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Student talk in large-size mathematics classrooms: a case study of a sequence of ten consecutive lessons in China

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Abstract
This study aims to reveal features of student talk over a sequence of consecutive mathematics lessons in a large-size class in mainland China. By examining the time allocation for student talk and the number of Chinese characters spoken by the students, this study finds that, in some of the lessons observed, student talk added up to a longer duration and included a larger number of Chinese characters than teacher talk. But individual students were observed to have unequal opportunities to participate in public talk and there is a large gap regarding the number of Chinese characters that an individual student could speak in public. Each individual student's accountability to talk was recorded to be less diverse in public presentation than in non-presentation contexts (e.g., answering teacher questions). This study suggests that a unit of consecutive lessons can help a clearer and more comprehensive observation and analysis of student talk.

Keywords Student talk · Large-size class · Mathematics · Consecutive lessons · China

Introduction

During the past decades, it has been well accepted that social interaction is essential for the development of mathematics knowledge and conceptual understanding (Walshaw and Anthony 2008). When a student engages in mathematical explanation and argumentation, he or she can clarify and refine mathematical thinking and understanding. Meanwhile, deeper thinking and reasoning emerge when students attempt to make sense of peers' talk and make judgments about other students' talk. Productive student talk in classroom can also allow the teacher to monitor and reflect on the progress of students' learning and understanding and thereby adjust classroom teaching accordingly. It is also argued by some researchers (Clarke et al. 2013a) that students' spoken mathematical fluency should be regarded as a valued learning outcome in mathematics classroom because the proficiency of explaining and justifying mathematical thinking could contribute to deeper mathematical understanding. Therefore, the recommendations of creating a supportive classroom environment to facilitate students' talk in mathematics classrooms can be found evidently in the curriculum documents all over the world.

In mainland China, mathematics curriculum used to be criticized as examination-oriented with a significant emphasis on practicing and drilling, which usually compromised students' internal process of constructing mathematics understanding. Since 2001, mathematics curriculum reform has been implemented in mainland China, aiming to provide students with sufficient opportunities to participate and make verbal contributions in mathematics classrooms

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communication, and thereby to shift classroom instruction from the conventional way of emphasizing knowledge delivery to an interactive way of knowledge construction (Li and Ni 2011; Seah 2011).

Many researchers have attempted to document the changes in mathematics classroom interactions resulting from curriculum reforms (e.g., Li and Ni 2011), and these studies have mainly focused on students' verbal participation at the collective level rather than at the individual level. That is, most of the previous studies have tended to regard all students in a class as a whole and to aggregate each student's opportunity to talk as the indicator of student participation in the class. This aggregation usually did not take into account the opportunities that each individual student could be given to talk about mathematics in the classroom.

In other words, what remains relatively underexamined is the systematic and comprehensive documentation of student talk in reform-based mathematics classrooms in mainland China. Not enough information has been reported yet to answer questions such as how much time is allocated for student talk, how long is each student's utterance, how sophisticated is the students' talk, what opportunity does each individual student have to talk about mathematics in public, and what variations can be observed regarding student talk over a lesson sequence. The answers to these questions are actually significant because they can contribute to a systematic and comprehensive understanding of student mathematics talk in changing contexts in mainland China and thereby inform instructional practices, teacher training and policy making. This study examines student talk over a sequence of consecutive lessons in reform-based mathematics classrooms, aiming to report as many details of student talk and thereby contribute to a better understanding of mathematics classroom communication in large classes in mainland China.

Literature review

How Chinese students talk in mathematics classrooms

Chinese students have been reported to make verbal contributions more frequently in reform-based mathematics classrooms than in the conventional classrooms. Li and Ni (2011) reported that, compared with those in traditional classrooms, students in reform-based mathematics classrooms were provided with more opportunities to discuss and evaluate their peers' ideas and to raise questions. By analyzing 64 video-recorded lessons by 16 teachers in mainland China, Zhao et al. (2016) reported the emergence of more student participation with deeper mathematical thinking in reform-based mathematics classrooms than traditional classrooms.

In addition, students in mainland China have been observed to give choral responses more frequently than individual responses. Cao and He (2009) found that the teacher typically interacted with the whole class by asking questions, and on very few occasions, the teacher interacted publicly with one individual student or with a group of students. The teacher's interaction with the whole class resulted in the frequent observation of choral responses in Chinese mathematics classrooms.

However, the choral responses were not limited to simple recitation and memorizing drills but could be so sophisticated that they required students to evaluate other students' statements or mathematics solutions or to complete the statement of a mathematical proposition (Clarke et al. 2013b). In addition, Xu et al. (2013) identified two discourse patterns of using choral responses in a mathematics classroom: (1) a teacher asked the whole class a question and requested a choral response, followed by teacher feedback; and (2) a teacher asked the whole class a question and requested an individual student to answer the question, followed by a choral evaluation of the answer. The authors argued that the combination of individual responses and choral responses was a typical way of eliciting multiple students' contributions in Shanghai mathematics classrooms.

Xu and Clarke (2013) compared teacher talk and student talk in the US, Australia, China, Japan, and South Korea, concluding that Chinese students were provided with fewer opportunities to talk in mathematics classrooms than their counterparts in the US and Australia. However, compared with their Western counterparts, Chinese students were using more mathematical terms in their public talk.

In addition, student presentation was reported to be another typical way of engaging students in classroom talk. Cao et al. (2013) analyzed six reform-based mathematics lessons in Beijing and identified various types of student whole-class presentations. For example, students could be selected by the teacher to present their mathematical thinking, or students could volunteer to supplement or comment on their peers' presentations. By allowing students to share their thinking by making a presentation, the teacher provided the students with more opportunities to participate in public talk.

Frameworks to investigate student talk in mathematics classrooms

Hufferd-Ackles et al. (2004) introduced a framework to characterize the mathematics-talk learning community developed by teachers and students in classrooms to support mathematics learning. This framework involved four components, namely, questioning, explaining math thinking, identifying the source of mathematical ideas, and taking responsibility for learning. In the Trends in International

Mathematics and Science Study (TIMSS) 1999 video study, Hiebert et al. (2003) introduced three indicators to analyze the transcripts of teacher talk and student talk in public interactions. The first indicator was the total number of words spoken by the teacher and students in one class during public interaction. The second indicator was the number of words spoken by the teacher relative to each word spoken by the students in one class during public interaction, which was argued to be "less sensitive to the possible effects of using English translations" (p. 109) in the transcripts. The third indicator concerned "the length of each utterance" (p. 110); the length of an utterance refers to the number of words in one speaker's talk with no interruptions by another speaker. In another international video-based comparative study, Clarke and Xu (2008) proposed an approach to analyzing classroom public interaction to capture the distribution of the responsibility for knowledge generation in different nations. This approach includes the examination of the number of utterances of each speaker (i.e., teacher, student, or student choral) and the frequency of the use of technical mathematical terms. Clarke and Xu (2008) suggested that the consideration of both the number of utterances and the productivity of the utterances could better reflect students' learning opportunities in classroom interactions.

Weaver et al. (2005) proposed a framework to examine both the quantity and quality of student talk in mathematics classrooms. The quantity of student talk was assessed by counting the number of incidents per hour in which students were observed to explain procedures, mathematical thinking, and understanding. To measure the quality of student talk, a classification of student discourse types was developed, and the frequency of different student discourse types was documented. Specifically, the types of student discourse included answering, stating or sharing, explaining, questioning, challenging, relating, predicting or conjecturing, justifying, and generalizing.

Based on the research by Stein (2007), the National Council of Teachers of Mathematics (NCTM) in the United States introduced a framework of student discourse level indicators by which student discourse was divided into three categories, namely, procedures/facts, justifications, and generalizations (NCTM 2010). With the framework of student discourse level indicators, the NCTM suggested that the teachers observe and identify students' participation in mathematics communication.

In addition to the investigation of the overall level of student classroom discourse, some researchers highlighted the importance of examining each individual student's talk and maintain the equality of student participation in classroom discussions (Civil and Planas 2004; Stein 2007; White 2003). Walsh and Sattes (2016) argued that students did not have equal opportunities to participate in classroom discussions. Some students dominate mathematics classroom discussions because the teachers tend to pick a few mathematically capable students to answer questions, whereas some other students are reluctant to talk due to a lack of mathematical ability, articulation capability, or confidence. There are even some students who never participate in the classroom discussions.

The analytical approach in most of the previous studies was to record and analyze one or a couple of lessons taught by a teacher (Hiebert et al. 2003). However, some researchers have argued that a sequence of consecutive lessons should be videotaped and analyzed to better observe and understand classroom teaching and learning in a classroom because the characteristics of mathematics teaching and learning could emerge, in a clearer way, from the sequence of consecutive lessons (Chen and Li 2010; Koizumi 2013).

In summary, the previous studies highlighted some important issues in examining student discourse in classrooms. First, to examine student mathematics talk in classrooms in a comprehensive way, it is necessary to consider both the opportunities that students have to talk in public and the nature of student talk (e.g., whether the talk is simply stating mathematics facts or explaining mathematical ideas). Second, it is necessary to document each individual student's public talk to reveal whether each individual student has equal chances to participate in classroom talk. Third, the examination of a sequence of lessons can help to reveal the sophisticated nature of student talk. Given the large class size (an average of 38–50 students in a class) in mainland China, it is nearly impossible to see every student to talk in public in the classroom. However, over a lesson sequence, it is quite possible to have a greater opportunity to observe more students talking in public in the classroom; thus, it is better to analyze a sequence of consecutive lessons to reveal a larger variety of classroom interactions in mainland China.

Research questions

This study was designed to address the following research questions: (1) what opportunities did the students have to talk in the selected mathematics classroom over the sequence of ten consecutive lessons, (2) how was the quality of the student talk in the selected mathematics classroom over the sequence of ten consecutive lessons, and (3) what were the possible factors that support or constrain student talk's opportunities and quality over the sequence of ten consecutive lessons?

Methods

Case study

A case study is the study of a specific instance, providing a detailed description of real people within real contexts

(Cohen et al. 2007). Through analytical rather than statistical generalization, cases studies can facilitate the understanding of other similar cases, phenomena, and situations (Robson 2002). Compared with other research methods, case study has a definite advantage for investigating and describing the targeted phenomenon in context (Baxter and Jack 2008; Yin 2003) and should be employed when it is important to examine the contextual condition of the phenomenon under study (Yin 2003).

This study aims to examine Chinese student talk over a sequence of ten lessons in the same classroom. It required detailed transcripts of student utterances in classroom interaction. In addition, the context of student talk and the connections between lessons need to be considered in order to investigate the quality of student talk. Thus, such a detailed investigation required the employment of a case study approach. The case in this study concerns one mathematics classroom in a middle school of China.

Settings and participants

Jiangsu province is one of pioneer provinces initiating the education reform pilot experiments and one of the first regions to implement the new mathematics curriculum (OECD 2016). Jiangsu province was one the four regions in mainland China that participated in PISA 2015 test. Within Jiangsu province, Haimen city is one of the cities with best school education in mainland China and at the time of data collection, most of the schools in this city were using reform-based approaches (e.g., group learning) to teach mathematics which encouraged student talk in classroom.

Given the above analysis, it can be seen that Haimen city started school curriculum reform much earlier than most of other cities all over China. Therefore, it is more likely to observe rich student talk in Haimen's classrooms than most of the other schools in China. An average school in Haimen city was selected for data collection. The term "average" means that this selected school's reputation, teacher quality, and students' achievements are in average level, compared with all the schools in Haimen City. In this selected school, an experienced teacher expressed his interest in participating in this study and invited the first author to observe and record his classroom teaching.

The participants include a male teacher and 45 students (24 females and 21 males) in a year eight mathematics class. The average class size in mainland China, when compared with other nations, is much larger, with 50 students sharing one classroom lower secondary schools (OECD 2015). Thus, the selected class is a typical large-size class in mainland China.

The participating teacher has 16 years of teaching experiences, holding a bachelor's degree in mathematics and a teaching certification diploma. He is the school leading teacher in mathematics and quite passionate in reforming the traditional ways of teaching and learning mathematics. Most importantly, he is proactive in working with education researchers to and willing to participate in this study to enhance his understanding and practices in terms of implementing reform-based mathematics curriculum.

Therefore, such an exemplary mathematics classroom in Haimen city, Jiangsu province is a suitable lens to support the observation of potentially rich student talk in mathematics classrooms.

Data collection

Data were collected in May, the second last month of year 8. Group learning had been implemented into this classroom for nearly 2 years at the time of data collection. A sequence of ten consecutive lessons was recorded with three cameras focusing separately on the teacher, the whole class and a focus group of students. The video recording documents the whole process of teaching implementation and classroom interactions between the teacher and students, thereby enables the detailed analysis of student talk.

In addition to classroom videos, this study also collected teaching and learning materials such as teacher plans, notes and PowerPoint slides, copies of student notes taken in classroom, and copies of student written work on learning sheets. The record of three mathematics tests' results was collected. Students participated in the first two tests separately in the middle and end of year 7. The third test was taken in the middle of year 8. All three tests were designed by the school teachers to examine students' knowledge, skills and understanding of mathematics learnt before the tests. These materials help to better understand what the teacher and students talked in classrooms, facilitating a comprehensive interpretation of student talk.

The teaching topic of the lesson sequence was quadratic functions. The purpose of choosing quadratic functions for data collection is that the nature of this teaching topic is exploratory and includes a larger proportion of investigation task and activities (e.g., investigating the graph of quadratic functions) than other mathematics topics such as solving equations. Thus, the selection of quadratic functions can increase the potential opportunities to observe a larger variety of sophisticated student mathematics talk in classrooms. The details of each lesson in the lesson sequence are listed in Table 1.

Data analysis

All the videos were transcribed into written texts with details about when and what teacher and students talked in classroom instruction. A public utterance spoken by the teacher or students were identified as teacher or student talk unless

Table 1 Details of the ten consecutive lessons in the lesson sequence

	Topics
L01	Introduction to quadratic functions
L02	The graph and features of $y = ax^2$
L03	The graph and features of $y = ax^2 + k$
L04	The graph and features of $y = a(x - h)^2$
L05	The graph and features of $y = a(x - h)^2 + k$
L06	The graph and features of $y = ax^2 + bx + c$
L07	Determining the equation of quadratic functions with the method of undetermined coefficients
L08	Quadratic functions and quadratic equations
L09	Quadratic functions and real-world problems
L10	Review of quadratic equations

the public utterance was not related to mathematics (e.g., teacher utterances about classroom management). The term "public" here means that the audiences of the talk were meant to be the whole class. In this regard, the talk among group members during group work was not included as student talk. Likewise, if the teacher interacted with a group of students during group work, the teacher utterances and student utterances were also excluded.

The first step of data analysis was to determine the broad category of student public talk. Three types of student public talk (namely student choral talk, individual student presentation talk, individual student non-presentation talk) are distinguished. The second step of data analysis focused on the opportunity and quality of student public talk. When analyzing the opportunity and quality of student public talk, two levels were considered: the collective and individual level. In the collective level, each student's talk was aggregated and examined as a whole, whereas in individual level each individual student's talk was examined separately. Further details were presented in the following paragraphs.

Three types of student public talk

In this study, three types of student public talk are distinguished: (1) student choral talk, which refers to many students' simultaneous talk in the class; (2) individual student presentation talk which refers to an individual student public talk when presenting his or her works or ideas to the whole class; and (3) individual student non-presentation talk which refers to an individual student public talk other than the talk in presentation. There are more than one student speaking at one time in public in student choral talk, whereas only one student speaks at one time in public during individual student presentation talk and individual student non-presentation talk. If an individual student talks in public but does not make public presentation, then this student's talk is coded as individual student non-presentation talk. For example, individual student non-presentation talk includes individual student's comments on peer's presentation, or individual student's responses to the teacher's questions.

Analyzing the opportunity of student talk

To investigate the opportunity for students to talk in mathematics classroom, the framework developed by Hiebert et al. (2003) was applied in this study. As was discussed in the literature review, the three indicators for the opportunity of student talk developed by Hiebert et al. (2003) are as follows: (a) the allocation of lesson time for student public talk, (b) the total number of words spoken by students in public, and (c) the length of each student utterance spoken in public. In this framework, Hiebert et al. (2003) only considered student public talk while student private talk (e.g., talk in groups) was excluded, because it was easier to identify student public talk in the recorded videos of classroom instruction. In this study, private talk was included when examining the allocation of lesson time for student talk, because student private talk can be recognized as an improvement in mathematics classroom in mainland China. So, it is worthwhile to see how much time was allocated for student private talk in reform-based mathematics classroom. For the other two indicators (i.e., indicators (a) and (b)), this study only considered student public talk.

When examining the number of words spoken by the students in public and the length of each student utterance, there emerged an issue of instructional language. Hiebert et al. (2003) examined seven countries for some of which the language of instruction was not English. In order to maintain the legitimacy of the comparison, all the transcripts in non-English speaking lessons were translated into English. In this study, the language of instruction is Chinese Mandarin for all the lessons. Because the aim of this study is not to make comparisons between two nations, there is no need to translate the transcripts into English. Therefore, all the transcripts in this study were analyzed in the original language, Chinese Mandarin. Because the term "the number of words" was formulated for English language rather than Chinese Mandarin in the study of Hiebert et al. (2003), this study used the term "the number of Chinese characters" to replace the term "the number of words". Similarly, when examining the length of each student utterance spoken in public, the number of Chinese characters included in a student utterance was counted and presented.

Therefore, the eventual revised framework for the opportunity of student talk is as follows: (a) the allocation of lesson time for student public talk and private talk; (b) the total number of Chinese characters spoken by students in public; and (c) the length of each student utterance spoken in public.

Analyzing the quality of student talk

The framework for the quality of student talk was developed based on the frameworks developed by Stein (2007), NCTM (2010) and Weaver et al. (2005), which were reported in literature review. The eventual framework used to code the quality of student talk is in Table 2.

Different from Stein (2007), NCTM (2010) and Weaver et al. (2005), this study distinguishes explanation and justification by the functions they serve as argued by Cobb et al. (1992). Students give mathematical explanations to clarify aspects of their mathematical thinking that they think might not be readily apparent to others. In contrast, students give mathematical justifications in response to challenges to apparent violations of normative mathematical activity. This distinction helps to clearly document students' talk about mathematics argumentation which usually requires students' high level of cognitive demands and spontaneous responding.

Interrater reliability

One lesson was selected for interrater reliability check, in which two coders (one of whom is the first author) in the field of education research independently applied the above frameworks to analyze teacher talk and student talk. An agreement of 85% was achieved between the two coders' coding results. Any differences arising from the inconsistent coding results were resolved by refining the categories' descriptions.

Statistical analysis

To assess the impact of student's gender on student talk, an independent-samples *t* test was conducted to compare the number of Chinese characters spoken by male students and that by female students. In addition, to assess the impact of student mathematics achievement, the three mathematics tests' results added together as the variable of students' mathematics achievement. Then Pearson's correlations were conducted between the number of Chinese characters and mathematics achievement.

Results

Collective student voices

Time of student talk

Figure 1 presents the time share for student talk and teacher talk over the lesson sequence. Altogether in all the ten lessons, students were given half of the lesson time to have conversations in groups or speak to the whole class. In contrast, the proportion of teacher public talk only took up 26% of the total lesson time of all the ten lessons.

The first six lessons seem to be quite different from the last four lessons regarding the time allocation for student talk and teacher talk. The time proportion for student group talk was stable at around 20% in the first 6 lessons, but this proportion decreased in the last four lessons except lesson 8. The extreme case was observed in lessons 7 and 9 where the proportion of time for student group talk dropped to 0%. Similarly, the time for student public talk took up about 30% of the lesson time in the first six lessons, and this percentage declined by 10% in the last four lessons except lesson 9. In contrast, for the first 6 lessons, the teacher used about 20% of the lesson time to speak in public, while this percentage increased to more than 30% in the last four lessons.

Figure 2 shows the time proportion for three types of student public talk over the lesson sequence. Altogether in all the ten lessons, students' public talk consisted mainly of individual student presentation talk and individual student non-presentation talk, which separately took up around 40%

Table 2 Coding schemes for the quality of student talk

Codes	Descriptions
Procedures/facts (P/F)	Short answers to a direct question Restating facts/statements made by others Showing methods/steps Describing what and how Making observations/connections
Explanation (E)	Explaining strategies Explaining/sharing mathematical ideas Explaining why by providing mathematical reasoning
Justification (J)	Challenging the validity of an idea by providing mathematical reasoning Giving mathematical defense for an idea that was challenged
Generalization (G)	Using mathematical relationships as the basis for (1) Making conjectures/predictions about what might happen in the general case or in different contexts (2) Explaining and justifying what will happen in the general case

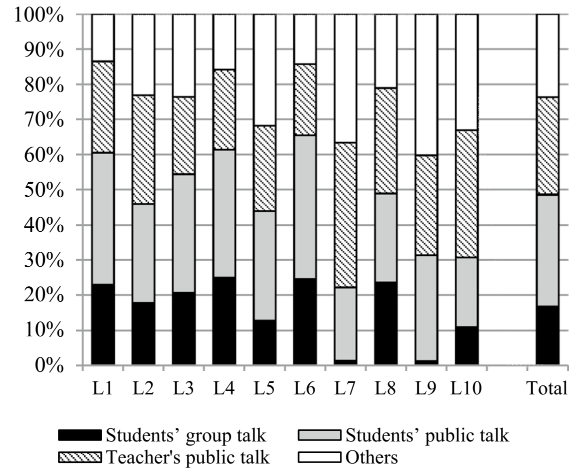


Fig. 1 Time allocation for student talk across the lesson sequence

Note: ***Students' group talk***: Video segments when students have private interactions in groups and the targeted audiences are group members within one group;
Students' public talk: Video segments when students talk in public and the targeted audiences are the whole class and the teacher;
Teacher's public talk: Video segments when the teacher talks in public and the targeted audiences are the whole class;
Others: Video segments when no one talks in the classroom. "Others" includes the video segments of the following activities: student seatwork, teacher writing on the blackboard, teacher adjusting the visual presenter or computers, and so on.

and 52% of all the time for students' public talk. In contrast, the time for student choral talk represented only about 8% of all the time for students' public talk.

The time allocation for student talk in the first six lessons presented different features from that in the last four lessons. The time allocation for student choral talk and non-presentation talk was larger in last four lessons than in the first six lessons. In addition, the time proportion of individual student presentation talk relative to the time for student talk decreased substantially in the last four lessons.

The number of Chinese characters for student public talk

When students talked in groups, the whole class was very noisy. As a result, the cameras could not record every student's talk in group discussion. So the number of Chinese characters spoken by students in group talk was not counted. In this section, only the number of Chinese characters for student public talk and teacher public talk was presented. Altogether in all the ten lessons, students were recorded to speak 25,355 Chinese characters in public, while the teacher spoke 30,239 Chinese characters. The number of Chinese

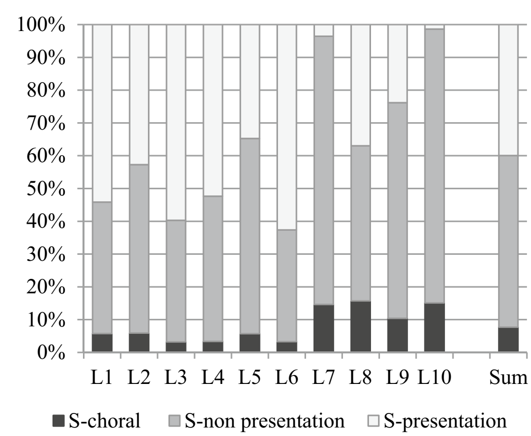


Fig. 2 Time of student public talk

Note: ***S-choral***=student choral talk; ***S-non presentation***=individual student non-presentation talk; ***S-presentation***=individual student presentation talk.

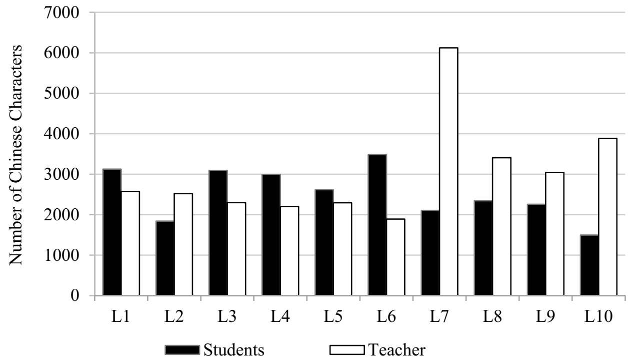


Fig. 3 The total number of Chinese characters spoken by the teacher and the students

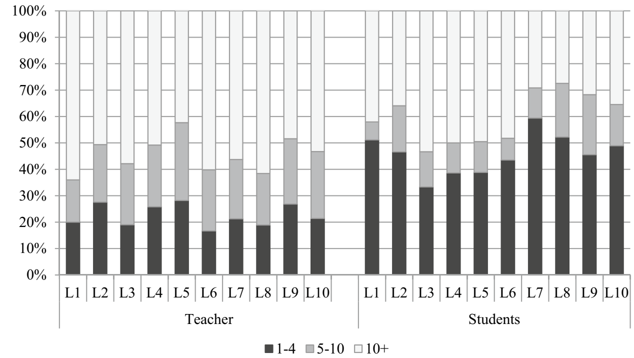


Fig. 5 The percentage of teacher utterances and student utterances of each length

characters spoken by the students and the teacher in each lesson is presented in Fig. 3.

Although the teacher spoke a larger number of Chinese characters altogether in all the ten lessons than students, it is evident that in each lesson the Chinese characters recorded in teacher's public utterances did not always outnumber those in all the students' public utterances. Actually, in five out of the first six lessons, Chinese characters spoken by all the students were more than those spoken by the teacher. By contrast, the number of Chinese characters in teacher's public utterances was larger than that in all students' public utterances in the last four lessons.

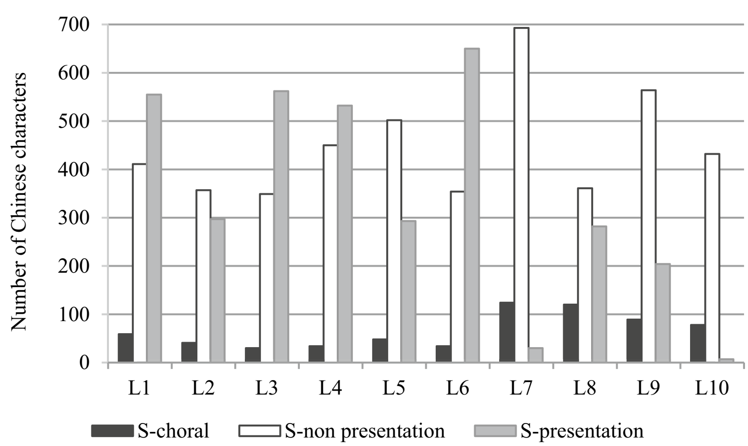
Figure 4 shows the number of Chinese characters in three types of student public talk over the ten lessons. Few Chinese characters were recorded in student choral talk over all the ten lessons. In fact, the number of Chinese characters recorded in student choral talk stayed at about 50 for the first six lessons. Although this number increased to around 100 in the last four lessons, it was much smaller compared with the number of Chinese characters recorded in individual student presentation talk and non-presentation talk.

For each of the first six lessons except lesson 2 and lesson 5, the majority of students' public talk occurred in students' presentations where students spoke around 500 Chinese characters. This number, however, dropped to less than 300 words in the last four lessons. Compared with the first six lessons, the last four lessons saw a larger number of Chinese characters recorded in individual non-presentation talk.

Length of utterance in public talk

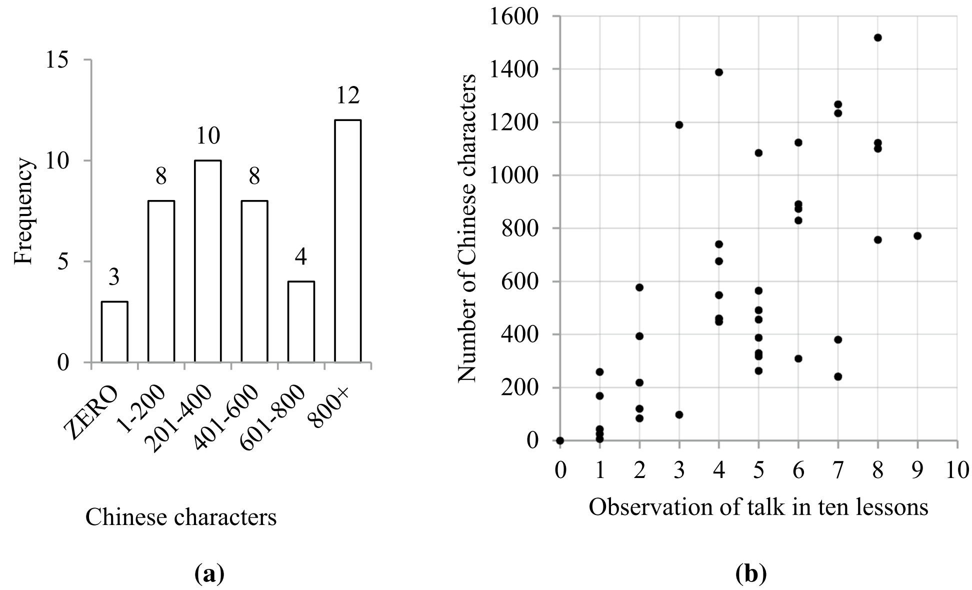
Figure 5 shows the length of each teacher utterance and each student utterance over the ten lessons. All the utterances were divided into three categories: (1) short utterances with less than 5 Chinese characters, (2) medium-long utterances

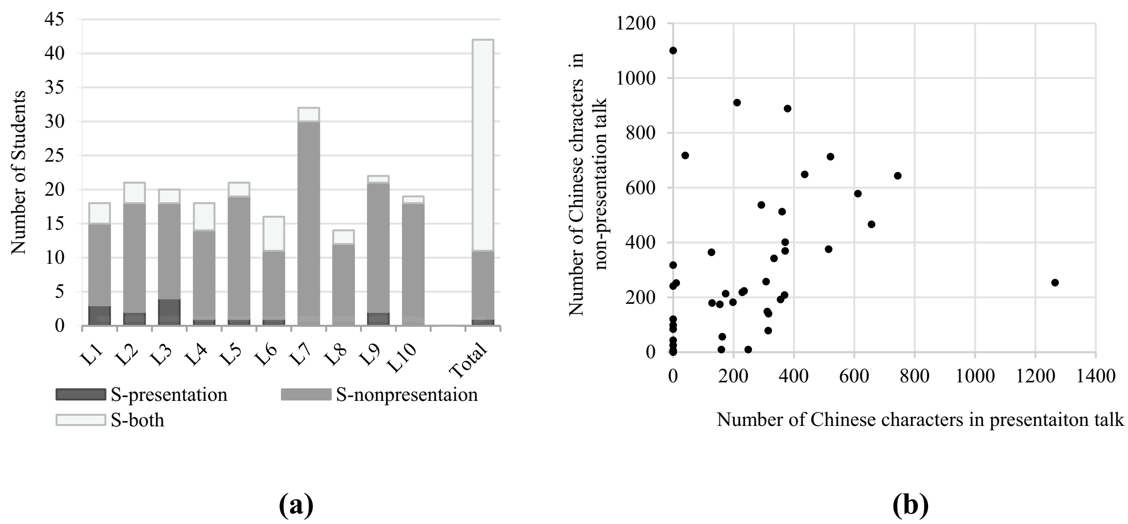
Fig. 4 The number of Chinese characters within student talk in three different occasions



Note: ***S-choral***=student choral talk; ***S-non presentation***=individual student non-presentation talk; ***S-presentation***=individual student presentation talk.

Fig. 6 The number of chinese characters spoken by individual students





Note:
S-presentation=students who ONLY participate in individual student presentation talk;
S-individuals=students who ONLY participate in individual student non-presentation talk;
S-both=students who participate in BOTH individual student presentation talk and non-presentation talk.

Fig. 7 How students talked over the lesson sequence

with 5–10 Chinese characters, and (3) long utterances with more than 10 Chinese characters.

It can be seen that over the lesson sequence, about 50% of the utterances that the teacher spoke were long (i.e., more than 10 Chinese characters) and the proportion taken by the medium-long utterances containing 5–10 Chinese characters is about 25%. By contrast, around 50% of student utterances were observed to be short (i.e., fewer than 5 Chinese characters).

Individual student voices

Student's public talk in the individual level only includes individual student presentation talk and individual student non-presentation talk, and student choral talk was excluded.

The number of Chinese characters spoken by each student

Figure 6a shows the grouping of individual students according to the total number of Chinese characters spoken in all the ten lessons, and Fig. 6b shows the number of Chinese characters spoken by each individual student in public talk, in contrast with the frequency of talk for each individual student in classroom interaction.

Over the ten lessons, 42 students were observed to talk in public, whereas 3 students did not talk at all in any of the ten lessons. It is also obvious that there existed huge individual differences regarding the number of characters spoken over the ten lessons. For example, 18 students spoke no more than 400 Chinese characters, whereas 12 students spoke more than 800 Chinese characters.

In Fig. 6b, it can be seen that nobody got the chance to talk in all the 10 lessons, and only one student got the chance to talk in 9 lessons. Only 14 students had opportunities to talk in more than 5 lessons, whereas most of students (31 out of 45) had the chance to talk in fewer than 5 lessons. In addition, it seems that the more frequently a student was observed to talk, the more Chinese characters spoken by the student were recorded.

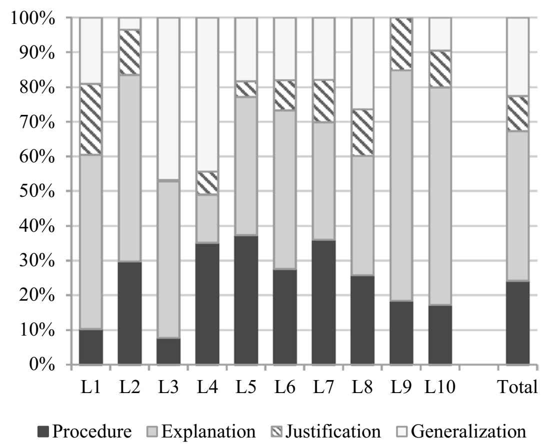


Fig. 8 The quality of student's public talk in the lesson sequence

Presentation talk and non-presentation talk

Figure 7a shows the number of students who talked in public and indicates whether a student was observed in presentation talk, non-presentation talk, or both. Figure 7b presents the number of Chinese characters spoken in presentation talk in contrast with the number of Chinese

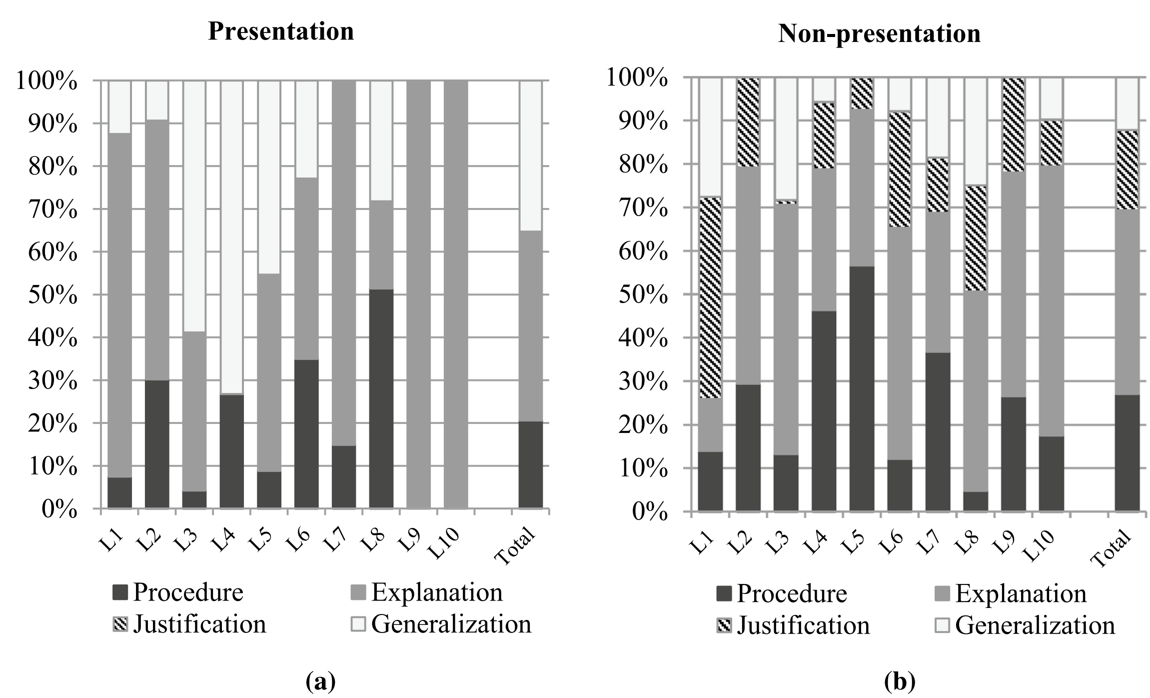


Fig. 9 The quality of student presentation talk and non-presentation talk over the lesson sequence

characters spoken in non-presentation talk by each individual student.

As can be seen in Fig. 7a, the number of students who talked in public was about 20 in each lesson, which means in one lesson nearly half of all the 45 students had opportunities to talk about mathematics in class. For the individual students who talked in one lesson, most of them were recorded to participate in non-presentation talk rather than presentation talk. Some students participated in both presentation talk and non-presentation talk, whereas a couple of students only had the chance to present their ideas without further opportunities to participate in non-presentation talk.

By contrast, there were a total number of 42 students out of 45 having the chance to talk in public over the lesson sequence, and nearly three quarters (31 students) of all the students had the opportunities to both present their ideas and participate in non-presentation talk. Both of the two numbers were much larger than the records in each individual lesson. Thus it could be inferred that the recorded 20 some students who talked in each lesson did not constitute the same group of individuals. In other words, even though the total number of students given chances to talk in each lesson was stable at around 20, the students actually took turns to talk in different lessons. The students who were silent in one lesson were given opportunities to talk in another lesson and similarly some students who talked in one lesson were silent in another lesson. Also, one individual student took turns to make presentations and contributed to non-presentation talk over the lesson sequence, and as a result most of the students could have chances to participate in both presentation talk and non-presentation talk.

It can be seen in Fig. 7b that, the more Chinese characters a student spoke in presentation talk, the more Chinese characters were observed in his/her non-presentation talk. But some exceptions can be identified very obviously. For example, one student actually spoke around 1300 Chinese characters in public presentation altogether in the ten lessons and this record (i.e., 1300) was the highest in all 45 students. But this student did not make as many contributions to non-presentation talk since only about 300 Chinese characters were observed in this student's non-presentation talk.

Descriptive data showed that male students spoken similar number of Chinese characters (presentation talk: M = 214.43, SD = 238.57; non-presentation talk: M = 298.14, SD = 317.362) to the female students (presentation talk: M = 267.17, SD = 269.037; non-presentation talk: M = 293.04, SD = 236.281). The independent-samples *t* test was employed to examine the potential differences between male and female students in the number of Chinese characters recorded in the talk. The results did not show significant differences in the number of Chinese characters in presentation talk (t (45) = 0.062, p = 0.951) or in non-presentation

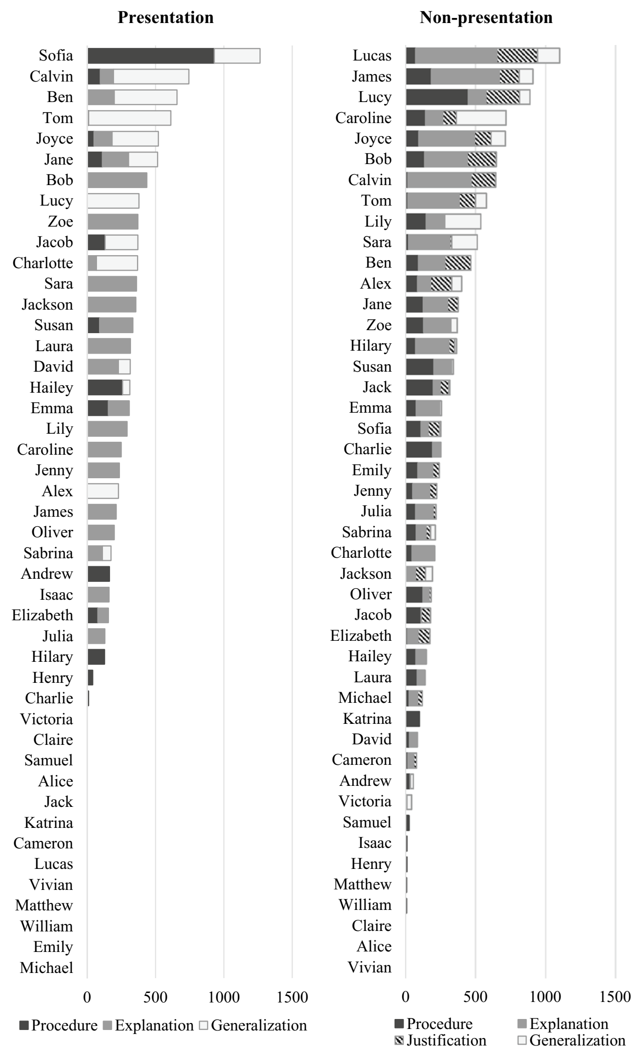


Fig. 10 The quality of each individual student's presentation talk and non-presentation talk

talk (t (45) = − 0.691, p = 0.493). In other words, neither gender group was given more opportunities than the other to talk about mathematics in the classroom.

Pearson's correlational analysis showed no significant relationship between the number of Chinese characters in presentation talk and student mathematics achievement (r = 0.311, p = 0.464). It seems that the teacher did not provide students with opportunities to make presentations according to students' mathematics achievements. However, Pearson's correlational analysis showed significant connections between the number of Chinese characters in non-presentation talk and student mathematics achievement (r = 0.392, p < 0.01). This means that students with higher mathematics test scores were more likely to contribute to non-presentation talk than those students with lower mathematics test scores.

Quality of student collective voices

Overall quality of student public talk

Figure 8 shows the overall quality of student public talk over the ten lessons.

Here student public talk includes student presentation talk and non-presentation talk, whereas student choral talk is excluded. Each bar represents the proportions taken up by each category of student talk in each lesson by dividing the number of Chinese characters in each of the four categories of student talk by the total number of Chinese characters spoken by the students.

Altogether in all the ten lessons, student talk about mathematics procedures represented about 23% of all student public talk, while the proportions taken up by student talk related to explanation, justification, and generalization were respectively around 45%, 10%, and 22%. During student public talk over the lesson sequence, students were mainly involved in mathematics explanation in the beginning (lessons 1 and 2) and end (lessons 9 and 10) of the lesson sequence. In the middle of the lesson sequence, student talk about mathematics procedures became evident (in lessons 4–7) and student talk about drawing mathematics general conclusions was more frequently observed in lessons 3 and 4 than in any other lessons.

Quality of student presentation talk and non-presentation talk

Figure 9 shows the proportions of procedure, explanation, justification, and generalization in student presentation talk and non-presentation talk. There was no justification-related talk in students' public presentation over the lesson sequence. In public presentation, students were mainly observed to explain their mathematical thinking (i.e., explanation) and to make general conclusions (i.e., generalization). By contrast, the presentations about mathematics procedures were less frequently observed except in lesson 8. For student non-presentation talk, the majority of student non-presentation talk in each lesson was characterized by mathematics explanation and justifications, whereas mathematics procedures and generalization were less frequently observed. In summary, students had more chances to share mathematics explanations and generalizations during presentation talk, whereas non-presentation talk allowed students to make explanations and justifications.

Quality of individual student voices

Figure 10 shows the quality of each individual student's presentation talk and non-presentation talk in the lesson sequence. Each bar represents the number of Chinese characters spoken by one individual student in all the ten lessons. All the students' names are pseudonyms (Fig. 10).

It seems that each student had a fixed accountability in making contributions to the presentation talk. For example, the majority of Sofia's (the first student from the top in the left graph) presentation talk was about mathematics procedures, while Tom (the fourth student from the top in the left graph) mainly gave generalizations in the presentation talk. Bob (left graph: 7th; right graph: 6th) had more chances than Elizabeth (left graph: 28th; right graph: 29th) to make explanations and justifications in classroom talk. The transcript of an example was provided (Figs. 11, 12).

In this episode, students were observed to speak mathematics more frequently than the teacher. After Elizabeth presented her answers to task and provided a brief explanation, the teacher invited Bob to give some comments. Bob argued against Elizabeth's answers but did not make his points as clearly as the teacher expected. Then the teacher asked Bob to show more details. Instead of allowing Elizabeth to respond to Bob's argument, the teacher stayed on Bob's argument and continued to give Bob more chances to talk. Clearly, the teacher did not allow them to make justifications in an equal way, although both Elizabeth and Bob were given chances to talk mathematics in classroom. Overall, Bob had more chances to make explanations and justifications than Elizabeth did. Besides, those talkative students (i.e., in the top section of the lists in Fig. 10) tend to be more associated with sophisticated mathematics talk (i.e., explanation, justification, and generalization) than those students in the bottom section who were mainly accountable for mathematics procedures.

For each student, the numbers of Chinese characters for talk about explanation, justification, and generalization

Fig. 11 The task about the definition of a function in lesson 1

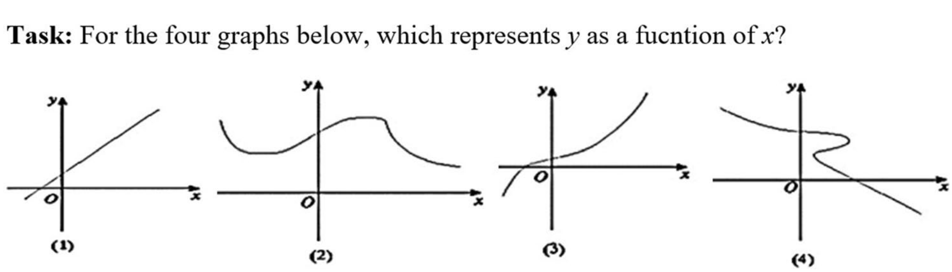


Fig. 12 Transcripts of teacher-student conversation in lesson 1 (0:02:30–0:05:03)

T: OK. Let us see how Elizabeth works on this problem?
S: **[Elizabeth]** For the four graphs below, which represents y as a function of x? The graph one and three represent y as a function of x. The curves two and four don't, because more than one x value can correspond to the same y value. One x value must correspond to only one x value.
[03.02-03.07] The teacher waited for students to think about what Elizabeth said and then invited Bob to speak.
S: **[Bob]** I think the graph two can represent y as a function of x. The rule is that, each x value must correspond to a unique y value. For any x value, we can construct a vertical line and check the intersection points between the vertical line and the graph. We can find there is always one intersection point wherever we construct the vertical line.
T: Does it make sense to everyone? [To Bob] I think some students might feel puzzled about what you said? Could you please come up and show us how you construct the vertical line?
[04.14-04.16] The student was making preparations.
S: **[Bob]** For example, take an x value here. We can construct a vertical line. It is parallel to the y-axis. You can find there is only one intersection point between the vertical line and the graph. No matter how you move the x value and the vertical line, there is always only one intersection point.
T: **[to the whole class]** In other words, [we can say] the corresponding y value is?
Class: Unique.
T: **[to Bob]** What about the next graph [the fourth graph]?
S: **[Bob]** in the next graph, in this part, there is one intersection point, one intersection point. Starting from this part, there are three intersection points. Therefore, there are three x values for each y value in this part. So, it is not a function.
T: Two or three points of intersection, right?
S: **[Bob]** Yes.
T: Which part of the definition does this [the fourth graph] contradict with?
S: **[Bob]** For every given x value, there is a unique y value. It [the fourth graph] contradicts with this part.
T: OK.

in both presentation talk and non-presentation talk added together as the number of Chinese characters in more sophisticated mathematics talk, as opposed to student talk about procedure. Then Pearson's correlational analysis showed significant relationship between student mathematics achievement and the number of Chinese characters in more sophisticated mathematics talk (i.e., explanation, justification, and generalization = 0.346, $p < 0.01$). In other words, students with higher test scores tended to engage in potentially higher-order thinking than students with lower test scores, despite most students were allowed to talk in the classroom.

By examining the quality of each student's talk in presentation and non-presentation situations, it can be found the presentation could enable students to talk with a large number of Chinese characters, but the variety of the types of student talk is limited. In contrast, non-presentation situations provided students with more chances to engage in classroom talk with various cognitive demands. However, in both presentation talk and non-presentation talk, only a few students were given chances to make mathematics generalizations.

Discussion

Rich opportunities for collective student voice

In this study, very rich opportunities for student talk were observed. In some lessons (e.g., lessons 4 and 6), the time for student talk and the number of Chinese characters spoken by the students even exceed those of teacher talk. Instead of student choral talk reported by other researchers (Clarke et al. 2013b), the observed student talk in this study was mainly individual student presentation talk and individual non-presentation talk. In addition, the number of Chinese characters spoken by students altogether in individual student presentation talk and individual non-presentation talk was much larger than in student choral talk. Besides, most of the students were accountable for public talk in the mathematics classroom. In this study, half of all students (about 23 students) were observed to talk in each lesson, but no one student was observed to talk in all the ten lessons. It can be inferred that the talkative students observed in different lessons did not constitute a select group of students. In other words, some students might have an opportunity to speak a large number of words in one lesson, but kept silent in another lesson.

The above results are different from the previous findings. By analyzing the videotaped recordings of 15 Shanghai mathematics lessons, Cao and He (2009) pointed out that the main type of classroom interaction in Chinese mathematics classrooms was the interaction between the teacher and the whole class, which suggested that student choral talk was observed as a major way for students to participate in classroom talk. Therefore, student choral response can be regarded as a good strategy to improve students' engagement and verbal participation in classroom discussion (Clarke et al. 2013a). However, in this study student choral talk was not observed as frequently as other types of student talk, such as individual student presentation talk. Although the class size was very large (45 students) in this classroom, more chances were given to individual student talk rather than student choral talk.

This study presents sufficient details about each individual student's participation in classroom interaction in mainland China. Compared to the previous study which reported 3 students were observed to make public presentation during 6 mathematics lessons (Cao et al. 2013), this study showed that a larger number of students were given chances to share their mathematical thinking in public presentations. In half of all the ten lessons, there were at least five students talking in public presentations, and altogether in ten lessons a total of 32 students were given chances to present mathematics thinking in public.

Limited chances for developing students' spoken mathematical fluency

This study made comparisons between the length of student utterances and the length of teacher utterances. The majority of student utterances in public talk was either very long (more than 10 Chinese characters) or very short (1–4 Chinese characters) in each lesson over the lesson sequence. In contrast, teacher utterance was mainly made up of medium-long (5–10 Chinese characters) and very long utterances. Even in the lessons (e.g., lessons 4 and 6) where students altogether spoke more Chinese characters than the teacher, the proportion of very short utterances (1–4 Chinese characters) relative to all student utterances was as high as around 40%.

Compared with shorter utterances, the observations of longer utterances by students are associated with spoken mathematical fluency, requiring higher level of mathematics thinking/reasoning and more articulation skills. Thus, the high proportion taken up by short student utterances suggests that, students were given few chances to develop spoken mathematical fluency in nearly half of the total number of student utterances across the ten lessons. In other words, altogether in the ten lessons a large number of Chinese characters were recorded in student talk, but a significant proportion of the observed student talk showed that students did not speak more than four Chinese characters.

The opportunity gap in individual student voice

This study examined a sequence of ten lessons and found that about 20 students were observed to speak in each lesson but over the lesson sequence 42 out of 45 students were recorded to participate in public talk. This suggests that through the lesson sequence students actually took turn to participate in presentation talk and non-presentation talk. In other words, the teacher strategically distributed the chances of speaking in public to nearly every student in the class. It reflects the teacher's strategy to construct an equal environment for students to participate in classroom talk in a large-size class.

However, a big gap was observed regarding the opportunity that each student was given to talk in public. Although most of the students were observed to speak during the sequence of ten lessons, the total number of Chinese characters spoken by an individual student over the ten lessons ranges from 0 to more than 800. 3 students were not observed to talk in any lesson of the lesson sequence. For the 42 students who had chances to speak during the lesson sequence, 18 of them each spoke fewer than 400 Chinese characters during all the ten lessons.

Besides, the students had unequal opportunities to participate in individual non-presentation talk. Compared with their peers, some students were given fewer chances to participate in non-presentation talk. For example, one student (Sofia) was observed to speak the largest number of Chinese characters in public presentation altogether in the ten lessons, but this student did not speak too much in non-presentation talk (see Fig. 7b).

The previous studies focused mainly on the overall level of student talk (e.g., Zhao et al. 2016), or were limited to the gender differences in classroom participation (e.g., Song 2015), without examining each individual student's chance to talk mathematics in public. The above findings in this study make some supplement into the present literature by considering each individual student's talk in the mathematics classroom. The results remind the researchers of the importance of paying attention to each individual student when examining the construction of the discourse community in mathematics classrooms.

The quality of student public talk

When all the students' talk in the ten lessons was regarded as a whole, it can be seen that the Chinese characters in students' talk about mathematics procedures or facts occupied about 22% of those in all the students' talk. In other words, nearly 80% of Chinese characters recorded in students' talk were about mathematics explanation, justification, and generalization. In other words, when students were given chances to talk in public, classroom interaction tends to involve mathematics explanation, justification, and generalization rather than simply procedure or facts. This aligns with recent study conducted by Zhao et al. (2016) who found Chinese students' public talk tends to involve high-level thinking in both traditional and reform-based mathematics classrooms. In addition, the above findings echo the results reported by Xu and Clarke (2013) who suggested that Chinese student public talk were more efficient in using mathematics terms than Western students.

This might be attributed to Chinese mathematics teachers' specific views about effective lessons and their expectation of what students should say in presentation talk. From the perspective of mainland Chinese teachers, an important indicator for an effective mathematics lesson is the design of cognitively demanding and challenging activities and at the same time maintaining a certain teaching pace so as to cover the mathematics content prescribed in the curricula (Wang and Cai 2007). Due to the time constraints, the communication process and classroom questions are usually designed and prepared in advance rather than generated by responding to student talk during classroom interaction. While engaging student in classroom talk aims to build an environment for mathematics communication, Chinese teachers tended to believe that student public talk is supposed to align with rather than interfering with the progress of classroom instruction. To better make use of lesson time, student public talk is expected or controlled by the teacher to be efficient and productive in highlighting the essential part of the mathematics content.

In addition, this study finds that students' verbal contributions with various cognitive levels were more likely to be observed in non-presentation talk instead of presentation talk. In other words, when coding student's talk during public presentation over the ten lessons, an individual student's talk in different lessons usually falls to one or two of the four categories (i.e., procedure/facts, explanation, justification, and generalization). In contrast, during individual student non-presentation situations, three or four categories are usually needed to code an individual student's talk over all the ten lessons. It seems that during the public presentation each individual student played a particular role in making verbal contributions rather than being given opportunities to talk mathematics with various levels of quality. This situation might result from various mathematics capabilities of the students who made presentations, or the teacher's selection of the students for public presentation. This might reflect the challenge of improving students' participation in classroom talk by allowing them to make public presentations. In the previous studies, it was argued that pushing students to share their thinking and understanding could be beneficial in facilitating students' construction of mathematics knowledge (Cao et al. 2013). Here this study suggests the benefits of student talk in public presentation might be constrained because students might go through lower-level cognitive processes when making public presentation.

The possible factors that support or constrain the opportunity and quality of student talk

During classroom teaching, the mathematics teacher needs to strike a balance between the coverage of content and students' participation (Ryve et al. 2013). Among many potential factors such as the teacher's teaching experiences, the construction of opportunities for students' participation in classroom talk is significantly influenced by the teacher's strategies to design and implement classroom activities. It is not an easy task to design such classroom activities that maintain an open environment for students to participate in classroom communication, especially in large-size classrooms. By examining the opportunity and quality of student talk in one large-size classroom in mainland China, this study gives some insights into how the teacher's strategies of designing classroom activities can support or constrain student talk in a large-size mathematics classroom.

Cognitive demand and nature of one lesson within the lesson sequence

Over the lesson sequence, the opportunities for student talk in one lesson seem to be associated with the location of this lesson within the sequence. In this study, compared with the last four lessons, students were provided with more time to talk in the first six lessons and students spoke a larger number of Chinese characters during the first six lessons.

The variations of the opportunities for student talk can be attributed to the teacher's changes in the design of classroom activities, which might result from the increasing cognitive load within the lessons sequence. By examining a whole unit of the topic of 'quadratic functions' that was presented over ten consecutive lessons, this study has allowed us to understand how student talk is planned for different aspects in the teaching of each topic. Within the sequence, the order of lessons is arranged in such a way that students can learn quadratic functions from the basics (e.g., the introduction of quadratic functions in lesson 1) to some easy subtopics (e.g., the graph and features of $y=ax^2$ in lesson 2), then to some sophisticated subtopics (e.g., quadratic functions and quadratic equations in lesson 8), and then to the summarization of the whole topic. So, the cognitive requirement of mathematics content is increasing over the lesson sequence. Accordingly, it can be seen in this study that the teacher decreased the allocation of time for time-consuming classroom activities such as group discussion and public presentation.

In addition, the opportunities for student talk in a lesson are also affected by whether the lesson is exploratory in nature. Within the lesson sequence in this study, the first six lessons involve more open-ended investigations (e.g., some quadratic functions' graphs and features) than the last four lessons which included more close-ended mathematics tasks. Therefore, in each of the first six lessons, students were given opportunities to talk and present mathematics and the total number of Chinese characters spoken by the students is even more than that of the teacher. But for the last four lessons, more procedures for solving mathematics tasks were covered. These mathematics tasks are included in the prescribed curriculum and the high-stakes test. Due to the higher requirements of these mathematics tasks and the large class size, the teacher decided to demonstrate the strategies to solve these mathematics tasks in classroom instruction, rather than allowing the students to have group discussions and public presentations. As a result, the teacher shifted his way of teaching from the interaction-oriented (in the first six lessons) to the lecture-oriented (in the last four lessons) so as to cover the prescribed curriculum in the limited time available.

Classroom routine of making public presentations

In this study, the teacher made efforts to allow students to have opportunities to talk in public. Different from the previous findings that student choral talk can be observed very frequently, the teacher in this study constructed opportunities for each individual student to speak in public. Due to the large class size, the teacher asked students to share mathematics thinking in public presentation after students discussed their thinking in groups. The advantage of the public presentation is to give some otherwise silent students some chances to make preparation and clarifications during group discussion and then speak in the public presentation. It is noteworthy that the presentation talk might be a bit less challenging than spontaneous classroom interaction (such as questions and answers) which requires higher level of mathematics capabilities and articulation skills. By contrasting the total number of Chinese characters spoken by each student in presentation talk and non-presentation talk over the ten lessons, this study finds that some students spoke few Chinese characters in public presentations but spoke a large number of Chinese characters in non-presentation talk. Similarly, some other students were observed to speak far more Chinese characters in public presentation talk than in non-presentation talk. The teacher distributed the opportunities for talk to most students (especially those less capable in mathematics or articulation) through strategically selecting students to speak in presentation and non-presentation situations. The group discussion before the presentation could provide those less capable students with more time and confidence to prepare for the presentation and thereby these less capable students could have chances to share their mathematics thinking in public. At the same time, student public presentation is more productive and to the point, which would help to maintain the efficacy of classroom talk. In summary, the public presentation can help to provide students, especially those less capable students, with opportunities to engage in mathematics talk in large-size classrooms.

However, it is also pointed out in this study that public presentation, if not well implemented, has a limitation in maintaining the quality of each student's talk. Compared to talk about mathematics procedures, students' engagement in mathematics explanation, justification, and generalization is more likely to enable them to think and reason in deeper levels. Some students' talk in public presentation was observed to be limited as mathematics procedure or facts instead of explanation, justification, or generalization. In other words, these students might be given chance to talk in public presentation, but they did not engage in high-level mathematical thinking (i.e., explanation, justification, or generalization). Given the large class size, it is a big challenge to maintain both the opportunity and quality of each individual's talk in mathematics classroom.

Student mathematics achievement

The statistical analysis (the independent-samples t test and Pearson's correlation) showed that students with higher mathematics test scores were observed to be more talkative than those with lower test scores. In addition, during classroom talk students with higher mathematics test scores were more likely to engage in mathematics explanation, justification, and generalization than those with lower test scores. Although the teacher in this study made attempts to provide students with as rich opportunities as possible to talk about mathematics in the classroom, he consciously or unconsciously constrained mathematics talk of students with lower mathematics achievement. This reflects that how to engage low-achieving students in mathematics talk might be a big challenge for the teacher to cope with.

Limitations and implications

There are some limitations in this study, in the context of which the results and implication of this research should be considered. Firstly, due to the nature of the case study, this specific Chinese teacher in this investigation could not be taken as representative of all the mathematics teachers in China. The teaching topic in the participating teacher's instruction was limited to quadratic functions. Since the instructional topics and tasks could influence the ways of teacher-student interaction in classrooms, it cannot be concluded that the student talk observed in the collected videos would be exactly the same in the teaching of other mathematics topics.

Secondly, this study measured the quantity and quality of student talk according to the number of Chinese characters spoken by the students, which did not take into account the differences regarding students' articulation. In other words, this study did not fully consider the fact that some students might be more eloquent and thereby explain their ideas in a precise way, while some others' talk might contain more redundant information.

In addition, this study did not collect data from other classes in the same school or other local school. Thus, this study could not compare student talk in the selected class with that in other classes, which left us little information about whether student class talk could influence the teaching effect in the classroom.

However, the value of case studies should be interpreted by moving beyond the issue of generalizability. The findings in this study suggest several implications for the approaches to conducting video analysis on classroom teaching and for classroom practices in sustaining students' talk and engagement.

Firstly, this study analyzed a sequence of ten lessons rather than a couple of lessons, aiming to identify more features of student talk emerging over the lesson sequence. The results suggest the validity of examining the sequence of consecutive lessons. Given the large class size of the classroom in this study, the examination of a lesson sequence can contribute to a better understanding about the construction of opportunities for student talk in mathematics classrooms. For example, the analysis of one or more of the last four lessons might result in the misconceptions that students were given few opportunities to talk in the classroom, whereas the analysis of one or more of the first six lessons might lead to an impression that students always spoke many more Chinese characters than the teacher without noticing the teacher's change of strategies in the last four lessons.

Secondly, the opportunity of student talk can be identified in a better way by the analysis of lesson sequence. This study finds that only about 20 students can be observed to talk in each individual lesson but eventually over all ten lessons 42 students altogether had chances to talk in public. Without documenting student talk in all ten lessons, the observation of a potentially rich student talk would not have been possible. The examination of student talk in the lesson sequence also could help to reveal the variations regarding the opportunity and quality of student talk over the lesson sequence, which can contribute to unpack those factors that could support or constrain student talk in classroom.

Thirdly, this study presents a case about rich student talk taking place in a large-size mathematics classroom in mainland China. In Western culture, students learning and classroom interaction have been believed to be hampered by large classes (Choi and Kim 2014). But the findings demonstrated that student talk can be so rich that almost all the students can have chances to talk in public and students can speak more utterances than the teacher even in large-size classrooms. It contributes to explain the claim why larger classes in Asia Pacific nations (e.g., Korea, Singapore, and China) could bring out outstanding academic achievement (Harfitt and Tsui 2015). Therefore, the findings in this study suggest that culture might make such a big difference in mediating classroom processes that educational values and practices in Western communities have to be considered carefully by educational researchers and practitioners in Asia Pacific region (Harfitt 2012).

In addition, given group learning and public presentation is recommended to enhance student participation in mathematics classroom, this study reminds the practitioners and researchers of the challenge when using public presentation to maintain both the opportunity and the quality of student talk. Due to the fact of large classes in Asia Pacific school systems, this study contributes to provide suggestions about how to improve the efficacy of classroom teaching in large classes.

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References

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report, 13*(4), 544–559.

Cao, Y., Guo, K., Ding, L., & Ida, M. (2013). Students at the front: Examples from a Beijing classroom. In B. Kaur, G. Anthony,

M. Ohtani, & D. Clarke (Eds.), *Student voice in mathematics classrooms around the world* (pp. 53–64). Melbourne: Sense Publishers.

Cao, Y., & He, C. (2009). Research of the type of teacher-student interaction behavior subject in junior middle school mathematics classroom on the LPS video date [In Chinese]. *Journal of Mathematics Education, 18*(5), 38–41.

Chen, X., & Li, Y. (2010). Instructional coherence in Chinese mathematics classroom—A case study of lessons on fraction division. *International Journal of Science & Mathematics Education, 8*(4), 711–735.

Choi, B. K., & Kim, J. W. (2014). The influence of student and course characteristics on monotonic response patterns in student evaluation of teaching in South Korea. *Asia Pacific Education Review, 15*(3), 483–492.

Civil, M., & Planas, N. (2004). Participation in the mathematics classroom: Does every student have a voice? *For the Learning of Mathematics, 24*(1), 7–12.

Clarke, D., & Xu, L. (2008). Distinguishing between mathematics classrooms in Australia, China, Japan, Korea and the USA through the lens of the distribution of responsibility for knowledge generation: Public oral interactivity and mathematical orality. *ZDM–The International Journal on Mathematics Education, 40*(6), 963–972.

Clarke, D., Xu, L., & Wan, M. (2013a). Students speaking mathematics: Practices and consequences for mathematics classrooms in different countries. In B. Kaur, G. Anthony, M. Ohtani, & D. Clarke (Eds.), *Student voice in mathematics classrooms around the world* (pp. 33–52). Melbourne: Sense Publishers.

Clarke, D. J., Xu, L., & Wan, M. E. V. (2013b). Choral response as a significant form of verbal response in mathematics classrooms in seven countries. In A. M. Lindmeier & A. Heinze (Eds.), *Proceedings of the 37th Conference of the international group for the psychology of mathematics education* (Vol. 2, pp. 201–208). Kiel: PME.

Cobb, P., Yackel, E., & Wood, T. (1992). Interaction and learning in mathematics classroom situations. *Educational Studies in Mathematics, 23*(1), 99–122.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th edn.). New York: Routledge.

Cortazzi, M., & Jin, L. (2001). Large classes in China: "Good" teachers and interaction. In D. A. Watkins & J. B. Biggs (Eds.), *Teaching the Chinese Learner: Psychological and pedagogical perspectives* (pp. 115–134). Hong Kong/Melbourne: Comparative Education Research Centre, The University of Hong Kong/Australian Council for Educational Research.

Ding, R., & Wong, N. (2012). The learning environment in the Chinese mathematics classroom. In Y. Li & R. Huang (Eds.), *How Chinese teach mathematics and improve teaching* (pp. 150–163). New York: Routledge.

Harfitt, G. J. (2012). How class size reduction mediates secondary students' learning: Hearing the pupil voice. *Asia Pacific Education Review, 13*(2), 299–310.

Harfitt, G. J., & Tsui, A. B. (2015). An examination of class size reduction on teaching and learning processes: A theoretical perspective. *British Educational Research Journal, 41*(5), 845–865.

Hiebert, J., Gallimore, R., Garnier, H., Givving, K. B., Hollingsworth, H., Jacobs, J., et al. (2003). *Teaching mathematics in seven countries: Results from the TIMSS 1999 video study*. Washington, DC: National Center for Education Statistics.

Hufferd-Ackles, K., Fuson, K. C., & Sherin, M. G. (2004). Describing levels and components of a math-talk learning community. *Journal for Research in Mathematics Education, 35*(2), 81–116.

Koizumi, Y. (2013). Similarities and differences in teachers' questioning in German and Japanese mathematics classrooms. *ZDM—The International Journal on Mathematics Education, 45*(1), 47–59.

Li, Q., & Ni, Y. (2011). Impact of curriculum reform: Evidence of change in classroom practice in mainland China. *International Journal of Educational Research, 50*(2), 71–86.

NCTM. (2010). *Reflection guide-Let's Talk: Promoting mathematical discourse in the classroom*. Retrieved February 10, 2018, from http://www.nctm.org/Conferences-and-Professional-Development/Professional-Development-Guides-(Reflection-Guides)/Let_s-Talk---Promoting-Mathematical-Discourse-in-the-Classroom/.

OECD. (2015). *Education at a Glance 2015: OECD Indicators. Resource document*. OECD Publishing. https://doi.org/10.1787/eag-2015-en. Accessed 13 Nov 2017.

OECD. (2016). *Education in China: A snapshot*. Retrieved January 15, 2018, from http://www.oecd.org/china/Education-in-China-a-snapshot.pdf.

Robson, C. (2002). *Real world research* (2nd ed.). Oxford: Blackwell.

Ryve, A., Larsson, M., & Nilsson, P. (2013). Analyzing content and participation in classroom discourse: Dimensions of variation, mediating tools, and conceptual accountability. *Scandinavian Journal of Educational Research, 57*(1), 101–114.

Seah, W. T. (2011). Ten years of curriculum reform in China: A soft knowledge perspective. In J. Ryan (Ed.), *Education reform in China: Changing concepts, contexts and practices* (pp. 161–184). Oxford: Routledge.

Song, Y. (2015). An investigation into participation in classroom dialogue in mainland China. *Cogent Education, 2*(1), 1065571.

Stein, C. C. (2007). Let's Talk: Promoting mathematical discourse in the classroom. *Mathematics Teacher, 101*(4), 285–289.

Walsh, J. A., & Sattes, B. D. (2016). *Quality questioning: Research-based practice to engage every learner*. Thousand Oaks: Corwin Press.

Walshaw, M., & Anthony, G. (2008). The teacher's role in classroom discourse: A review of recent research into mathematics classrooms. *Review of Educational Research, 78*(3), 516–551.

Wang, T., & Cai, J. (2007). Chinese (mainland) teachers' views of effective mathematics teaching and learning. *ZDM—The International Journal on Mathematics Education, 39*(4), 287–300.

Weaver, D., Dick, T., & Rigelman, N. R. (2005). *Assessing the quality and quantity of student discourse in mathematics classrooms*. Portland: RMC Research Corporation.

White, D. Y. (2003). Promoting productive mathematical classroom discourse with diverse students. *The Journal of Mathematical Behavior, 22*(1), 37–53.

Wong, N. Y. (2004). The CHC learner's phenomenon: Its implications on mathematics education. In L. Fan, N. Y. Wong, J. Cai, & S. Li (Eds.), *How Chinese learn mathematics: Perspectives from insiders* (pp. 503–534). Singapore: World Scientific.

Xu, L., & Clarke, D. (2013). Meta-rules of discursive practice in mathematics classrooms from Seoul, Shanghai and Tokyo. *ZDM—The International Journal on Mathematics Education, 45*(1), 61–72.

Xu, L., Wan, M. E. V., & Clarke, D. J. (2013). Discourse patterns employing choral response in mathematics classrooms in seven countries. In A. M. Lindmeier & A. Heinze (Eds.), *Proceedings of the 37th conference of the international group for the psychology of mathematics education* (Vol. 5, pp. 196–203). Kiel: PME.

Yin, R. K. (2003). *Case study research: Design and methods* (3rd ed.). Thousand Oaks: Sage.

Zhao, W., Mok, I. A. C., & Cao, Y. (2016). Curriculum reform in China: Student participation in classrooms using a reformed instructional model. *International Journal of Educational Research, 75*, 88–101.