Promoting Mathematical Reasoning in the Early Years Through Dialogic Talk

Anita Stibbard
Charles Sturt University
astibbard@csu.edu.au

Christine Edwards-Groves
Griffith University
c.edwards-groves@griffith.edu.au

Christina Davidson
Charles Sturt University
cdavidson@csu.edu.au

This article presents research focused on establishing ways that dialogic talk between teachers and students promotes mathematical reasoning in early years classrooms. Data are drawn from recorded and transcribed Year 1 mathematics lessons. Conversation analysis provides close examination of the talk-in-interaction practices of teachers and students and reveals how mathematical reasoning is co-produced through the turn-by-turn exchange structures between teachers and students. Analysis of selected transcripts illustrates how different teacher talk moves create a dialogic space that make student mathematical reasoning possible. Implications for classroom practices are made.

Lessons by their very nature are interactive events where teachers and students come together in interactions centred around promoting and eliciting student's learning (Edwards-Groves, 2024). In mathematics lessons, one of the central pedagogical goals is facilitating students' reasoning; for students, reasoning is generally experienced as they participate in whole class, small group or paired discussions (Mercer, 2008). Mathematical reasoning is well addressed in both the research literature and curriculum documents as being a critical process necessary for supporting young learners to identify patterns, organise ideas, solve problems, discern relationships between concepts, and draw logical well justified conclusions (Australian Curriculum, Assessment Reporting Authority [ACARA], 2022; Russell,1999). Interaction research also establishes that talk and interaction itself is a reasoning activity (Hutchby & Wooffitt, 2008) which requires interlocutors, like teachers and students in lessons, to display their reasoning in their turns where intersubjectively, sense is made as conversations unfold turn-by-turn (Schegloff, 2007). Therefore, to support early years teachers to develop deeper understandings about mathematical reasoning, there is a critical need to draw closer attention to the complexity that reasoning talk in mathematics lessons presents. For effective teaching, this requires accounting for the inextricable interrelationship between classroom dialogue, communication practices and mathematical reasoning, and what this means for early reasoning proficiency. To understand the nature and influence of classroom talk on young children's mathematical reasoning, this article examines some core (and often taken-for-granted) dialogic talk practices of teachers and students in their mathematics lessons.

Literature Review

In this section, two main bodies of literature relevant to mathematical reasoning and classroom talk are presented.

Mathematical Reasoning

Mathematical reasoning has a central role in learning mathematics and is critical for student's developing mathematical understandings, creative thinking, problem solving, and knowledge (Chapin et al., 2007; Vale et al., 2017). In classroom lessons, developing mathematics reasoning aims to strengthen student competencies for solving increasingly complex mathematical problems (Stein et al., 1996; Wusterberg et al., 2012). Mathematical

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reasoning is comprised of three main reasoning actions: analysing, generalising and justifying. These reasoning actions are necessary for engaging in tasks requiring students to examine and interpret concepts and problems, elicit generalisations and provide well-reasoned justifications. It is through participating in more extended discussions with and among students that account for these reasoning actions, that an interconnected web of understandings and knowledge is built (Zevenbergen et al., 2001). This provides a foundation for mathematical sensemaking and so create conditions for developing one's mathematical memory (Russell, 1999).

In the *Australian Curriculum: F–10 Mathematics* (ACARA, 2022), reasoning is one of four interrelated proficiencies students are expected to develop as part of their learning. Along with understanding, fluency and problem-solving, reasoning is described as a necessary process for working mathematically. In lessons, students are required to engage in reasoning by working on mathematical tasks that require them to 'discover' and make sense of mathematics concepts and ideas. According to the curriculum, the reasoning process and the actions which comprise it, requires Early Stage One and Stage One students to demonstrate: (1) an increasingly sophisticated capacity for logical thought and actions; (2) thinking through their explanations; (3) mathematical thinking that creates and validates mathematical ideas and new knowledge; and (4) meaning making. Further, an emphasis on mathematical reasoning incorporates the study of flawed or incorrect reasoning as an avenue towards a deeper development of mathematical knowledge (ACARA, 2022, pp. 1–2). "Greater discussion among students and the recognition that mathematics is not constrained by always having a single answer" (Zevenbergen et al., 2001, p. 9) is necessary for providing educative conditions for students to produce and display mathematical reasoning. One way to foster such discussion is by creating a dialogic talk space that forms a strong pedagogical basis for facilitating mathematical reasoning.

Dialogic Talk

A growing body of research has focused on understanding and promoting teachers and students' repertoires of talk moves that form a critical feature of pedagogical efficacy (Attard et al., 2018; Chapin et al., 2013). As explained by Edwards-Groves et al. (2014), understanding talk moves concerns the work of a turn in an interaction; for example, this might be in the form of a question that opens a discussion sequence, a response to a prior speaker's turn/question, or an assessment of a turn through verbal (a comment, a rephrasing) and/or nonverbal (a gesture, a nod) means. Each, and in combination, evoke a particular kind of next turn speaker action and signals the function of a speaker's turn (e.g., a *why* question solicits a reasoning response) (Edwards-Groves, 2024). Hinton et al. (2021) described *dialogic talk moves* as turns which deliberately and strategically move *student turns* to:

- *Sustain a point* where a particular line of thinking is pursued and to produce evidentiary talk by providing clarifications, exemplifications, reasons and justifications;
- *Extend and deepen thinking* about their ideas by orienting to and building on the thinking of others, to learn from the opinions, reasons and knowledge of others;
- *Challenge and question* the thinking of others by building argumentation through agreeing and disagreeing and promoting the acceptance and production of a range of alternative points of views;
- *Demonstrate active listening* by providing feedback to the turns of others, asking for clarification, and responding directly to the thinking of others (saying what they think about what they'd heard in the prior turn or across a sequence), repeating (word-for-word) and revoicing (rephrasing in their own words) what they have heard;
- *Reflect on and review* their learning (often through retelling, paraphrasing or summarising) at different points across a lesson.

It is argued that these moves are dialogic since they move the next turn speaker towards producing longer more sustained turns, and so have the potential to make discussions more academically productive, high leverage and intellectually rigorous (Chapin et al., 2007). Edwards-Groves (2014) identified two deliberately used *communicative strategies* that further extend opportunities for student to talk and engage with the thinking of others: i) *wait time* (a deliberate pause of more than three seconds after a teacher turn); and ii) *vacating the floor* (reflected in strategies such as turn-to-talk, walk-and-talk, think-pair-share). Allowing longer *wait time* provides more time for student thinking, formulating and rehearsing ideas, helping them produce a more considered, and often longer, response before they 'go public' with their contribution. When teachers *vacate the floor* they 'remove' themselves from the immediacy of the conversation to allow students time and opportunity for practicing, rehearsing and 'testing' ideas, and managing, controlling and taking responsibility for the conversation, their contributions, and ultimately their learning. Vacating the floor might take the form of the teacher withholding of turns to allow students take consecutive turns. Importantly as Stibbard et al. (2020) also showed, that student-student talk sequences focused on the task (in paired or small group interactions) are reflective of a dialogic classroom.

The Study

Participants and Contexts

Data for this article are drawn from a broader study conducted in five Early Stage One/Stage One classrooms in three primary schools in regional NSW, Australia, aiming to understand the nature and influence of classroom talk on young children's mathematical reasoning. This article examines some core (and often taken-for-granted) dialogic talk practices of teachers and students in their mathematics lessons, and sought to answer this specific research question: *What is the nature of teacher talk moves which promote mathematical reasoning in early years problem solving lessons?* To answer this question, recorded and transcribed mathematics lessons (15 in total) formed the corpus of data for analysis. Participants were recommended by the district mathematics consultant, then invited to participate. Informed consent was requested and given from teacher participants, along with the parents of students in each class. Class sizes ranged from 14–28 students. Selected transcript excerpts are from one Year 1 problem solving lesson where in the whole classroom discussion phase the teacher was focused on eliciting student's understandings about the differences between rows and columns.

Data Analysis

In this study, conversation analysis (Sacks et al., 1974) was employed to reveal the detail and intricacies of conversational exchanges in Year 1 mathematics lessons to show how reasoning is accomplished turn-by-turn and across teacher and student sequences. Reasoning, as a core process for working mathematically, emerged as a prominent analytic focus since accomplishing mathematical reasoning simultaneously requires interactive reasoning. Conversation analysis (CA) was applied to the data as a method for conducting a systematic analysis of the turn structure and organisation in the lesson talk-in-interaction (Sacks et al., 1974). As a premise, CA researchers study audio and/or video recordings of interactions, transcribing them into detailed transcripts, followed by the close analysis of interactional phenomena as it is produced in the talk (Davidson, 2009). Analysis focuses on the basic taxonomy (presented below) for understanding the speech-exchange system suggested by conversation analyst Emmanuel Schegloff (2007). This system is useful for identifying and understanding the talk-in-interaction produced by teachers and students in lessons (Edwards-Groves, 2024); specifically, attention is given to the:

- Length of the turns and exchanges;
- Nature of the contributions provided by each party to the talk (teachers and students);

- Types of interactive processes used in the task-setting, instructional or discussion parts of the talk (e.g., what is being asked of the students in terms of mental activity or what thinking is needed, verbal/literate activity or what language and discourses are required, material activity or what activities, tasks and resources will be spoken about, and relational activity or what grouping and interactive arrangements are required);
- Orientation, logical order, and relevance of the talk related to the:
    - *local*—what was just said or done then and there in the interaction;
    - *sequential*—what has been said & heard in and across a sequence or lesson;
    - *topical*—the relationship of the turn to the topic at hand;
    - *categorical*—the expectations or norms displayed by participants in and by their turns, like a teacher or student (as they talk in pairs, groups or whole class); and
    - *reasoning*—the specialised reasoning and/or linguistic practices of a discipline/ curriculum like mathematics (Schegloff, 2007).

These features are typical of how meanings are produced in ordinary talk-in-interaction, but also highlight the complex interactional demands required of students participating in lessons asking them to demonstrate reasoned sensemaking about what is happening at the same time produce mathematical reasoning.

Results and Discussion

The excerpts presented next are drawn from the 'launch' phase (Sullivan et al., 2016) in the final lesson of a five-lesson sequence focusing on multiplication and division. To begin, the 14 students were asked to organise themselves into rows of three, after which the teacher asked the framing question "*what's a row?*" The mathematical knowledge for the task included understanding arrays (specifically arrays with the dimensions of 4 by 3); knowledge of arrays being structured using equal rows and columns; and understanding remainders (items left over). The students were expected to make four rows of three students, with two students 'left over'. In this first excerpt, several teacher and student talk moves illustrate how reasoning is promoted across a series of turns. (Note: each excerpt accounts for less than two minutes of talk).

Excerpt 1: Producing and Co-Producing Reasoning

37 Tea: Charlie↑ have you thought about how many rows we will have↑(0.5)
38 Cha: four rows
39 Tea: you'll end up with four rows↑(.) okay↑
40 how did you(.) why do you think four Charlie?
41 Cha: because I knew four
42 Tea: one row yep↑ tell me more
46 Cha: and um Mischa and(.)and Cassie and (.)
47 Tea: ye:ah↑=
48 Cha: =and me and Fletcher=
49 Fle: =but there's not enough three peoples
50 Tea: hang on, let Charlie finish↑
51 Cha: me, Noah and Fletcher then two (.) then we'd need one more
53 Tea: we'd need one more to make our↑(.)
54 Fle: fifth row
55 Mis: it has to be one, to make a full row=
56 Tea: =row Charlie(.) well done I think you did some good maths thinking
57 then↓ remember you are making rows of three

In this sequence, the teacher's use of wait time (the non-typical extended pause of 5 seconds (0.5) in line 37), the "why" question (line 40), the "tell me more" request (line 42), that more turns than is typical is allocated to Charlie to sustain his point so that he could continue his line of thinking where he could explain his reasons for his initial answer "four" (line 38), form a collection of turns that exemplify a more dialogic sequence of talk.

The "why" question (line 40) not only functioned as a pass on talk move which returned the floor to the Charlie after his first response (Willemsen et al., 2020), but signalled that a reasoning response was required. Why questions form a dialogic talk move as they typically provoke a reasoning response whereby student/s are asked to explain their thinking (Edwards-Groves, 2024). Here, reasoning is produced not as a single student response, but as evident in this excerpt, across a series of turns involving Charlie, other students, and the teacher. The teacher, in a deliberately orchestrated way, allowed Charlie more turns to provide a more complete explanation, then justification for his answer. That the teacher (line 50) made it clear that she wanted Charlie's line of thinking to not be interrupted by another student created the space for Charlie to do so. Charlie extended his initial response by explaining the thinking he used to work out his answer of four; he did this by grouping students into rows. Contributions by other students Fletcher and Mischa provided additional evidence of how mathematical reasoning was co-produced in this instance.

As the lesson progressed, the teacher called for students to suggest other examples that answer the framing question, "what's a row"? The next excerpt shows how the responsibility for producing examples and explanations is shared among the students as they work through the problem.

Excerpt 2: Sharing the Responsibility for Making Thinking Evident

Tea: ok so back to our question, what's a row↑ (0.3) what's a row↑ (0.3)
do you know what a row is↑ (0.2) what do you think Cleo↑
Cle: um(.) like a line↑ (0.2)
Tea: like a line↑ so do you think rows can go (.) like this? ((teacher draws
three 0's horizontally on the whiteboard)) or this↑ ((draws three 0's
vertically)) or this (.) or this↑ ((draws three 0'S diagonally))
Sts: no↓ ((no:o)) ((one student saying "they're not rows when they go down"))
Lia: any way↑ they can go any way↑ rows can go any way↑
Tea: you think rows can go any way↑
Cle: look they're going that way, going that way
Tea: I heard someone say no though↓ who said no↓ you don't think they're
rows↓ alright (.) Cassie you said they're not rows when they go down↑
(0.3) tell us why you think that
Cas: rows are like(.) the movie theatre
Tea: can you show us (0.1) can you draw some rows for us↑ ((Cassie draws
straight lines horizontally on the whiteboard to demonstrate rows))
so Cassie(.) said rows are like when go to the movie theatre (0.5) thanks
Cassie↓ (0.4) *what do you think* about what Cassie has just shown us↑(.)
Lin: Cassie's right, she said rows are like (.) when you go to the movie theatre
and you sit in the seats in rows …

In this sequence, producing mathematical reasoning is aligned with both articulating thinking and showing evidence (e.g., Cassie's drawing her ideas on the board). This is made prominent in the teacher's prompts and requests, such as "what do you think" (line 122), "so do you think?"(line 124), "you think" (line 129), "you don't think" (line 131), "why you think that' (line 133), "can you draw some rows…" (line 135), and "what do you think about..." (line 138). The sequence progresses with a range of student responses, that "rows are like lines", that "rows can go any way", and that "rows are not rows if they go down". It is at line 131, that the teacher shifts the student responses to move from the reasoning action of generalising (rows are like lines) to exemplifying (drawing rows on the board) to justifying (tell us why you think that). Here the teacher turn "Can you show us…?" (line 136) functions as a request for producing evidence to support Cassie's earlier point (line 127) that "they're not rows when they go down". Lincoln's subsequent agreement with and rephrasing of Cassie's explanation (lines 139/140) is a demonstration of active listening by overtly indicating his orientation and interpretation of another person's ideas. This brief excerpt shows how the mathematical reasoning is co-produced in the talk-in-interaction that students are supported (through prompts and requests) to make their thinking 'public' through extended explanations and justifications.

In this final excerpt, alternative responses are offered as possible solutions to the framing "why" question. Teacher prompted the dialogue in strategically and sequentially relevant ways, through talk moves such as using "I wonder", inviting multiple ideas like "let's have thumbs up if you have something to share", or asking open questions that require students to produce analysing, generalising and justifying their reasoning.

Excerpt 3: Using 'I wonder' for Producing Alternative Responses

141	Tea:	I wonder what other ideas (.) let's have thumbs up (.) if you've
142		got something else to share (.)…((turns omitted)) what do you think Noah↑
143	Noa:	um when Cassie said rows at the civic theatre but they they
144		could not be equal because you don't know if people could make it↑
145	Tea:	[okay
146	Noa:	[there could be some empty seats↓
147	Tea:	there could be empty seats but can you see what Cassie has [drawn↑
148	Noa:	[yeah
149	Tea:	so let's look at what Cassie is saying that (0.1) lines like that are rows↑
150	Noa:	yes
151	Tea:	whereas before people said that lines could go anyway(.) and
152		they're rows so what do you think about that↑(.) I wonder if it's a row
153		or is it just a line? (0.3) which one do you think might be rows(.) Noah↑
154	Noa:	the top one ((Noah refers to teacher drawing horizontal 0s))
155	Tea:	you think that's rows(.) why↑
156	Noa:	because um it doesn't matter how long your row is because(.) they're rows
157		aren't different to most of the [rows

In the first turn of this excerpt, the teacher's use of "I wonder" (line 141) functions as a move designed to open up the conversation to elicit other ideas and thoughts. Here, the teacher moves provided students with extended opportunities to articulate their thinking and justify their ideas and form evidence of the dialogic nature of this exchange. The use of 'I wonder' frees the students to contribute further explanations and designed to enhance student participation. This is a direct dialogic move as it is an opening-up rather than closing-down move. According to Houen et al. (2016), the use of "I wonder" plays an important role in discussions as a move that intentionally elicits additional "thoughts, ideas and opinions rather than being required to recite facts" (p. 75).

In this example, the "I wonder" formulation recruits Noah to answer. He subsequently demonstrates the analysing reasoning action (lines 143–4, 146, 154, 156) as he orients to, engages with, and challenges, Cassies' earlier explanation. Noah challenges Cassie's point by proposing a problem with her idea (albeit not entirely correct in terms of what she was proposing). To address this flawed reasoning (Russell, 1999), the teacher reformulates her question "what do you think about that" (line 152) into a wondering, "I wonder if it's a row or is it just a line?" (lines 152–53). This wondering seeks clarification and solicits more reasoning to rectify Noah's partially correct answer. As a response, Noah pursued his thinking by adding "but they need to be parallel", and on his reasoning, rows in a movie theatre are not parallel.

Summary

Analysis of these brief excerpts from this Year 1 mathematics lesson showed ways dialogic talk in this problem-solving lesson supported these early years students to produce the mathematical reasoning actions of analysing, explaining, and justifying. Across the sequences, dialogic talk was evident in how teacher talk moves opened the communicative space for students to analyse the ideas and the turns of others, generalise concepts (like rows and lines) and justify their responses as they attempted to explore 'rows' at the local, sequential, and topical levels. Across the turns, through interpretations, explanations and justifications, students jointly produced mathematical reasoning as they oriented to, took up, and extended the thinking of others. When the teacher vacated the floor (to withhold a turn or wait longer with a pause), students directly built on and responded to the ideas of others. It was evident that students were provided with extended and additional opportunities to offer alternatives to other student's ideas, take up or present new ideas, challenge others, and/or contribute additional information, personal opinions and alternative reasons.

Findings shows ways that Schegloff's (2007) five interactional features for meaning making and coherence is evident across the turns *as* students created and maintained meaning at the local turn level, sequential (across the turns and sequences), topical (about rows), categorical (as student and teachers co-producing meaning) and reasoning (in terms of producing mathematical reasonings) as they displayed their meanings about the talk, the topic and the task at hand was displayed.

Implications

Conversation analysis, through its fine-grained attention to how talk unfolds turn by turn, provided a useful method for understanding the nature of interconnectedness of interactive and mathematic reasoning with implications for dialogic talk practices. Analysis of this Year 1 lesson showed evidence that mathematical reasoning is co-produced across a series of turns rather that found in a single student response. It is shown that through the strategic and deliberate teacher use of talk moves, mathematical reasoning is accomplished. For example, moves such as the use of "I wonder", the use of a "why" question to provoke a reasoning response, affording students the opportunity to sustain and/or extend a point, challenging ideas, and/or producing alternatives are notable. This has important implications for teachers' understandings about how mathematical reasoning is produced as a process, and that it is made evident by students as a lesson unfolds, turn by turn, and across sequences of talk-in-interaction. Further, it is necessary to understand that talk-in-interaction is a reasoning task requiring intersubjective meaning making, that at the same time produces mathematical reasoning.

Conclusion

This article examines one of the most fundamental, yet taken-for-granted, activities that goes in classrooms—the talk and interaction that happens between teachers and students in their lessons. It is through this talk and interaction that intersubjective meanings are made, that mathematical reasoning is promoted and demonstrated, and that mathematical knowledge is developed. Given what is at stake, how lesson talk is understood and practiced by teachers and students matters to student learning is necessary for improving mathematical reasoning.

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