. A validity argument approach to evaluating teacher value-added scores. *Am. Educ. Res. J.* **2011**, *48*, 794–831. [CrossRef]
34. Hill, H.C.; Charalambous, C.Y.; Kraft, M.A. When rater reliability is not enough: Teacher observation systems and a case for the generalizability study. *Educ. Res.* **2012**, *41*, 56–64. [CrossRef]
35. Praetorius, A.K.; Pauli, C.; Reusser, K.; Rakoczy, K.; Klieme, E. One lesson is all you need? Stability of instructional quality across lessons. *Learn. Instr.* **2014**, *31*, 2–12. [CrossRef]
36. Liu, H.H.; Su, Y.S. Effects of Using Task-Driven Classroom Teaching on Students' Learning Attitudes and Learning Effectiveness in an Information Technology Course. *Sustainability* **2018**, *10*, 3957. [CrossRef]