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ORIGINAL ARTICLE

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

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Abstract The research reported in this paper examined spoken mathematics in particular well-taught classrooms in Australia, China (both Shanghai and Hong Kong), Japan, Korea and the USA from the perspective of the distribution of responsibility for knowledge generation in order to identify similarities and differences in classroom practice and the implicit pedagogical principles that underlie those practices. The methodology of the Learner's Perspective Study documented the voicing of mathematical ideas in public discussion and in teacher–student conversations and the relative priority accorded by different teachers to student oral contributions to classroom activity. Significant differences were identified among the classrooms studied, challenging simplistic characterisations of 'the Asian classroom' as enacting a single pedagogy, and suggesting that, irrespective of cultural similarities, local pedagogies reflect very different assumptions about learning and instruction. We have employed spoken mathematical terms as a form of surrogate variable, possibly indicative of the location of the agency for knowledge generation in the various classrooms studied (but also of interest in itself). The analysis distinguished one classroom from another on the basis of "public oral interactivity" (the number of utterances in whole class and teacher–student interactions in each lesson) and "mathematical orality" (the frequency of occurrence of key mathematical terms in each lesson). Classrooms characterized by high public oral interactivity were not necessarily sites of high mathematical orality. In particular, the results suggest that one characteristic that might be identified with a national norm of practice could be the level of mathematical orality: relatively high mathematical orality characterising the mathematics classes in Shanghai with some consistency, while lessons studied in Seoul and Hong Kong consistently involved much less frequent spoken mathematical terms. The relative contributions of teacher and students to this spoken mathematics provided an indication of how the responsibility for knowledge generation was shared between teacher and student in those classrooms. Specific analysis of the patterns of interaction by which key mathematical terms were introduced or solicited revealed significant differences. It is suggested that the empirical investigation of mathematical orality and its likely connection to the distribution of the responsibility for knowledge generation and to student learning ourcomes are central to the development of any theory of mathematics instruction and learning.

Keywords International comparative research · Mathematics classrooms · Spoken mathematics · Oral interactivity

1 Introduction

The Learner's Perspective Study (LPS) sought to investigate the practices of well-taught classrooms internationally (Clarke et al. 2006a, b). Data generation focused on sequences of ten lessons, documented using three video cameras, and interpreted through the reconstructive accounts of classroom participants obtained in post-lesson video-stimulated interviews (Clarke 2006a). By conducting case studies of classroom practices over sequences of at least ten lessons in the classes of several competent eighth grade teachers in each of the participating countries, the

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LPS approach offers an informative complement to the survey-style approach of the two video studies carried out by the Third International Mathematics and Science Study (TIMSS) (Hiebert et al. 2003; Stigler & Hiebert 1999). The criteria for the identification of the competent teachers studied in the LPS were constructed locally, specific to each country, in order to reflect the priorities and values of the school system in that country. No claims of national representativeness are made (see Clarke et al. 2006b, Chap 1), but the consistent occurrence of distinctive practices in classrooms situated within a single school system may reflect cultural, national or regional norms of practice.

In this paper, we report analyses of a subset of the lessons documented in classrooms in Australia (Melbourne), China (Hong Kong and Shanghai), Japan (Tokyo), Korea (Seoul), and the USA (San Diego). In reporting the results of our analyses we have been careful to make explicit reference to "*the* Shanghai lessons" (or students, teachers or classrooms), for example, meaning *only* those Shanghai lessons (or students, teachers or classrooms) for which we have data. In English usage, reference to "Shanghai lessons" or "Shanghai teachers" (without the specific use of "the") would imply generalization to all Shanghai lessons or teachers, and we have made every attempt to avoid this implication. If regularities among particular groups of classrooms or teachers appeared to indicate commonalities of practice across different settings, then the possibility of regional, cultural or national norms of practice has been suggested explicitly. On the other hand, evident disparity of practice among classrooms that might otherwise have been seen as similar can be used to contest simplistic generalized categories, such as Asian.

One of the most widely reported results from studies of international assessment of student achievement such as the TIMSS (Beaton & Robitaille 1999) has been the high national mean scores for students from 'Asian' countries. This appears to have triggered the following (naïve) line of reasoning: If Asian countries are consistently successful on international measures of mathematics performance, then less-successful non-Asian countries would do well to adapt for their use the instructional practices of Asian classrooms. Such a line of reasoning is grounded in four key assumptions:

1. That the term 'Asian' identifies a coherent cultural conglomerate with respect to educational practice;
2. That the performances valued in international tests constitute an adequate model of mathematics, appropriate to the needs of the less-successful country;
3. That differences in mathematical performance are attributable primarily to differences in instructional practice, such as lesson structure (rather than to other differences in culture, societal affluence or aspiration, or curriculum); and
4. That the distinctive instructional practices of more-successful countries (e.g., norms of lesson structure), should these exist, can be meaningfully adapted for use by less-successful countries.

Each of these key assumptions can be problematised on a variety of grounds (see Clarke 2003). In the LPS, we base our claims regarding the value of the documented practices not on tenuous connections between classroom practice and national student test performance, but on the location of the lessons in the classrooms of competent teachers in a variety of school systems internationally, and on evidence of learning outcomes provided directly in documented classroom interactions over the lesson sequence or in the post-lesson interviews.

In relation to the role of culture, Wang and Lin (2005) reviewed the research literature with respect to the mathematical performance of Chinese, Chinese-American and other US student groups. Their review problematised "ambiguous cross-national categorizations of East Asian students from Japan, China, Korea, and other East Asian regions and countries" (p. 4). Wang and Lin (2005) noted that while there does appear to be a "widening gap between Chinese and US students… the performance gap between Chinese Americans and Caucasian Americans also increases as both groups move through US schools" (p. 5). Most importantly, Wang and Lin conclude "whether Chinese students actually outperform Chinese American students is still unresolved" (p. 5). Their review, therefore, suggests that the cultural affiliation of the learner (whatever their geographical location) is possibly as important as the cultural alignment of the school or school system and certainly should not be simplistically identified with nationality.

The reference by Wang and Lin to ambiguous cross-national characterisations warrants further investigation. The inclusive use of such terms as 'Asian,' 'East-Asian' and 'Chinese' as descriptive characterisations of classroom practice or of teaching, has been recently problematised (Huang & Leung 2004; Mok & Morris 2001). Fine-grained analyses of classroom practices in a variety of Asian and non-Asian settings (e.g. Lopez-Real, Mok, Leung, & Marton 2004; O'Keefe, Xu & Clarke 2006) have provided empirical support for the challenge to simplistic characterisations along national or even cultural lines. For example, Lopez-Real and his colleagues (2004) challenged the Asian stereotype explicitly.

> The Japanese lessons described in the (TIMSS) video study certainly do not "fit" the Asian stereotype. In addition, our own experience of teachers in Hong Kong, and elsewhere in Asia suggests that the Japanese "image" as portrayed in "The Teaching Gap" [Stigler & Hiebert 1999] is not at all typical. Our own

impression of the popular pedagogy in Hong Kong is closer to the German model reported in "The Teaching Gap" where concepts are carefully explained but the "transmission" mode is still dominant. (Lopez-Real, Mok, Leung & Marton 2004, p. 383)

Mok has elsewhere suggested that terms such as "teacher-dominating" can be misleading as a characterisation of the teaching in some Chinese classrooms (Mok 2006). Clarke has similarly challenged the usefulness of the popular dichotomisation of classrooms as "student-centred" or "teacher-centred" (Clarke 2006c). Attention is therefore focused on what theoretical framework might support cross-classroom comparisons and provide significant insights into essential differences in practice and the principles on which any such differences are based. The distribution of responsibility for knowledge generation has been suggested as a suitable framework (Clarke & Seah 2005), but the challenge then became how to operationalise this framework in a form that could be applied to classroom data. The focus of the analysis reported in this paper is the oral articulation (particularly student articulation) of mathematical terms during classroom whole class and teacher–student discussion. By selecting these two categories of interaction, our analysis excluded "private" student–student interaction, defining other interactions, including teacher–student interactions as "public" from the perspective of the student. Significant differences emerge between the practices of classrooms situated in countries that would all be characterised as Asian.

2 Spoken mathematics and the distribution of the responsibility for knowledge generation

The analysis reported in this paper focuses on two classroom activities: the generation of mathematical knowledge in school classrooms, and the associated (oral) articulation of mathematical terms. The overarching question we sought to address was "Who is responsible for the public generation of mathematical knowledge in the classroom and how is this responsibility distributed between the teacher and the students?" It seemed to us that a classroom in which students were accorded significant responsibility and agency in the public generation of mathematical knowledge ought to be a very different place from a classroom in which the responsibility for public knowledge generation resided wholly with the teacher.

Contemporary theories of learning may locate the activity of generating new knowledge within the head of the individual learner or, alternatively, conceive of this activity as being distributed among the learner, her teacher and classmates, and the physical and conceptual artefacts employed in that activity. In either case, the agency of the learner in that activity is universally acknowledged. The adoption of a particular theory of learning does not prescribe a specific pedagogy. Instructional practice is subject to a variety of constraints and conventions, of which culture is one of the most significant. A theory of learning must accommodate and explain the actions of learners in a wide variety of settings and instructional programs. The mistaken extrapolation of the term "constructivist" from its use in theories of learning to the characterisation of an approach to instruction: "constructivist teaching"—as though learners in any instructional setting could do anything other than "construct" knowledge—has distracted theorists and researchers from the obligation to detail the criteria by which we might distinguish one method of instruction from another according to the pedagogical principles that each method enacts. One of these criteria might be: Who is responsible for introducing a mathematical concept or procedure into classroom discussion?

The immediate challenge in our recent work has been to interpret the enactment of the distribution of responsibility for knowledge generation in terms of actual (and "observable") classroom actions undertaken by teacher and students. By focusing on the documentation of spoken mathematical (and pseudo-mathematical) terms, through video recording and post-lesson reconstructive interviews, we have employed spoken mathematical terms as a form of surrogate variable, possibly indicative of the location of the agency for knowledge generation in the various classrooms studied (but also of interest in itself) (see Clarke & Seah 2005).

3 Data generation

Data generation in the LPS used a three-camera approach (Teacher camera, Student camera, Whole Class camera) that included the onsite mixing of the Teacher and Student camera images into a picture-in-picture video record that was then used in post-lesson interviews to stimulate participant reconstructive accounts of classroom events. These data were collected for sequences of at least ten consecutive lessons occurring in three "well-taught" eighth grade mathematics classrooms in each of the participating countries. Each participating country used the same research design to collect videotaped classroom data for at least ten consecutive mathematics lessons and post-lesson video-stimulated interviews with at least 20 students in each of three participating eighth grade classrooms.

In each lesson, two students sitting next to each other were selected as "focus students" for that lesson. The focus students' conversation with each other or with other students was recorded through a single microphone connected to the student camera. In each of the classrooms studied in this paper, these two students were interviewed individually after the lesson, using the video record of the lesson as stimulus for the students' reconstructive accounts of their experience of the lesson. A different pair of students were selected to be focus students in each lesson. In this way, the practices of the classroom could be examined from the multiple perspectives of at least 20 students over the lesson sequence. The mathematics teacher was interviewed at least three times during the period of videotaping: typically, once per week. As with the students, the video record of a recent lesson (chosen in consultation between the teacher and researcher) was used to stimulate teacher reconstructive accounts.

The three mathematics teachers in each country were identified for their locally defined 'teaching competence' and for their situation in demographically diverse government schools in major urban settings. Rather than attempt to apply the same definition of teaching competence across a dozen countries, which would have required teachers in Uppsala and Shanghai, for instance, to meet the same eligibility criteria, teacher selection was made by each local research group according to local criteria. These local criteria included such things as status within the profession, respect of peers or the school community, or visibility in presenting at teacher conferences or contributing to teacher professional development programs.

The complete research design has been detailed elsewhere (Clarke 2006a, b, c). For the analysis reported here, the essential details relate to the standardization of transcription and translation procedures. Since three video records were generated for each lesson (teacher camera, student camera, and whole class camera), it was possible to transcribe three different types of oral interactions: (1) whole class interactions, involving utterances for which the audience was all or most of the class, including the teacher; (2) teacher–student interactions, involving utterances exchanged between the teacher and any student or student group, not intended to be audible to the whole class; and (3) student–student interactions, involving utterances between students, not intended to be audible to the whole class. All three types of oral interactions were transcribed, although type (3) interactions could only be documented for the selected focus students in each lesson. Where necessary, all transcripts were then translated into English. All participating research groups were provided with technical guidelines specifying the format to be used for all transcripts and setting out conventions for translation (particularly of colloquial expressions).

The analysis reported in this paper was concerned only with utterances that would be viewed as 'public' from the student's perspective [types (1) and (2) interactions] and made use of only the relevant video records of the first five lessons recorded for each classroom. This standardized the data base accessed for each classroom and focused on those introductory lessons when public discussion was likely to be most frequent. Since the focus was primarily numbers of utterances and the spoken use of particular terms, both of which could be readily identified from the video data, interview data did not need to be considered in this analysis.

4 Analytical approach

It is important to note that the oral articulation of mathematical terms by students could have value in itself, even where it consists of no more than the choral repetition of a term initially spoken by the teacher. Some of the classrooms we studied clearly attached value to this type of recitation. In other classrooms, the emphasis was on the students' capacity to produce a mathematically correct term in response to a very specific request (question/task) by the teacher. In such classrooms, both of these activities accorded very limited agency to the learner and the responsibility for the public generation of mathematical knowledge seemed to reside with the teacher. By contrast, in some classrooms, the instructional approach provided opportunities for students to "brainstorm" or to generate their own verbal (written or spoken) mathematics, with very little (if any) explicit cuing from the teacher (e.g. the classrooms in Tokyo).

Bakhtin's use of "utterance" placed emphasis on situating any word, phrase or proposition in its spoken and social setting (Bakhtin 1979). This paper reports the first two stages of a layered attempt to progressively focus on the significance of the situated use of mathematical language in the classroom. An utterance is taken to be a continuous spoken turn, which may be both long and complex. Identification of distinct utterances treated either a change of speaker or an extended silence (greater than 5 s) as the demarcation indicators separating utterances. Since our target construct is "public oral interactivity," rather than simply public speech, the frequency of speaker interchange (including the unexploited opportunities for oral contribution offered by extended pauses in teacher speech) is best measured by the frequency of utterance as defined.

In our first analytical pass, we counted the number of utterances made by anyone participating in whole class or teacher–student interaction ("public utterances" from the student perspective). We restricted our second-pass analysis to those (fairly technical) mathematical terms (e.g. a single word such as "solution" or a phrase such as "system of linear equations") that referred to the substantive content of the lesson: both the terms that labeled the target concepts for the lesson and those technical terms used to explicate or negotiate the meaning of the key terms. An utterance may contain more than one mathematical term, and our second analytical pass counted key mathematical terms rather than utterances. Our previous attempts at unpacking the distribution of responsibility for knowledge generation and its potential as a core precept in instructional theory were hampered by the sheer scale of the logistics of analysing the transcripts of a large number of lessons in a wide variety of classrooms distributed across many countries. The approach employed in this analysis exploited the capacity of available software (*Studiocode*) to determine the frequencies of both public utterance and key mathematical terms. By attending specifically to "public oral interactivity" and "mathematical orality" we attempt to identify patterns of language use indicative of forms of agency in knowledge generation. The results that are recorded in this paper certainly suggest that the classrooms in this study differed widely in the opportunities that the teachers provided for student spoken articulation of mathematical terms and suggest differences in the extent to which they devolved agency for public knowledge generation to the students.

The demonstration of such differences (and we would like to argue that these differences are profound and reflect fundamental differences in basic beliefs about effective instruction and the nature of learning) in the practices of classrooms situated in school systems and countries that would all be described as "Asian" suggests that any treatment of educational practice that makes reference to the "Asian classroom" confuses several quite distinct pedagogies. This observation is not to deny cultural similarity in the way in which education is privileged and encountered in communities that might be described as "Confucian-heritage" (for example). But, the identification of a one-to-one correspondence between membership of a Confucian-heritage culture and a single pedagogy leading to high student achievement is clearly mistaken, and we must look elsewhere than only at culture in our attempts to single out those instructional practices that might be associated confidently with the educational outcomes that we value.

The following results examine differences in the practices of 'well-taught' classrooms with respect to the spoken articulation of mathematical terms and the inferences that such an analysis might support regarding the distribution of responsibility for knowledge generation and the pedagogical principles on which each teacher's actions were predicated.

5 The spoken use of mathematical terms: mathematical orality

The earlier analysis conducted by Clarke and Seah (2005) distinguished between primary mathematical terms explicitly identified in the teacher's lesson plans, secondary mathematical terms employed in whole class discussion to explicate the primary terms, and transient terms, many pseudo-mathematical (e.g. "steep"), occurring typically in the conversations of students discussing the lesson's content among themselves or with the teacher. The initial tabular method of coding and display proved so labor-intensive as to be impractical if implemented on the large-scale required by the extensive LPS data set. New video-coding software *Studiocode* has offered a new approach, combining basic descriptive coding statistics with a capacity to reveal temporal patterns in a highly visual form (cf. Fig. 1). *Studiocode* connects a time-coded transcript to the video record of a lesson and supports coding of either events in the video record or the occurrence of specific terms in the transcript.

The 'Asian' data set analysed in this paper included three sequences of five lessons from three mathematics classrooms in Shanghai, three similar sequences from Hong Kong, three sequences from Tokyo, and three sequences from Seoul. 'Western' classroom practice was represented in this analysis by three sequences of five lessons from Melbourne and two-five-lesson sequences from San Diego. The third data set from San Diego were excluded because of difficulties in applying the definition of "public" in a classroom in which extensive use was made of student groupwork with the teacher as a frequent and mobile peripheral participant in each group's activity. Using *Studiocode*, a timeline display could be generated of the occurrence of selected mathematical terms throughout a given lesson (see Fig. 1). For the purposes of this paper, those mathematical terms were coded that comprised the main focus of the lesson's content. In the terminology used by Clarke and Seah (2005), this analysis focused on primary and secondary terms.

Figure 1 shows the occurrence of specific mathematical terms and phrases: linear equations in two unknowns; equation; unknown; solution; integral solution; and solution set, in the public discussion occurring in one lesson in the classroom of Shanghai Teacher One. We are employing 'public' in the same sense as previously: that is, spoken participation in whole class or teacher–student interaction.

The occurrence of each distinct term or phrase is indicated here by a particular shade of grey. Within a shaded band, each line represents the use of a particular term, such as "equation," by an individual in the classroom discussion. The width of a shaded band is an immediate indication of the number of individuals who made use of the term in public discussion. Not surprisingly, the teacher (signified by "T") made most frequent use of each term. All other timelines refer to student use of each term.

The highly visual nature of the timeline display can reveal temporal patterns in the occurrence of the coded

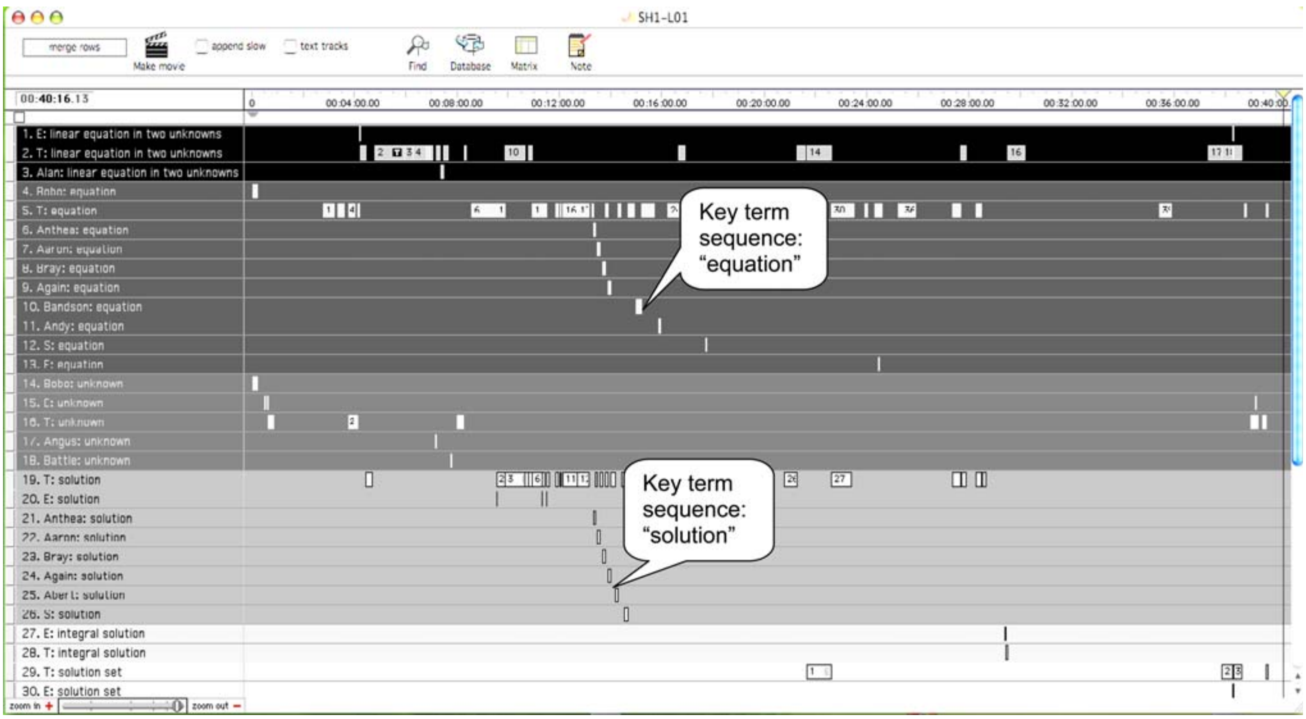
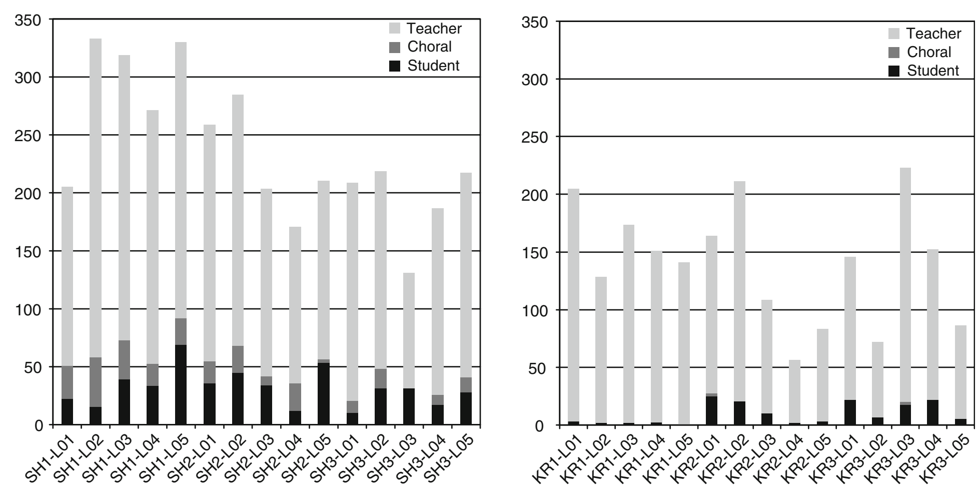


Fig. 1 The occurrence of mathematical terms and phrases in SH1-L01

Fig. 2 Frequency of use of key mathematical terms in classrooms in Shanghai and Seoul



terms. In the case of Shanghai Teacher One, the solicited articulation of a key mathematical term (e.g. "equation" or "solution") from a sequence of students seems to be a distinctive characteristic of that teacher's practice. Once identified, such distinctive patterns can be examined in more detail. Consider specifically the transcript of a 2-min interaction (min:s) focusing on the term "solution."

This level of frequency of student spoken articulation of key mathematical terms was evident in all three classrooms in Shanghai. The pattern of elicited rehearsal of a key term, so visible in Fig. 1 and Table 1, was also clearly evident in the practice of Shanghai Teacher Two.

We defined mathematical orality as the frequency of occurrence of the key mathematical terms pertinent to that lesson. Our focus in this analysis was on the occasions when these were spoken in either whole class discussion or teacher–student interaction. The classrooms studied could also be distinguished by the use made of choral responses from the whole class. The occurrence of whole class choral response can be interpreted as signifying the value attached by the teacher to the recitation by students of key terms. A comparison of the mathematics lessons in Shanghai and Seoul serves to illustrate the capacity of this analysis to distinguish one classroom from another (Fig. 2).

Table 1 Elicited public rehearsal of "solution": classroom transcript (SH1-L01)

12:42 (m:s)	T:	So let's read… ah, let's read question one, question one. It says… in the following pairs of number value, each of them can be matched with a pair of *x* and *y*. So, let's read this. It is asking, which of them are the *solutions* of the equation two *x* plus *y* equals three? Which are the *solutions* of the equation three *x* plus four *y* equals two? Come on, have a try
13:10	T:	So, let's take a look. How about the first one? Oh, ok, you
13:14	Anthea:	*x* is equal to zero, *y* is equal to three. It is
13:17	T:	It's an equation. That means, *x* is equal to zero, *y* is equal to three. It is…?
13:21	Anthea:	It is a *solution* of the equation two *x* plus *y* equals three…
13:24	T:	A *solution*. Okay, sit down please. How about you, Aaron?
13:28	Aaron:	*x* equals zero and *y* equals one over two is a *solution* of the equation three *x* plus four *y* equals two…
13:35	T:	Ah, a *solution* of this. Sit down please. Let's continue. Question three, question three. Come on, (…) [APOLLO and AMANDA raising their hands]
13:41	Bray:	If *x* equals negative two, *y* equals two, it is the *solution* of the equation three *x* plus two *y* equals two.
13:48	T:	Oh,…… it's a *solution* of the equation three *x* plus four *y* equals two. A *solution*, right? Ok, sit down please. Let's continue. Come on.
13:55	Again:	When *x* equals one over two, *y* equals two, it is the *solution* of the equation two *x* plus *y* equals three.
14:00	T:	Okay, it is a *solution* of two *x* plus *y* equals three. Okay, sit down please. So now, *x* equals one, *y* equals one over two, come on, (…) Tell me.
14:12	Abert:	When *x* equals one, *y* equals negative one over two, it is a *solution* of three *x* plus four *y* equals two.
14:17	T:	Okay, he says when *x* equals one, *y* equals negative one over two, and the equation is three *x* plus four *y* equals-
14:23	T:	Oh, he says-
14:24	C:	No it isn't.
14:26	T:	It's a *solution* of two *x* plus *y* equals three. And so, okay, (…) Tell me.
14:33	S:	When *x* equals one, *y* equals negative one over two, it is neither the *solution* of two *x* plus *y* equals three nor the *solution* of three *x* plus four *y* equals two.
14:41	T:	Right. So he says they are neither the *solution* of the equation two *x* plus *y* equals three nor the equation three *x* plus four *y* equals two. So why? Why aren't they?

Students whose names are given in full were subsequently interviewed

S student whose name cannot be identified; *C* choral response by many students; *T* teacher, throughout

Figure 2 shows how the frequency of public statement of mathematical terms varied among the five lessons from each of the three Shanghai and the three Seoul classrooms. Each bar represents one lesson. The display distinguishes statements by the teacher (light grey), individual students (black) and choral responses by the class (dark grey). All lessons were of a similar length—between 40 and 45 min—and, for the purposes of comparison, the frequencies were standardized to a lesson length of 45 min.

Figure 2 provides an indication of the degree of variability/consistency of practice across five lessons for each of the six teachers.

It is immediately apparent that the key mathematical terms were spoken less frequently in the three Seoul classrooms than was the case in the three Shanghai classrooms. As will be seen, even allowing for the relatively low public oral interactivity of the Korean lessons that we analysed, the Korean students in those classrooms were given disproportionately fewer opportunities to orally rehearse the mathematical terms that were the focus of the lesson's content.

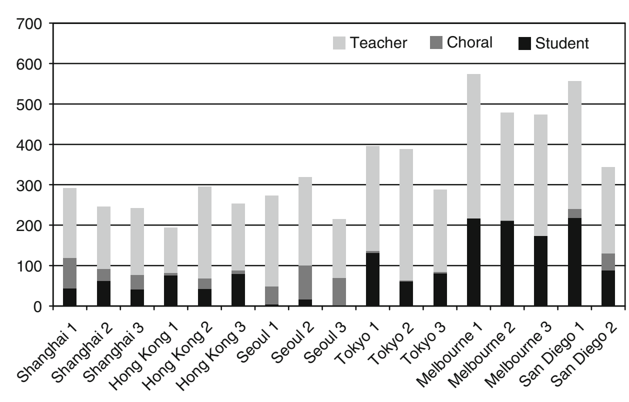


Fig. 3 Average number of public utterances per lesson in whole class and teacher–student interactions (public oral interactivity)

6 Public oral interactivity and mathematical orality in 'Asian' and 'Western' classrooms

Figure 3 shows the average number of utterances per lesson occurring in whole class and teacher–student interactions over the five consecutive lessons for each of the classrooms studied in Shanghai, Hong Kong, Seoul, Tokyo, Melbourne and San Diego. As discussed above, an utterance is a single, continuous oral communication of any length by an individual or group (choral). We have identified the average number of public utterances per lesson with the level of "public oral interactivity" of the classroom. This construct is more appropriate than either the average length of time occupied by an utterance or the average number of words used in an utterance (which would be problematic in a multi-lingual study like this one). Figure 3 distinguishes the number of utterances by the teacher (light grey), individual students (black) and choral responses by the class (e.g. in Seoul) or a group of students (e.g. in San Diego) (dark grey). Lesson length varied between 40 and 45 min and the number of utterances has been standardized to 45 min.

Figure 3 suggests that the lessons analysed from Melbourne and San Diego demonstrated a much higher level of public oral interactivity than lessons from Shanghai, Hong Kong, Seoul, or Tokyo. There were also substantial differences in the relative frequency of teacher, student and choral utterances. This paper does not make comparisons of temporal length or complexity of utterance. For the purposes of this paper, it is the frequency of interchange of speaker, namely the oral interactivity that is being compared.

As foreshadowed earlier, the classrooms studied could also be distinguished by the relative level of mathematical orality of the classroom (that is, the frequency of spoken mathematical terms by either teacher or students in whole class discussion or teacher–student interactions) and by the use made of the choral recitation of mathematical terms by the class. This recitation included both choral response to a teacher question and the reading aloud of text presented on the board or in the textbook. The value attached to affording student spoken mathematics in some classrooms could be interpreted as adherence to a theory of learning that emphasizes the significance of the spoken word in facilitating the internalisation of knowledge. The use of choral response, while consistent with such a belief, could be no more than a management strategy. Whatever the motivation, it is quite clear that the practices of some classrooms promoted the spoken use of mathematical terms by students and some did not. The consistency of both practices suggests quite distinct underlying pedagogies.

Figure 4 shows how the frequency of public statement of mathematical terms varied among the classrooms studied. In classifying the occurrence of spoken mathematical terms, we focused on those terms that represented the main lesson content (e.g. terms such as "equation" or "co-ordinate"). This meant that our categorisation did not include utterances that constituted no more than agreement with a teacher's mathematical statement or utterances that only contained numbers or basic operations that were not the main focus of

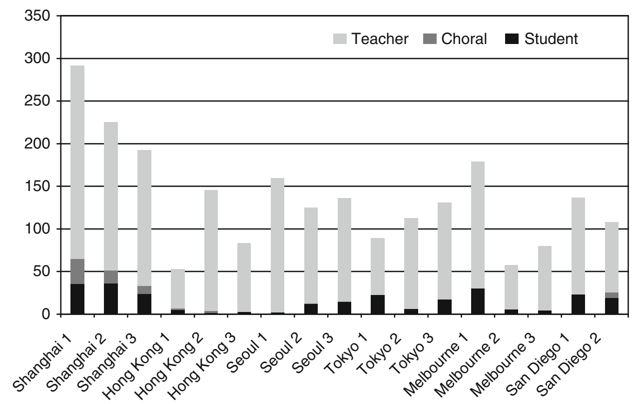


Fig. 4 Frequency of occurrence of key mathematical terms in public utterances (mathematical orality)

the lesson. In the case of the Korean lessons, the frequent choral responses by students took the form of agreement with a mathematical proposition stated by the teacher. For example, the teacher would use expressions such as, "When we draw the two equations, they meet at just one point, right? Yes or no?" And the class would give the choral response, "Yes." Such student statements did not contain a mathematical term and were not included in the coding displayed in Fig. 4. Similarly, a student utterance that consisted of no more than a number was not coded as use of a key mathematical term. It can be argued that responding "Three" to a question such as "Can anyone tell me the coefficient of x?" represented a significant mathematical utterance, but our concern in this analysis was to document the opportunity provided to students for the oral articulation of the relatively sophisticated mathematical terms that formed the conceptual content of the lesson. Frequencies were again adjusted for the slight variation in lesson length.

The most striking difference between Figs. 3 and 4 is the reversal of the order of classrooms according to whether one considers public oral interactivity (Fig. 3) or public mathematical orality (Fig. 4). The highly orally interactive classrooms in San Diego and Melbourne made relatively infrequent use of the mathematical terms that constituted the focus of the lesson's content. By contrast, the less orally interactive classrooms in Shanghai made much more frequent use of key mathematical terms. Since a single utterance might contain several such terms, and it was terms that were being counted in this analysis, Fig. 4 provides a different and possibly more representative picture of the Chinese lessons, where both teacher and student utterances appeared to be longer and more complex than elsewhere.

Specific comparison between those classrooms that might be described as 'Asian' is interesting. Key mathematical terms were spoken less frequently in the Seoul classrooms than was the case in the Shanghai classrooms. In contrast to the teachers in Shanghai and Tokyo, the teachers in the Hong Kong and Seoul classrooms did not appear to attach the same value to the spoken rehearsal of mathematical terms, whether in individual or choral mode. Although the overall level of public oral interactivity in the Tokyo classrooms was similar to that in Seoul, the Japanese classrooms resembled those in Shanghai in the consistently higher frequency of student contribution (Fig. 3), but with little use being made of choral response. The three Hong Kong classrooms were among the lowest in the use of spoken mathematical terms of all the classrooms studied, and student spoken mathematical contribution, whether individual or choral, was extremely low, even though the general public oral interactivity of Hong Kong classrooms 2 and 3 was at least as high as in the three Shanghai classrooms. In summary: there are commonalities among classrooms situated in the same school system that suggest the existence of distinctive regional pedagogies. These commonalities were sustained over five-lesson sequences in each classroom and were of sufficient consistency to suggest an established pattern of practice. There are also similarities in aspects of practice across regions, particularly with regard to public oral interactivity. But it does appear that the variation between the classrooms in those countries typically described as Asian challenges any simplistic characterization of the 'Asian Classroom.'

It is important when interpreting these findings to remember that these analyses were restricted to only whole class and teacher–student interactions. In the Melbourne and San Diego classrooms, student–student conversations were an integral part of the classroom practice, endorsed and even encouraged by the teacher. Consideration of these "private" statements for students in all classrooms was excluded from this analysis, but will provide the focus of a later paper. In noting the high level of public oral interactivity in the classrooms in Melbourne and San Diego (see Fig. 3), it must be noted that the frequency of 'private' conversations was also much higher than in the Asian classrooms, where conversations between students were much less common.

7 Conclusions

To summarise the argument that we have pursued in this paper [and building on earlier writings, such as Clarke and Seah (2005) and Clarke (2006c)]:

- The use of the teacher-centred/student-centred dichotomy as means of distinguishing significant pedagogical differences between classrooms has been shown in earlier studies to be mistaken and misleading;
- It has been proposed that classroom pedagogies are more effectively distinguished by consideration of the distribution of responsibility for knowledge generation;
- This paper suggests that language use (and in particular the initiation of mathematical terms into classroom discussion) provides a useful indicator of the distribution of responsibility for knowledge generation;
- In specific relation to the responsibility for knowledge generation, issues of voice and agency are rendered visible through consideration of who is speaking, how frequently particular voices (teacher and students) are heard, and what is the nature of the individual utterances in terms of their technical content;
- In the classrooms discussed in this paper, there are evident differences in the frequency of public utterances by teachers and by students, both as a total measure of frequency of public utterance (public oral interactivity) and as an indication of how the right and responsibility to speak is distributed between the teacher and the students;
- One measure of the sophistication of the content of a teacher or a student's utterance is the presence of technical terms relevant to the content being taught. Our analyses recorded the relative frequency of occurrence of such technical terms (mathematical orality) in public discussion in a variety of classrooms and for both teacher and students.

It appears to us that the key constructs Public Oral Interactivity and Mathematical Orality distinguished one classroom from another very effectively. This was particularly true when the two constructs were juxtaposed (by comparing Figs. 3, 4). The contemporary reform agenda in the USA and Australia has placed a priority on student spoken participation in the classroom and this is reflected in the relatively high public oral interactivity of the San Diego and Melbourne classrooms (Fig. 3). By contrast, the "Asian" classrooms, such as those in Shanghai, were markedly less orally interactive. However, this difference in public oral interactivity conceals striking differences in the frequency of the spoken occurrence of key mathematical terms (Fig. 4), from which perspective the Shanghai classrooms can be seen as the most mathematically oral.

Despite the frequently assumed similarities of practice in classrooms characterised as Asian, the Asian classrooms studied displayed significant differences in the level of mathematical orality, particularly with respect to the frequency of spoken mathematical terms employed by students. A further critical distinguishing characteristic was the form of prompt by which the teacher elicited student spoken mathematics. Students in the Shanghai classrooms had the opportunity to articulate their understanding of key mathematical terms through a structured process of teacher invitation and prompt that built upon the contributions of a sequence of students. If the responsibility for knowledge generation can be identified with the individual who first introduces a mathematical term into the classroom discussion in a particular lesson, then the classrooms in Japan provided many instances where a student made the first announcement of a mathematical term without specific teacher prompting. These differences are non-trivial and suggest different instructional theories underlying classroom practice. Similarities in the practices of teachers from the same country suggest the existence of national norms of practice that may reflect cultural or national pedagogies indicative of specific local assumptions about learning and teaching.

Consideration of the non-Asian classrooms is also interesting. With frequent teacher questioning and eliciting of student prior knowledge, the students in the Melbourne 1 classroom were given many opportunities to recall and orally rehearse the mathematical terms used in prior lessons. In terms of overall public mathematical orality and level of student contribution, Melbourne 1 resembles Shanghai 3 (without the use of choral response). This public mathematical orality is potentially augmented by small group discussions, in which students draw upon their mathematical knowledge to complete tasks at hand. Such student–student conversations occurred much more frequently in the Melbourne and San Diego classrooms, but these non-public exchanges were not included in the analyses reported in this paper. The teacher's purposeful utilization of student–student conversation as a key instructional tool provides a further analytical lens by which to distinguish the practices of one mathematics classroom from those of another. Certainly Melbourne 1 could be distinguished from Shanghai 3 on this basis. Systematic comparison of levels of mathematical orality in student–student interactions (in which the teacher was not participant) will be undertaken as a separate analysis. The post-lesson interviews may provide the connection between classroom mathematical orality (both public and private) and student learning outcomes. The analysis of public interaction in the seventeen classrooms (85 lessons) analysed for this paper suggests that public oral interactivity and mathematical orality warrant further investigation as units of comparative analysis in international studies of mathematics classrooms.

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