

Recognizing The Interweaving Zone of Dialogic Teaching in a Mathematics Classroom in Singapore

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Despite awareness of its merits, reports on the use of dialogic teaching in Singapore's mathematics classrooms have been relatively scarce. Furthermore, past research has given little recognition to the role of monologic interactions in the classroom and to the interweaving nature of monologic and dialogic teacher-student interactions during lessons. This mixed-methods research thus seeks to acknowledge the presence of dialogic teaching in the interweaving of different modes of teacher-student interaction through the lens of a secondary two mathematics classroom in Singapore. Recordings of lesson sequences on the teaching of direct and inverse proportion, as enacted by the teacher of this classroom, were analyzed. Data analysis was carried out using a monologic-dialogic continuum framework. Although it revealed an overall dominance of monologic interaction during the observed mathematics lessons, the study recognized the interweaving nature of monologic and dialogic teacher-student interactions. In addition, it argues for the value of a monologic type of interaction in the classroom. The discussions later demonstrate how this approach can be decisive in supporting classroom practice. Suggestions for future research were later provided.

Introduction

Teachers as 'conduits of knowledge' is a premise that has gone out of step in the modern classroom, which now moves to the beat of learner-centeredness and learner-drivenness (DíezPalomar & Olivé, 2015). The hope is for teachers to function as knowledge-generating, agentive professionals in the classroom (Sanchez & Athanases, 2023). To this tune, dialogic teaching has gained traction and interest in educational research and classroom practice over the past years (Clark et al., 2016; Mercer & Littleton, 2007) because complex knowledge and skills are best learnt through interactions with others (Vygotsky, 1978). On that note too, the emphasis by the Singapore mathematics education system on being able to "pose questions, justify claims, write and critique mathematical explanations and arguments, devise different strategies to solve an open-ended problem or formulate different mathematical models to represent a real-world problem [and to] simplify an ill-defined real-world problem" (MOE, 2020) has drawn greater impetus to foster dialogic teaching in mathematics classrooms in Singapore. Furthermore, despite being known for a high level of mathematical proficiency, dialogic teaching remains relevant in Singapore classrooms because it is well-positioned to support the education system's desired outcomes by fostering competencies such as communication skills and critical thinking. These remain crucial in preparing Singaporean students to face a world fueled by rapid globalization and unknown challenges to society (MOE, 2023)

Implications of Dialogic Teaching

While the literature has mainly focused on contexts outside the mathematics classroom, it has informed the field of the benefits of dialogic teaching (Alexander, 2005; Teo, 2016; Volfson et al.,

2023) and for students, reported benefits such as developing critical thinking (Hajhosseiny, 2012), promoting student agency (Lugalia et al., 2015) and cultivating confidence in the learners' communication and in the subject content (Bound & Chee, 2019; Mukuka et al., 2021) afforded support for the adoption of dialogic teaching. Mercer and Littleton (2007) argue that dialogic teaching will encourage students to appreciate the value of proper understanding beyond mere short-term goals of obtaining correct answers to problems. As for teachers, dialogic teaching can particularly bring out the facilitative role of the teacher (Mortimer & Scott, 2003; Phillipson & Wegerif, 2007). This is possible because, in dialogic teaching, classroom activities and tasks move away from the teacher's influence and central authority (Alexander, 2008, 2020).

Though few, there have been reports of the positive impact of dialogic teaching in mathematics classrooms. For example, Lugalia et al. (2015) observed that the infusion of dialogic teaching methods in a computer-based algebra lesson of a state-run boarding school in Nairobi witnessed greater "pupil engagement and interaction, and enhanced pupils' learning about algebra" (p. 5071). McGuire and Harshman (2002) also reported that the dialogic environment established in two classrooms of students in an urban school in the Pacific Northwest of the United States enabled the students to gain confidence in articulating vocabulary related to probability, thus providing evidence of conceptual understanding. In addition, Gurbuz and Ağsu (2017) explained how dialogic teaching in mathematics classrooms in Turkey helped students develop a strong conceptual understanding of algebraic inequalities, as there were more opportunities to build on their classmates' ideas.

Unpacking Dialogic Teaching

The use of the terms *dialogue* and *dialogic* in this research subsumes commonly used classroom interaction terminology, such as *discussion*, *exploratory talk*, or discourse (see Aw, 2017; Mercer & Hoewe, 2012), since all imply facets of openness, co-construction of knowledge, and the postponement of judgment in the interaction. Furthermore, since dialogues in the modern classroom can take many formats, such as one-on-one conferences between teacher and student, student-student discussions, and group discussions (Sammons, 2018), the current research focuses solely on teacher-student interactions in the context of a whole-class discussion.

Dialogic teaching, as explained by Alexander (2008), is the "harnessing of talk to engage interest, stimulate thinking, advance understanding, expand ideas, and build and evaluate arguments" during a classroom lesson. Based on Bakhtin (1981) and the earlier work of Alexander (2001), dialogic teaching can be further understood as a classroom learning mechanism that entails a critical interrogation of the topic at hand by both students and the teacher. During these moments of critical interrogation, various points of view are presented but respected, thus creating equitable classroom relations. Furthermore, this interactional process enables the teacher and students to co-construct knowledge. All in all, dialogic teaching can thus be operationalized through the interweaving of three key dimensions: 1) openness, 2) postponement of judgment, and 3) co-construction of knowledge (Bakhtin, 1981).

It remains imperative for practitioners to recognize that dialogic teaching is more than merely having classroom dialogues. Rather, dialogic teaching represents a collective set of teaching practices through which "teachers energize their own and their students' talk" (Alexander, 2018,

p. 561). As such, dialogic teaching can take place as long as the enacted classroom practice maintains a tension between teacher-telling and the passing of judgments so that different voices can be represented in the classroom interactions (Bakhtin, 1981; Sedova, 2021). Considering that, fostering dialogic teaching need not entail a complete replacement of all monologic interactions in the classroom, given the everyday business of the classroom (Alexander, 2005, 2020; Nassaji & Wells, 2000). In fact, this study argues that fostering dialogic teaching, particularly in the classroom, should not be reduced to mere dialogue. Too much dialogic interaction can risk fragmentation and cause classroom interactions to drift away from the lesson's instructional objectives. Hence, there is an indication that recognizing dialogic teaching in a classroom also entails realizing the interweaving of both monologic and dialogic types of interaction during classroom lessons (Kathard et al., 2015; Reznitskaya, 2012). This now allows classroom practitioners who want to pursue dialogic teaching to recognize the need to maintain a healthy tension between authority, openness, and, consequently, meaning-making, rather than the concern to replace monologic interactions as commonly proposed in the literature (see Ko, 2023; Malek, 2011). Hence, taken together, a classroom engaged in dialogic teaching could exhibit dialogic interactions interspersed with pockets of monologic ones.

Alexander (2020) reminded us that the interweaving of monologic and dialogic episodes in a classroom lesson can bring forth a broader range of teacher-student interaction, since both monologic and dialogic interactions serve different purposes during a lesson. Lotman (1988) noted that while dialogue functions as a 'thinking device' that fosters the co-construction of meaning, the monologic text (written or spoken) plays an equally pivotal role in ensuring baseline knowledge is transferred from teacher to student. So, by its very nature, monologic episodes would be authoritative, not open to questions or alternative perspectives, since they need to ensure the transmission of baseline knowledge. However, monologic interactions are not insignificant. Contrary to a large body of research, Nassaji and Wells (2000) counter-argue that the monologic modes, such as the IRE, can have a place in the classroom. This is very much dependent upon the goal of the activity that the intended discourse is to mediate. Thus, in contrast to replacing the monologue as prescribed by previous studies (e.g., Kaur et al., 2019; Ko, 2023; Malek, 2011), this study seeks to acknowledge the monologue moments within the classroom. In fact, Alexander (2020) explicated teacher talk as the interaction that triggers and shapes dialogic learning opportunities. This is much in sync with more recent research that also proposes that teachers should aim to differentiate between monologic parts of their lessons that could be tweaked into a dialogic form (Lefstein & Snell, 2011; Liu, 2016) from those that were deemed necessary for the intended purpose of the lesson (Nassaji & Wells, 2000). In this manner, dialogic teaching can become more accessible (Lefstein & Snell, 2011; Liu, 2016) since teachers will recognize that engaging in dialogic teaching would imply that teacher-student interactions during lessons oscillate across a monologic-dialogic continuum.

Therefore, analysis of classroom interaction needs to move beyond quasi-statistical methods. (e.g., *Engaging Messages* framework (Munns, 2007), *Low Inference Dialogic Observation (LIDO) tool* (O'Connor & LaRusso, 2014)) which is more interested in quantifying specific dialogic features. As Myhill and Newman (2019) advised, the tendency to view dialogic and monologic interactions as binaries should be avoided. Tao and Chen (2023) recommended that failing to promote a clear understanding and recognition of certain forms of interaction that foster student learning may undermine the overall efficiency of classroom dialogue. In this light, the

current study puts forth that using an analytical system that sees how the interactions span across a monologic-dialogic continuum could provide a more realistic depiction of the classroom. Teachers may then be able to distinguish between monologic interactions, which possess the potential to transcend into a dialogic form, and those that are crucial for classroom instruction.

Research Aims

Thus, this paper sets out to contribute to the field an approach to analyzing classroom interaction that focuses on the oscillatory reality of teacher-student classroom interaction across a dialogic-monologic continuum. It aims to go beyond the commonly reported lack of dialogic moments enacted in classrooms by informing the field of the interweaving nature of both dialogic and monologic types of interaction. Providing such knowledge in the field offers greater opportunities for classroom practitioners to maximize the potential of dialogic teaching. In this lens, this paper is guided by the research question: how is dialogic teaching enacted in a Secondary 2 mathematics classroom in Singapore? It examined dialogic teaching in the mathematics classroom through a continuum that enabled awareness of the interweaving and oscillatory nature of monologic and dialogic teacher-student interactions during lessons.

Method

This study's design was based upon a convergent parallel mixed-method research design (see Creswell & Plano Clark, 2011; Creswell, 2014). This design entailed collating qualitative and quantitative elements and enabling the integration of data so that results could be interpreted together (Creswell & Plano Clark, 2011). Such a design enables the strength of the individual sets of qualitative and quantitative data to be further magnified.

Data collection

The study entailed 20 hours of audio recording of sequences of mathematics lessons taught by the two participating teachers, followed by a systematic analysis of the verbatim transcriptions of these recordings using the monologic-dialogic continuum framework (see later). The two participating teachers were recorded for one complete mathematics topic. The topic of direct and inverse proportion was chosen as it followed the order of topics to be taught as listed in the school's mathematics department scheme of work. The key focus of this unit is to enable students to "examine the concept of proportionality by exploring quantities that are related by direct proportion or those that are related by inverse proportion" (Yeo et al., 2021, p. 155). To do so, the topic was designed by the prescribed textbook (which was used by both classes) to "guide the learning of what direct and inverse proportions are, help students explain the concept of proportion using tables, equations and graphs, and enable them to form a formula between variables which are related in direct and proportions" (Yeo et al., 2021, p. 155).

Each teacher taught the topic over five classroom lessons, in accordance with the duration prescribed by the school's mathematics department. The audio recordings of these lessons were made using a digital voice recorder to capture "spontaneous and transitory information to be captured" (Penn-Edwards, 2012). Only in-person lessons were recorded and considered as data sources.

Research Participants

The teacher participant (*pseudonym: Luke*) in this research was from a local government secondary school in Singapore and was purposefully selected based on the Head of the Mathematics department's recommendation to participate in the study. Criteria such as the teacher's efficacy in classroom management, confidence in the delivery of mathematics content, and experience in the field of teaching (see Cleary & Groer, 1994; Livingston & Borko, 1989) were among the key pointers that aided the selection process to ensure that the teacher participant possessed a substantial level of teaching ability. A strict requirement for participation in the study was that the teacher teach the way he/she did all the time, i.e., no special preparation was expected.

To ensure rapport, the student participants were 39 female students taught by Luke. The suitability of using this group of student participants for the study was also based on their cognitive developmental stage. Piaget (1952) informs the field that Secondary 2 adolescents aged 11+ are at the formal operational stage of development and hence "can do mathematical calculations, think creatively, use abstract reasoning, and imagine the outcome of particular actions". As a result, these student participants are expected to possess adequate mental acuity and a knack for dialogic engagement in the classroom. Such a viewpoint is also supported by the existing literature (Higham et al., 2013; Sedova & Sedlacek, 2023), which explains that secondary school students have ample experience and content knowledge across various subjects to participate effectively in classroom interaction.

Ethical Considerations

The data collection process abided by general ethical standards. All needed assent and consent were obtained from the various research participants (teachers and students). In addition, research approvals were acquired from the necessary ethics boards and school authorities. Confidentiality was also maintained by protecting participants' anonymity. Participants were assigned pseudonyms (e.g., *Student 1*, *Teacher A*) for the analysis and reporting of the collected data. Furthermore, all non-critical information collected via the lesson recordings was omitted to ensure that participants' identities remained concealed.

Data Analysis

Prior to data analysis, the audio recordings and corresponding verbatim transcripts were checked for accuracy in consultation with an academic professor and two doctoral students in mathematics education. A systematic analysis of these transcripts was then conducted using the monologic-dialogic continuum framework (see later).

Monologic-Dialogic Continuum Framework

This study used an analytical framework based upon the key dialogic dimensions of openness, co-construction of knowledge, and the postponement of judgement, as described by Bakhtin (1981). The analysis of each lesson consisted of three main steps: demarcating episodes within the lesson, grading and classifying each episode, and finally mapping the entire lesson onto the continuum.

Step 1: Demarcating Episodes in Each Lesson

In the current study, classroom interactions in each lesson were systematically categorized into episodes demarcated by the content of each interaction. Each episode hence spanned a period during which a single main topic was discussed. For example, in the sequence of teacher-student interaction shown in Table 1, Episode 1 would consist of the utterances from line 1 to line 6, in which the main content of the interaction was understanding what a perpendicular bisector is.

Table 1

Demarcating episodes within an interaction

Line	Utterances
1	Teacher: Now, can anyone recap what a perpendicular bisector would be? Peter?
2	Peter: <i>(after a pause)</i> it could be like a point.
3	Teacher: A point? No, it is not. Steven?
4	Steven: A line which cuts another line.
5	Ryan: Oh! I think it is a line which cuts another line at its middle and at 90 degrees...since bisector? And perpendicular?
6	Teacher: That is good and that is a perpendicular bisector.
7	Teacher: So, moving on...what can we say about a pair of parallel lines?
8	Ryan: They have equal gradients, right?
9	Teacher: Correct Ryan, what else? Any chances of these lines meeting one another?
10	Ryan: I doubt that is possible.

The subsequent utterances in lines 7 and 10 would be assigned to Episode 2, since the main content of the interaction has shifted from perpendicular bisectors to parallel lines. By denoting an episode by the content of the teacher-student interaction, the focus of analysis was on the role of the different utterances within the specific episode, while further examining their overall contribution to interactions spanning the monologic-dialogic continuum. This form of analysis gains its support from Correnti et al. (2015), who inform that analyzing classroom interaction as “collections of lines are greater than the sum of their parts because they describe how students are positioned to think during discussions” (p. 309).

Step 2: Grading and Classifying the Episode

Each identified episode was graded against a three-point scale for the extent of co-construction, postponement of judgment, and openness exhibited (refer to Appendix A). Following this, classifying the type of interaction (or interactions, since each episode could constitute multiple types of interactions) observed in the episode is then dependent on two criteria:

- (1) the number of dimensions that were deemed to be exhibited or well-exhibited, and

(2) the total overall score obtained for all three dimensions.

With the spotlight on recognizing evidence of how interactions in the episodes spanned the monologic-dialogic continuum, Criterion 1 was given precedence over Criterion 2 in the overall classification of the interaction type witnessed in a particular episode. This hierarchy is based on how dialogue is operationalized in this study as an interaction that enacts dimensions of co-construction, openness, and the postponement of judgment. As depicted in Table 2, to be classified as a dialogic or dialogue⁻ interaction, all three dimensions must be exhibited (i.e., at least 1 point in all three dimensions) and have a total score of at least 3 points. Just the same, a monologic or monologue interaction would be one with less than three dimensions classified minimally as exhibited. Classifications within the interweaving zone will be discussed in a later section.

Table 2
Scoring system for the episodes within an interaction

Classroom Interaction	Dialogic	Interweaving Zone		Monologic
		Dialogue ⁻	Monologue ⁻	
Grade	3 dimensions must be exhibited		2 dimensions must be at least exhibited	Less than 2 dimensions exhibited
	5-6 points	3-4 points		

Taken together, Table 3 illustrates how the monologic-dialogic continuum framework is used to analyze the classroom interactions described in Table 1. As shown, if a particular episode receives a total score of 4 points as a result of obtaining two points for each dimension of openness and co-construction of knowledge and zero points for the dimension of postponement of judgment, then the total score of the episode would be deemed not applicable (NA) and in turn classified as a monologic or monologue⁻ since it did not meet Criterion 1 (at least three dimensions exhibited). Nevertheless, an interaction with a total score of 3 points, resulting from 1 point per dimension of openness, postponement of judgement, and co-construction of knowledge, would be classified as a dialogue⁻ interaction.

Table 3

Overview of Analysis Via the Monologic-Dialogic Continuum Framework

	Episode 1		Episode 2	
	Dimension	Points	Dimension	Points
Scoring	Openness	2	Openness	1
	Co-construction of knowledge	2	Co-construction of knowledge	1
	Postponement of Judgement	0	Postponement of Judgement	1
No. of dimensions exhibited	2		3	
Total score	NA		3	
Classification of episode	Monologue ⁻ interaction		Dialogue ⁻ interaction	

Mediating the interweaving zone in the continuum. The interweaving zone of the monologic-dialogic continuum represents teacher-student interaction, which is neither purely dialogic nor purely monologic. These interactions are deemed to contain aspects of both, with some dimensions more apparent than others. Interactions that minimally captured aspects of all three dimensions and had a total score of 3-4 points were characterized as dialogue interactions. Loosely written, dialogue interactions were ‘weak dialogues’ that harbored residual aspects of monologic interactions within them. For example, Episode 2 (lines 7-10) in Table 1 exhibited evidence of all three dimensions (i.e., openness, co-construction of knowledge, and postponement of judgment). However, with all the interactions in this episode revolving around just one student and the teacher, it was not particularly strong in the openness dimension.

Additionally, the teacher’s query on line 7 (*...what can we say about a pair of parallel lines?*) provided an opportunity for students to share knowledge, typical of a pure dialogue. However, with the same student (Ryan) responding, the interaction falls short of exhibiting strength in the co-construction of knowledge. Also, it can be observed that the teacher imposes a judgment but urges the student on with a suitable scaffold in line 9 (*Correct Ryan, what else? and any chances of these lines meeting one another?*). Hence, with an overall score of 3 points and each dimension obtaining at least 1 point, Episode 2 is characterized as a dialogue-interaction, since it captures many aspects of a dialogue with only minor reflections of a monologic interaction. -

The interweaving zone is also characterized by monologue interactions, which lack one of the three key dimensions. For example, Episode 1 (lines 1-6) in Table 1 illustrates a monologue interaction. Ample avenues of openness are demonstrated by the involvement of multiple individuals in the interaction. Although it began with the teacher calling upon a student in Line 1 (*...Peter?*), the utterances that followed (in lines 4 and 5) involved at least two students. As a result, the episode was awarded two points for the openness dimension. In addition, the various

utterances were built upon the ideas that had been put forth initially. This series of utterances flowed coherently from the central query about the geometrical concept of perpendicular bisectors. As shown in lines 5 and 6, the initial suggestion of a perpendicular bisector being about the intersection between two lines (*A line that cuts another line*) was built upon by the next student, whose utterances added to the concepts of perpendicular lines and the midpoint between two vertices on a line. Likewise, Episode 1 in Table 1 can be awarded two points for the co-construction of knowledge. However, despite a total score of four points accumulated from those two dimensions, the strong imposition of judgment during the interaction as revealed in line 3 (*A point? No, it is not. Steven?*) where the teacher instantly calls upon the next student once the previous response was deemed as erroneous, causes the episode to be scored lowly in the dimension of postponement of judgment. In general, monologue interactions are ‘prospective dialogues’ that, upon minor alterations, could rise to a dialogue or a dialogic interaction.

Step 3: Mapping the lesson on the continuum

Figure 1 illustrates how a recorded lesson comprising five episodes could be mapped out via the monologic-dialogic continuum framework. Since the driving force of the monologic-dialogic continuum framework is to investigate the oscillatory nature of teacher-student interaction between monologic and dialogic types, the total scores for each episode were computed and graphed. This provided a clear exploration of the types of interactions and the transitions between them, as enacted in each lesson.

The graphical mapping of corresponding episodes in this study draws on Correnti et al. (2015), who explained the importance of capturing patterns in discourse moves. Their study further emphasized that research should avoid reporting “teachers’ discussion moves as isolates, independent of one another, primarily because we do not see high potential for evaluating teacher behaviors in isolation” (p. 309). With reference to the map in Figure 1, the bar graph indicates the number of dimensions exhibited in a particular episode, while the line graph plots the score for that episode. Since the minimum score for a dialogic type of episode would be three points (see Table 2), the horizontal dotted line signifies the dialogic threshold.

The exemplar classroom interaction, as charted in Figure 1, thus illuminates a span of the monologic-dialogic continuum. It also exhibits some dialogic teaching, with dialogue-like interactions during the lesson.

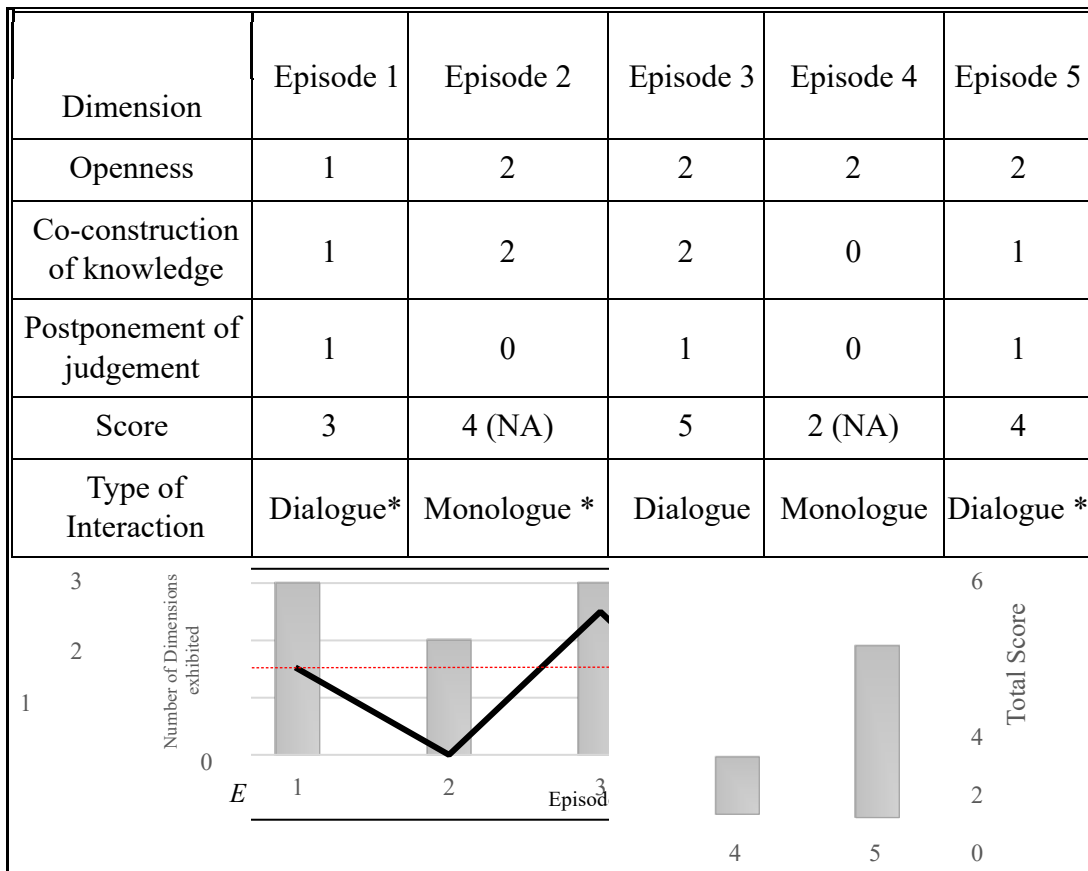


Figure 1. Exemplar for mapping classroom interaction through the monologic-dialogic continuum framework

Results

Results obtained in this research were validated to ensure accuracy and reproducibility (Kershner et al., 2020). Inter-rater coding conducted by the doctoral students yielded a positive percentage agreement of 71%-79% (i.e., 10 to 11 episodes of a total of 14 matched).

In the subsequent segment of the paper, the data analysis will be reported, including an account of what occurred during each lesson as enacted by the teacher (Luke). This will be followed by the results of the analysis conducted using the monologic-dialogic continuum framework.

Insights from Luke's Classroom

Lesson 1

Luke's first lesson was focused on direct proportion. It began with a discussion of how a library imposes fines for overdue books. Luke adapted this real-life context from the prescribed textbook to assist in developing the concept of direct proportion, which in turn enabled him to swiftly provide the class with a definition of the concept. Hereafter, a larger portion of the lesson was devoted to introducing the key notations used in the unit, along with equations representing direct

proportion. The following lines showed how Luke introduced the notation of the proportionality constant k :

15 divide by 1, 30 divide by 2, 45 divide by 3, I will also get 15. You will always get \$15. What does it say? This means that... Ok, at this part, you have to pay attention to it. This means that y/x , when it is directly proportional, it will be a constant number. In this case, here, it will be 15. But it will be a constant number, and in this particular case, we talk about proportionality. We have a constant and we give it a name, k (Lines 53 - 58).

Luke emphasized presentation modes as expected during assessments. While explaining the various concepts, he was particular to alert his students to the way their work was to be written. The following utterances depict it:

So, therefore, we need to state that k cannot be zero and k is a constant. Understand? During the exams, when you are writing, you must take note to include these two parts. In your textbook can you please highlight this portion and tell yourself must write during the exams (Lines 94 – 96).

Luke then went on to establish a connection between the general form of a line, $y = mx$, its graphical representation, and the consequential role of the line's gradient, m , as the proportionality constant k . Emphasis was also placed on the implications of the y -intercept of the line for proportionality. Luke worked to help his students grasp the concept that non-linear equations could be either rearranged or 'reassigned' so that they followed the linear form $y = mx$ and, consequently, could be viewed as directly proportional.

In the second half of the lesson, it was observed that Luke spent time working on textbook practice questions with his students. Luke provided a comprehensive demonstration of the working steps, expectations regarding its presentation, and the final solutions to the practice questions.

This first lesson consisted of 356 utterances that spanned over a duration of 60 minutes. Twenty-nine of these utterances were made by students, and the remaining ones by the teacher. Through the monologic-dialogic continuum framework, Luke's first lesson comprised 18 episodes. As shown in Appendix B, seven (38.9%) of these episodes were classified as either dialogic or dialogic⁻ since they exhibited all three dimensions of dialogue (i.e., openness, co-construction of knowledge, and postponement of judgement). On the contrary, 11 episodes were either monologic or dialogic, of which six episodes exhibited none of the dimensions of dialogue.

However, there was some mixing of interaction types in the lesson. 6 of the 18 episodes occurred in the interweaving zone, providing evidence of aspects of dialogue during those moments. For example, in Episode 17 (classified as monologic), Luke explained the role of the proportionality constant in the equation $y = 5x^3$, where y is directly proportional to x^3 . He provided an in-depth explanation on how the students will be able to prove that the relation between the group of variables is indeed true by re-expressing the equation in the form $y = __^3$. A student's query, "Does this mean that k is 5 cube?", prompted Luke to request clarification on what the query was about. The student further responded, saying, "But if you bring the x over to

the y... is it possible?” which prompted another student to say, “*You can bring the x, but not the 5.*” Recognizing that his students may be drifting into a misconception of how to prove that two groups of variables are proportional (by ensuring their ratios are constant), he quickly reasserts authority in the classroom interaction to provide further clarification.

Indeed, there was a more distinct swing towards the monologic end of the spectrum, which was made evident by the low scores attained for each dimension (refer to Appendix C). However, most of this monologic interaction appeared to take place while Luke was introducing abstract concepts of proportion (e.g., Episodes 3-5) or while practice questions were being solved (e.g., Episodes 16 and 18). The interactions heard from Episode 3 to Episode 5 were necessary and expected, since the students were unfamiliar with the new concept of proportionality at that point. To some extent, frontal teaching, as observed in Luke’s enactment, can be expected.

In this first lesson, there was some evidence of Luke facilitating dialogue. For example, in Episodes 8 and 9, it was observed that the students were willing contributors to the discussion that Luke facilitated about the relationship between the general form $y = mx + c$ (where $c = 0$) and direct proportion. However, the monologic interactions that followed in Episodes 16 and 18 could have arisen from a monologic state if Luke had instead facilitated classroom dialogue rather than directly telling.

Lesson 2

Luke began lesson 2 by going through practice questions like those in Figure 3. These were done to provide students with an opportunity to hone their skills in manipulating equations in direct proportion to solve for the needed unknowns. After completing these initial questions, Luke added more practice questions for the students, particularly those that were context-based. One of these practice questions was based on the volume of a cube, and another investigated the relationship between the length of a pendulum and the period for its oscillation.

Once again, Luke thoroughly taught how to solve the practice questions and the expected presentation of the working steps. He then went on to introduce the concept of inverse proportion by using the relationship between the concept of the speed of an object and the time taken for the object to travel a known distance:

Teacher: Look at the example here of speed and time taken to travel a total distance of 120km. Everybody, look at the table. As the speed increases, what do you notice about the time taken?

Student: decreases the time taken decreases. (Lines 84 – 88)

Following this, the general form of an inverse proportion relationship was taught to the class:

Teacher: So, in terms of the equation, what will it look like now? Previously, we had direct and $y = kx$. Now, when we talk about inverse proportion, we have $y = k/x$. (Lines 97 – 99)

This second lesson was divided into eight episodes, of which only two (Episodes 6 and 8) were recognized as dialogic. Also, one of the eight episodes (Episode 7) failed to exhibit any dialogue

dimensions. Nevertheless, there was evidence of oscillation across the spectrum of interaction types, although much remained on the monologic side. Appendix B shows the span of the eight episodes in the lesson.

The dialogic type of interaction witnessed in Episode 6 unfolded when Luke introduced the class to the general form of the equation connecting two variables, y and k , which are inversely proportional ($y = \frac{1}{x}$). During this process, there was an instance in Episode 6 in which he refrained from passing judgment on a student's response. Instead of completely ignoring (as seen in the other episodes of the lesson) or imposing judgments of right/wrong on student responses, Luke chose to repeat the student's response, thus providing a sense of assurance and acceptance, very much in keeping with the nature of a dialogue. A similar form of interaction was also seen in Episode 8. The students appeared more willing to engage with their teacher when judgments were not passed quickly. Table 4 shows an excerpt of this interaction as enacted in Episode 8.

Table 4

Instances Of Postponement of Judgement In Episode 8 Of Luke's Lesson 2

Line	Person	
120	T	Why did they tell you $y = 3$ and $x = 4$?
121	S5	Find k
122	T	To find k ! Thank you XXXX.
123	T	So, we shall use that precisely for that reason when $x = 4$, $y = 3$, $3 = k/4$ and therefore $k = 12$

The rest of the episodes in this lesson were largely monologic, with almost all the utterances made by Luke. Besides Episodes 6 and 8, monologic episodes were observed regardless of whether Luke was presenting new concepts to his students or going through practice questions. However, with an eye on the interweaving zone (5 of 8 episodes), Luke's second lesson did reveal a mix of dialogic⁻ (1 episode) and monologic⁻ episodes (4 episodes). In a large portion of these episodes (e.g., Episode 1), new concepts and practice questions were presented to the students. Thus, Luke adopted a more authoritative stance. Similarly, the presence of evaluative responses from Luke, as heard in Episode 2, was used to assess students' grasp of the content and the accuracy of their solutions to the various practice questions.

Overall, lesson 2 featured limited dialogue between the teacher and the students. These dialogic episodes were interspersed with a larger proportion of monologic episodes. Furthermore, with about 60% of these episodes occurring within the interweaving zone, lesson 2 can be said to have moved away from being purely monologic and towards a small degree of dialogic teaching.

Lesson 3

In Luke's third lesson, the emphasis was on guiding students through a collection of practice questions on inverse proportion. A portion of these were contextual types of questions similar to

those shown in Figure 4. Luke spent most of this lesson explaining the steps needed to solve the practice questions, emphasizing the need for specific statements and clear working steps.

Along the monologic-dialogic continuum, this lesson, comprising six episodes, included four (Episodes 1-3 and 5) that lacked all three dialogic dimensions (see Appendix B). In the period from Episode 1 to Episode 3, the teacher thoroughly explained the practice questions to the class. Both the work and the answers were given to the students by Luke. Hence, there was no student involvement. Also, with only two episodes in the interweaving zone, Lesson 3 showed negligible resemblance to dialogic teaching. Only one episode (Episode 6) was dialogic. It exhibited all three dialogic dimensions and was classified as a dialogue-type of interaction. This episode showcased an instance in which a particular sequence of interaction was initiated when a student enquired whether it was necessary to write the symbol for the physical quantity *Ohms* (Ω) in her working step. Instead of simply answering the student's query, Luke built on the initial utterance by posing a follow-up question to invite the student to offer even more opinions and suggestions. Table 5 shows an excerpt of this interaction.

Table 5

Excerpt From Luke's Lesson 3: Showing Student-Initiated Sequence Of Interaction

Line	Person	
67	S3	Must draw the symbol?
68	T	Oh no need...what is this symbol here?
69	T	What are the two things I just circled?
70	S3	The units?
71	T	They are the units yes!.
72	T	So, meaning to say when you are writing your equation you should just be writing $I = k / R$

Lesson 4

In lesson 4, Luke introduced his students to how non-linear equations could be rearranged or 'reassigned' so that they mimic the linear form $y = mx$, and, in doing so, direct and inverse proportionality can be investigated. Table 6 offers an insight into how he conveyed this idea in the context of inverse proportion.

Table 6

Excerpt From Luke's Lesson 4 On Showing Exploration Of Different Forms Of Inverse Proportion

Line	Person	
1	T	Alright, we know by now that whenever I tell you inversely proportional the first thing that comes to mind is y is equal to k/x
2	T	But of course, we can have other things here
3	T	I could tell you that y is inversely proportional to x^2
4	T	then you can simply write y equal k/x^2
5	T	I can tell you things like y is inversely proportional to square root of x^3

The remainder of lesson 4 involved the students solving two practice questions centered on the concept introduced initially. The first practice question involved proportional relationships that were represented by a table of values (numerically), while the second question involved an equation relating a constant of proportionality. These questions were designed to help students master using the formula $x_1y_2 = x_2y_1$ to relate two sets of values that are inversely proportional and linked by a common constant k . As in the previous lessons, emphasis was placed on the required algorithm to solve the questions, and the expected manner of mathematical working was to be presented by the students. This was evident in Luke's lengthy descriptions of each step of the work.

Contrary to lesson 3, lesson 4 had a distinctly larger number of instances of dialogue-like interaction between the teacher and students. As featured graphically in Appendix B and reflected by the scores attained for each dimension (see Appendix C), all the episodes in this lesson exhibited all three dimensions of a dialogue. It was also noted that Luke provided students with opportunities for student-student interaction. Furthermore, there were moments when Luke refrained from answering questions posed to him and instead redirected them to the students. These were almost always taken up by students and, consequently, opened avenues for more student-student interaction. Hence, although teacher talk remained dominant, there were more student utterances in lesson 4 (16 out of 140) than in the prior three lessons combined, and these were made throughout the lesson.

Lesson 5

Luke's final lesson for the unit on direct and inverse proportions focused on exposing students to higher-order inverse-proportion questions. The first question, which was a contextual question, investigated how the force of attraction between two particles and the distance between them were related. Most of the first question was solved by Luke. After that, the students were tasked with working on a second question: an inverse-proportion algebraic question. Luke gave the students time to discuss the question with their partners before explaining the procedures. Lesson 5 concluded with students attempting to solve a problem sum that combined skills and knowledge from the previous two practice questions (see Figure 2).

10. y is inversely proportional to x^2 and $y = b$ for a particular value of x . Find an expression in terms of b for y when this value of x is tripled.
11. The force of attraction between two magnets is inversely proportional to the square of the distance between them. When the magnets are r cm apart, the force of attraction between them is F newtons (N). If the distance between the magnets is increased by 400%, the force of attraction between them becomes cF N. Find the value of c .

Figure 2. Higher-order questions on inverse proportion

The students found the question challenging, as evidenced by instances in which some students articulated their inability to comprehend the meaning of specific phrases because they were unfamiliar with them. This prompted the students to ask questions and discuss openly in the hope of finding a solution to the problem (see Table 7).

Table 7

Excerpt From Luke's Lesson 5: Showing Students Difficulty While Attempting A Practice Question

Line	Person	
246	T	what does it mean by increase by 400%?
247	S4	times four?
248	T	times four? Are you sure?
249	S8	times 5?
250	T	what? why is 400% times five?
251	S8	because it is already 100% so increase by 400% will become 500%
252	T	now this part is like talking English.
		if they have said the distance is increased to 400%, then the final is
253	T	four times
		but if they say increase by, it means you are adding four times, so total
254	T	would be 5 times
255	T	you understand?
256	S6	say again

As shown in Appendix B, analysis of the classroom interaction in this final lesson uncovered one monologic episode (Episode 1) and four other dialogic episodes (Episodes 2, 3, 4, and 5). The single monologic episode in lesson 5 unfolded as Luke introduced a contextual problem-solving activity on inverse proportion to the class. Throughout the entire episode, only Luke spoke. As a result, none of the three dimensions was exhibited during this episode. On the contrary, the final four episodes of the lesson demonstrated a rich and productive approach, particularly Episodes 2, 3, and 4. During these episodes, Luke had gotten the students to attempt various questions. Instead of directly explaining to the students how to solve the questions, he used pedagogical strategies

such as think-pair-share, which allowed students to work with their table partners (in Episode 2), and ‘stepping out’ of the interaction so that students could respond to each other (in Episode 4).

Discussion and Conclusion

Overall, the current study found that dialogic teaching was enacted to a limited extent in Luke’s mathematics classroom. It was notably deficient across most dialogic dimensions, as shown by lower scores for each (see Appendix C). Only a third of all episodes (12 out of 41 episodes) fell in the dialogic end of the spectrum. This finding concurred with scholarly work in the field (e.g., Farrell, 2004; Kaur et al., 2019; Ko, 2023; Malek, 2011), which also found that classrooms were predominantly teacher-centered. The greater extent of monologic interactions observed in this study also aligned with those reported in the local literature, which found that “the kinds of math talk enacted in our Singapore classrooms are more often univocal than dialogic” (Kaur et al., 2019, p. 32).

However, the novelty of this study’s results lies in recognizing the interweaving zone in classroom interactions. With the awareness of the interweaving zone, the teacher’s classroom practice can be informed, and the resultant type of interaction can be justified. This is because the norms of a typical classroom, where a variety of content can be introduced and discussed within a single lesson, are given attention through the creation of episodes. This, in turn, enabled critical classifying and grading of specific classroom interactions in tandem with the classroom tasks at that specific moment. As shown in Luke’s lessons, certain classroom tasks required more authoritative input than others. Hence, unlike the commonly used quasi-statistical forms of analysis, the affordance of the interweaving zone in this continuum approach enabled a closer watch on the appropriateness of the type of interaction that unfolded, how far (if any) this interaction has moved away from being purely monologic, and if tweaks to the teacher’s classroom enactment could provide possibilities of a dialogic interaction.

In fact, by recognizing the interweaving zone, the study identified monologue episodes (8 out of 41). These episodes had exhibited some aspects of a dialogue. Furthermore, as shown in the results, the deficits in these episodes were not always attributed to missed opportunities but also to moments of necessity in which Luke required a more monologic approach to inform the class of specific mathematical content or skills. Acknowledging such episodes is effective since classrooms require a broad range of interactive forms (Alexander, 2005; Lefstein & Snell, 2011; Mehan, 1979). The analysis of Luke’s lessons showed that while dialogic interactions promoted multiple voices and the cocreation of knowledge, monologic episodes served both as a ‘thinking device’ and as a transfer of baseline knowledge (see Lotman, 1988). In short, the monologic-dialogic continuum approach supported the fact that mathematics classroom interaction need not consist solely of dialogic or monologic interactions. As seen in Luke’s classroom, the natural oscillation between authoritative transmission of knowledge and the opening of dialogic spaces for co-construction creates productive learning for students. Thus, the result of this study paves the way for greater awareness that, in classroom dialogic teaching, ‘more is not better’.

Besides acknowledging the value of monologic interaction, analytical tools must provide teachers with awareness of specific areas of their classroom practices that could be improved. In this study, the analysis of the mathematics lessons provided the teacher with insight into the extent

to which specific dialogic dimensions were exhibited. As shown in Appendix C, Luke's lessons tended to score better in openness as compared to the area of co-construction of knowledge (0.78 out of 3) and postponement of knowledge (0.83 out of 3). The evaluative nature of Luke's questions, coupled with the possible inability to frame an information-seeking question that ignites and uplifts the dialogic space in the mathematics classroom, may have been a barrier to more student voices. Thus, to improve classroom interaction in future lessons, Luke can consider giving more specific attention to his students' responses while cutting back on his evaluative questions and responses.

At a macro level, the presence of the interweaving zone and the resultant continuum approach to analyzing classroom interaction bridge the research-practice nexus by helping construct appropriate professional development programs for teachers. As emphasized by Wilkinson et al. (2016), professional development focused on dialogic pedagogy can positively impact teachers' perceptions and, in turn, their classroom practice. At this juncture, it is crucial to be cognizant that the mechanics of teacher-student interaction within the classroom naturally mimic an oscillatory motion spanning from dialogic to monologic. Thus, as described previously, while the dialogic-monologic continuum is poised to inform teachers of what is lacking, it in no way emphasizes the need to eradicate and replace all monologic interactions. Training Luke to reflect, identify, and highlight episodes in his lessons that could be more dialogic could help foster dialogic teaching in his classrooms.

In conclusion, the current study was focused on providing awareness of the continuum approach to analyzing teacher-student interactions. This approach to analysis provided the field with a springboard for further understanding and appreciation of the interweaving nature of dialogic and monologic interactions. At the same time, all the observed lessons revealed that teacher-student interactions oscillated across the spectrum; most resided at the monologic ends of the continuum. Nevertheless, unlike other quasi-statistical forms of analysis, the study showed that the continuum approach performed better at informing classroom practice while accounting for what was happening during lessons. Even more, despite the observed dominance of teacher talk, the continuum approach showed that about one-third of the entire unit captured some essence of dialogic teaching.

Contemporary pressures on the mathematics classroom have resulted in an increasing shift "from a traditional focus on educator and content to dialogical processes of teaching and learning that bring a focus to learners and learning" (Bound & Chee, 2019, p. 7). Considering that, the current study provides a pathway for future explorations in the field of dialogic teaching. For one, prospective findings from future comparative studies of other methods of analyzing classroom interactions vis-à-vis the continuum approach can allow for a deeper understanding of the pros and cons of the current method. In addition, a critical investigation of specific factors influencing the use of dialogic teaching modes in the mathematics classroom could be valuable.

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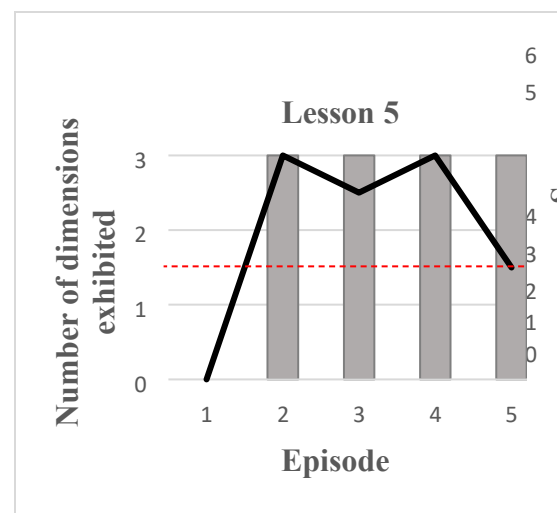
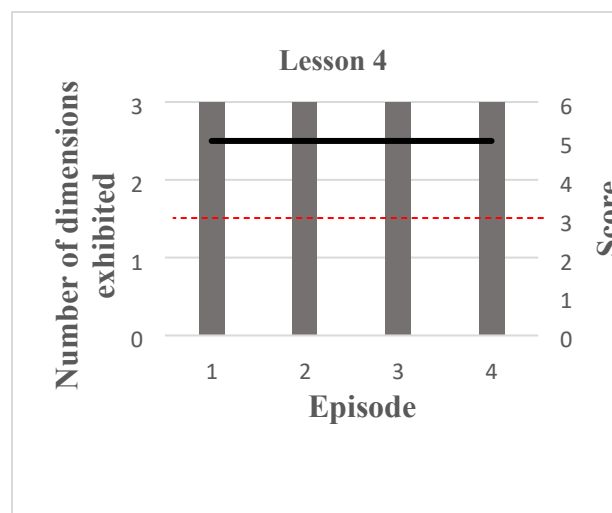
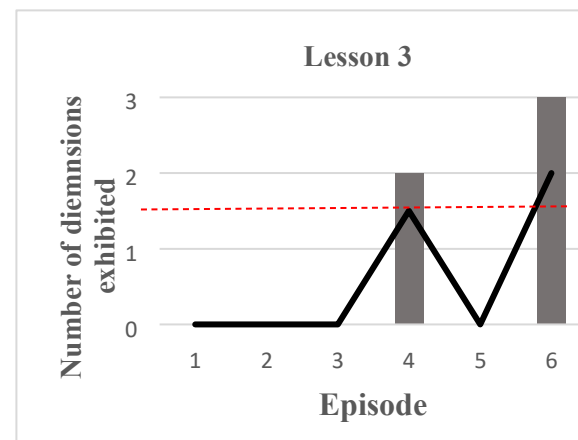
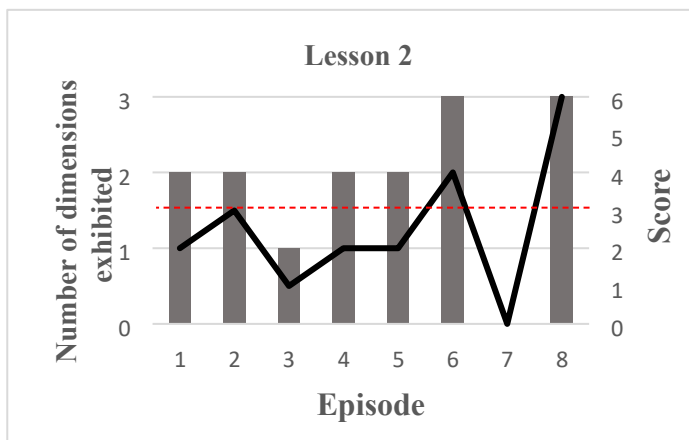
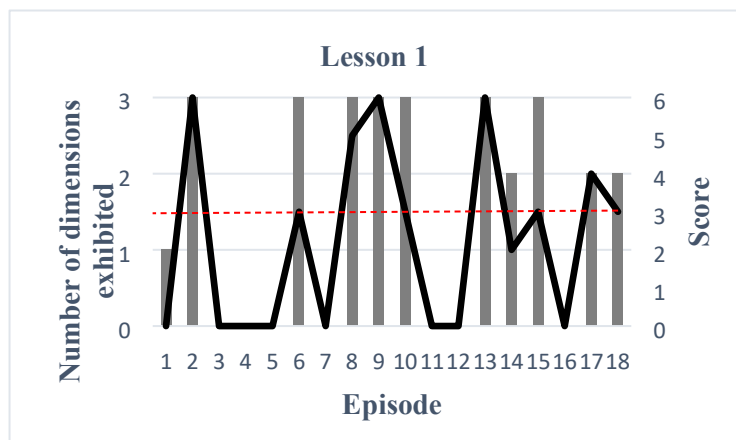
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Appendix A: Monologic-dialogic continuum framework

Dimensions	0 point	1 point	2points
Openness	The episode of teacher-student interaction involves only the teacher speaking and no evidence of opinions, suggestions and responses obtained from the students.	The episode of teacher-student interaction involves the teacher speaking and one other student. Student is called upon to provide opinions, suggestions and responses.	The episode of teacher-student interaction involves the teacher and two or more other students. The students may or may not be called upon in succession (i.e. only the first student was called upon by the teacher).
Co-construction of knowledge	The episode of teacher-student interaction is predominantly lecture style with the teacher providing all content and no evidence of building upon the initial ideas of the interaction.	The episode of teacher-student interaction is predominantly lecture style with the teacher providing most content and some evidence of building upon the initial ideas of the interaction.	The episode of teacher-student interaction is made up of inputs provided by the teacher, the students or both, where each input builds upon the previous.
Postponement of Judgement	The episode of teacher-student interaction shows the teacher immediately calling upon the next student when an erroneous response is received without providing another chance for the student to respond. Responses from the teacher are evaluated with utterances such as Yes/No, Correct/Wrong.	The episode of teacher-student interaction shows the teacher not setting aside erroneous responses but rather urges the student on with suitable scaffolds. Responses from the teacher are evaluated with utterances such as Yes/No, Correct/Wrong.	The episode of teacher-student interaction shows the teacher not setting aside erroneous responses but rather urges the student on with suitable scaffolds. Responses are not evaluated but are rendered feedback for improvement.

Appendix B: Results from the observed lessons



	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5
Dialogic Teaching	Enacted to small extent	Enacted to small extent	Enacted to small extent	Suitably enacted	Suitably enacted
Dialogue	Little presence	Little presence	Little presence	Present	Present

Appendix C: Scoring of the observed lessons

	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Unit Overall
Duration (min)	60	52	32	33	66	243
Total utterances	356	128	112	140	339	1075
No. of episodes	18	8	6	4	5	41
<i>Monologic episodes</i>	8	2	4	0	1	15 (36.6%)
<i>Monologue episodes</i>	3	4	1	0	0	8 (19.5%)
<i>Dialogue episodes</i>	3	1	1	0	1	6 (14.6%)
<i>Dialogic episodes</i>	4	1	0	4	3	12 (29.3%)
Mean score of each dimension in each lesson						
						Unit mean
<i>Openness</i>	0.89	1.13	0.5	1.75	1.4	1.02
<i>Co-construction of knowledge</i>	0.56	0.88	0.33	1.5	1.4	0.78
<i>Postponement of judgement</i>	0.83	0.5	0.33	1.75	1.2	0.83