

Contextual and Interactive Dynamics in Mathematical Discourse: A Study of Grade 9 Learners' Engagement with a Deepening Thinking Problem

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ABSTRACT

This qualitative study explored a facilitated conversation among Grade 9 learners as they engaged with a deepening thinking mathematical problem. Using an ethnomethodological approach combined with conversation analysis, the study highlighted the orderly nature of group discussions. Key findings include the significant influence of context on learners' strategies, the role of historical mathematical knowledge in their understanding, and the structured nature of their interactions. The study underscores the importance of engaging learners more deeply with mathematical concepts to enhance their thinking processes and retention of previously learned material.

Keywords: Productive practices, Ethnomethodology, learner engagement, conversation analysis

INTRODUCTION

Traditional mathematics classrooms often emphasise correctness and procedural knowledge, which can hinder creativity and deeper understanding. Conversely, educational reform promotes a more exploratory approach, where learners engage in conjecture, reasoning, and discussion. The Local Evidence Driven Improvement of Mathematics Teaching and Learning Initiative (LEDIMTALI) Project aims to support teachers in adopting such effective practices. This study examines how Grade 9 learners respond to instructional strategies designed to foster deeper mathematical thinking and engagement, using a facilitated conversation approach. The LEDIMTALI Project, part of the University of the Western Cape's CPD efforts, aims to enhance mathematics teaching through productive practices such as spiral revision and deepening thinking problems. It highlights the importance of designing and implementing instructional strategies that meet learner needs and contexts, fostering a deeper understanding and retention of mathematical concepts. In the mathematics classroom, the teacher and the textbook are key drivers, which reflect the correctness of mathematics, often limiting creativity and exploration within the subject. Mathematics is regarded as a certainty subject, so knowing it and arriving at the right answer quickly are considered important. Teachers typically validate learners' answers by simply stating the rule that must be followed, regardless of whether the answers are correct or not. However, education reformers propose different assumptions about mathematical knowledge and how it can be acquired. The National Council of Teachers of Mathematics (NCTM) recommends that at every level of schooling, learners should be making conjectures, abstracting mathematical properties, explaining their reasoning, validating their assertions, and engaging in discussion and questioning of their own and others' thinking. This encourages a shift away from traditional classroom practices and discourse towards a more thinking-oriented classroom.

One of the challenges teachers face is trying to teach mathematics in the way they experienced as learners (Anderson, D.S. & Piazza, J.A. 1996). We know that traditional teaching methods, which are often textbook-driven and focused on imitative learning, still exist. The question arises: how can we create a mathematics classroom using a particular teaching strategy that won't interfere with or disrupt the teaching habits teachers have developed over years of schooling or experience?

Over the past few years, the Local Evidence-Driven Improvement of Mathematics Teaching and Learning Initiative (LEDIMTALI) Project at the University of the Western Cape has embarked on a journey of Continuous Professional Development (CPD) for mathematics teachers. Its goal is to develop teaching through productive practices, including spiral revision and deepening thinking-like problems. The focus of LEDIMTALI is to help teachers improve their teaching by designing and implementing such problems, gaining insight into their teaching through learners' reactions.

The purpose of the LEDIMTALI project is to improve and develop new teaching strategies that teachers can adapt to their classroom contexts. To align with this purpose, the project endorses a specific teaching model that emphasises productive practices. Lithner (2008) argues that the traditional teaching model in mathematics classes offers little mediation of learner discourse and relies heavily on basic computational procedures (algorithmic imitative reasoning) and memorisation. Cobb, P. & Bauersfield (1995) suggest that in complex classroom environments, learner discussion requires mediation skills and heightened awareness of classroom dynamics. Consequently, Hufferd-Ackles, K., Fuson, K. C., & Gamoran-Sherin, M. (2004) emphasise the importance of establishing norms for learner interaction, such as encouraging learners to justify their solutions and to build upon one another's ideas, and ultimately sustain their interaction to reach some sort of practical achievement. Although the previous authors both mention mediation in different ways, LEDIMTALI's model of productive practices requires mediation skills to facilitate learning. Thus, the purpose of this paper was to investigate how a group of grade 9 learners reacted to the instructional strategies employed by the researcher to solve a deepening thinking-like question. According to Julie (2018), the productive practice teaching model acknowledges the teacher's pedagogical philosophies, be it textbook-driven, learner-centred or teacher-centred. The overarching idea of the teaching model is that the teacher becomes less of reliant on correctness and justification and the learners should do more and communicate more during lessons and the teacher less (May and Julie, 2018).

Figure 1 below gives an illustration of the teaching model, which is used for the development of teaching.

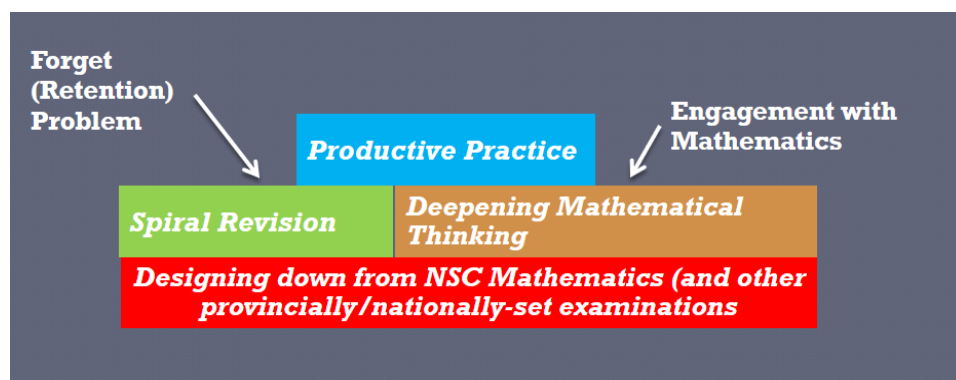


Figure 1: Teaching Model for the development of mathematics teaching

The productive practice model is used to deepen learners' conceptual knowledge of mathematics. In addition to the model, it is used as a pedagogical tool to improve teacher practices and allow learners to work with mathematics. The section on designing down represented in the model is merely showing a form of looking forward to what is relevant knowledge in the final phase of mathematics teaching, which then drives the thinking when designing mathematical problems. The pedagogical approach focuses on the retention of mathematical knowledge through learner engagement that then becomes a form of a productive struggle using deepening thinking-like questions.

Deepening Thinking-Like Mathematical Problems

The rules to solve the particular mathematical problem is made up through the discussion as learners build up their collective understanding of what is needed to reach a solution. Mathematics teachers face several challenges in facilitating deepening thinking problems that require high-quality discussion amongst learners. This study shows how learners through teacher facilitation follow a solution-seeking path made up through the discussion as they build up their collective understanding of what is needed to reach a solution. Thus facilitated

discussion is what the study analyses. It uses the learner's engagement as a reaction to instruction and facilitation from the teacher. Furthermore, the study attempted to show whether deepening thinking-like problems enhance or not the procedural and conceptual knowledge and ways of developing mathematical thinking of grade 9 learners.

Below is one example of a deepening thinking-like question, "Always, Sometimes and Never" (ASN). In this type of problem, learners are presented with a table with the heading such as the "Mathematical statement" in the first column, then the words in the other three columns stating "Always True, Sometimes True and Never True"

Learners must read to understand the mathematical statement then after discussions, tick the correct box. To complete the problem the group must write down why they chose a particular answer, hence a way of justifying their thinking.

1. Tick the box you think is correct for the given mathematical statement.

MATHEMATICAL STATEMENT	ALWAYS TRUE	SOMETIMES TRUE	NEVER TRUE
$9^{x-1} = \frac{3^{2x}}{9}$ is			

Reasons with possible examples for your choice:

.....

.....

Figure 1. An example of an "Always True, Sometimes True and Never True" question

Spiral Revision

Another strategy outlined in the productive practice model is Spiral revision, which is defined as the repeated practice of previously covered mathematical work in specific content areas (Julie, 2013). Julie (2013) views spiral revision more as a way of maintaining previously learned work or mathematical concepts related to a particular content area. According to Rohrer, D., & Taylor, K. (2006), the benefits of learning are often lost if the work is forgotten; this is especially common for knowledge acquired in school, where much of the learned material is forgotten within days or weeks. Another concept within the productive practice model is the design-down approach, which is based on what learners can expect to encounter in any externally set examination, such as the NSC high-stakes exam in the final year of schooling or the final school-based examination. This approach involves breaking down the exam content, for example, the high-stakes examination, to gain insight into the underlying sub-mathematical concepts. These concepts are then refined in detail, relevant for diagnosing performance in the high-stakes exam. In doing so, the underlying mathematical concepts are practised in a more profound, conceptual manner. Deep-thinking problems are an example of such practices. The design and facilitation of these problems in the mathematics classroom is what LEDIMTALI focuses on as a form of CPD for mathematics teachers.

This paper solely concentrates on the learner's engagement as a response to the teacher's facilitation of deep-thinking questions. A learner's effort to make sense of mathematics, to figure something out that is not immediately apparent, can advance the learners in their thinking and play an important role in deepening learners' understanding, if supported carefully toward a resolution and given appropriate time (Hiebert &

Grouws, 2007). The teacher's facilitation encourages learners to persevere in developing deeper mathematical understanding, emphasising that effort is more important than innate ability. To persevere, one needs to view the struggle that may inevitably be a part of solving a problem as an opportunity to learn. According to Warshauer (2014), the kind of guidance and structure that teachers provide may either facilitate or undermine learners' productive efforts. However, the focus of this paper is learner-learner rather than learner-teacher discussion. During these discussions, the learner's fragmented knowledge is facilitated because of active participation (Hoyles, 1985). This active participation has two functions: (1) a cognitive function for articulation of one's thought processes and (2) a communicative function to make one's ideas available to others (Givón, 1997). Hence, the analytical and theoretical perspectives of ethnomethodology and conversation analysis foreground this information from the discussion in situ.

Theoretical Considerations

This study uses ethnomethodology and conversation analysis to investigate how learners interpret mathematical problems through facilitated group discussions. Ethnomethodology aims to reveal the rules and structures behind everyday social actions, while conversation analysis looks at the orderliness and meaning within interactions (Sacks, 1989). Together, these approaches offer insight into how learners collaboratively develop understanding and solve mathematical problems, emphasising the importance of interaction in cognitive and conceptual growth.

The scientific approach to ethnomethodology is therefore to analyse the methods or procedures the learners used to carry out the various tasks they engaged in during their pursuit of solutions. Ethnomethodology examines all social actions or practices, including common-sense beliefs and behaviours related to the mathematics topic. This ontological basis means that the truth or accuracy of any statement is irrelevant, as ethnomethodologists focus on the processes of meaning-making and interpretation in context.

The point of social life in this context, particularly in the classroom setting, is that members themselves generate the idea of the lived orderliness of conversations (Silverman, 1998) and how the sequencing of utterances is something co-conversation participants are engaging in to be properly understood. Central to these social actions is organisation and orderliness that can be identified, described, and analysed to create formal terms that reflect the underlying structure. For this study, ethnomethodology and conversation analysis were utilised to describe approaches to the study of everyday life and interaction. In this case, the learner participated in a facilitated conversation to find a solution to a mathematical problem, which was assigned to them to interact with within their respective groups. Conversation analysis regards co-conversation participants as meaningful contributors who successfully use language and speech to organise the interaction.

Hence, the words and symbols used in any context to explain a specific meaning are the meaning of that situation at the moment when they are used. Ethnomethodology describes this notion of words in context, or words used in practical action, as indexical. Words acquire their full sense in the context of their actual production; in other words, how they are indexed in a situation (Coulon 1995). Instead, it focuses on the interactional work that specific utterances do, the implications they hold for what follows, and how they are employed in solving problems. Therefore, the facilitator played a pivotal role in group interaction. The particular utterances produced by the learners in the group were thus a result of how the conversation was managed. This approach aimed not only to understand how learners develop solutions to complex, mathematical questions but also to guide that understanding through a process of learning and reinforcement.

METHOD

This qualitative study involved Grade 9 learners from ten schools participating in the LEDIMTALI Project. Learners were divided into small groups and asked to solve a mathematical problem involving negative exponents. The interactions were video-recorded, transcribed, and analysed using ethnomethodological and conversation analysis frameworks. This approach enabled a detailed examination of how learners engaged with the problem, negotiated meaning, and built collective understanding.

The data were analysed using conversation analysis to identify patterns and structures in the learners' interactions. Ethnomethodology was employed to understand the context-specific practices and sense-making processes of the learners. Transcripts were examined for recurring themes, indexical references, and conversational structures that revealed how learners collaborated to solve the problem and develop their mathematical understanding.

Thus, the facilitator started by asking the learners to move into small groups of no more than four, after which the question was handed to each learner in the group. The question concerned negative exponents prescribed in the CAPS (Curriculum Assessment Policy Statement) for Grade 9 mathematics. Learners were then asked to read the question, after which the facilitator read it aloud to the whole class. About 1-2 minutes were allocated for questions to clarify any misunderstandings of what was expected of them. After clarification, learners were asked to discuss the problem within their groups to find a solution. For this study, only the learners' interactions with the problem were captured for analysis.

The study was guided by the frameworks of ethnomethodology and conversation analysis. Conversation analysis is a qualitative method of analysis focusing on the details of real-life conversations. Ethnomethodology, on the other hand, examines how people do what they do in everyday life. The mathematical problems presented are shown in figure 2 below.

1. Tick the box you think is correct for the given mathematical statement.

MATHEMATICAL STATEMENT	ALWAYS TRUE	SOMETIMES TRUE	NEVER TRUE
$5x^{-3} = \frac{1}{5x^3}$			

Reasons with possible examples for your choice:

Figure 2. Always true, sometimes true and never true question

The question was designed with a choice of answers such as “Always True, Sometimes True or Never True” followed by an explanation of their choice. The mathematical statement is what the learners discussed. After reaching their solution, they then had to explain the reason for their answer. The learner discussions were video recorded and transcribed to be analysed. The transcript captured the learners' conversation, showing how they went about doing what they do collaboratively to find a solution to the problem put to them. During the process of engagement, the researcher was merely a facilitator. The instructions given to the learners were to read the question. The teacher then read the question to the learners and provided a brief explanation of what was expected of them.

RESULTS AND DISCUSSION

1.1. Results

The analysis revealed several key insights into learners' interactions, firstly as a reflection of contextual influence showing learners' strategies were heavily affected by the problem's context and their prior mathematical knowledge. Secondly, the indexical understanding demonstrates that learners used contextual and conversational cues to build and refine their understanding of mathematical concepts. Lastly, structured interactions, where discussions followed a recognisable pattern of negotiation, clarification, and consensus-building, reflect the orderliness of mathematical discourse. The findings highlight the importance of context

and prior knowledge in shaping learners' approaches to mathematical problems. The structured nature of the discussions aligns with established patterns in mathematical discourse, emphasising the value of facilitated conversations in promoting more profound understanding. The study underscores the need for teachers to create opportunities for learners to engage in meaningful mathematical discourse, thereby enhancing both procedural and conceptual knowledge.

Transcript of learner conversation

Line 1. L1 Let's start at the beginning... Quick 5 on x minus 3 on 1... Quick put 5 x minus 3 on 1

Line 2 L2 5...

Line 3 L1 Yes on 1

Line 4 L2 So?

Line 5 L1 Because that exponent is part of the whole thing, everything has to go down...

Line 6 L3 Yes but...

Line 7 L2 Then it must go down because it is a negative then it becomes n positive...

Line 8 L2 Like the (demonstration)

Line 9 L1 Actually that is wrong because the positive number stays on top

Line 10 Pause in the conversation

Line 11 L1 So is 5x, 5x above (Referring to the numerator position)

Line 12 L2 Ha ... a ... ha ... a (No... no negating what L1 said)

Line 13 L1 x is positive because it is over 1 ... and the coefficient is positive ... the third may ... the minus 3 must be shared.

Line 14 L2 Isn't it minus 3; is that minus his exponent; then that one comes and that ...

Line 15 L1 Yes... so is 5 on x to the third power;

Line 16 L3 So wrong

Line 17 L1 Is 5 on x until the third power equals...

Line 18 L2 So wrong...

Line 19 L1 Yes is never true... (Jumping to selection of solution)

Line 20 L2 Ha... a is 5 on x to the third power...

Line 21 L1 Yes...

Line 22 L1 is never true...

Line 23 L2 Yes is never true...

Line 24 L1 Yes is never true, because the reason is...

Line 25 L2 x...

Line 26 L1 5 is positive... because the positive numbers remain above (backing up confirmation)

Line 27 L2 Yes...

Line 28 L1 Because the third power is part of the unknown power ... must remain one ... so is 5 on x to the third power.

Line 29 L2 Now all the things (indexical) that you said now you have to say again ...

Line 30 L1 Yes write the reason...

Line 31 L1 5 positive number must remain above and the negative exponent below.

1. In Line 1, L1 begins the conversation by telling the group what to start with. Lines 2 and 4 show that the role of co-conversationist is taken up by L2. The mentions of “5...” and “So...” indicate that there is an understanding of where to start, although it is not fully repeated. L2 is, in a way, contributing to the production and organisation of the conversation.
2. In Line 5, the indexical, natural incompleteness of words is illustrated. Its completeness lies in the pointing action. The “that” has its completeness within the context of the conversation. The “that” here refers to the exponent as part of the whole expression $[(5x)]^{-3}$. Still, in Line 5, the indexical use of the word “thing” refers to $5x$ as the whole, indicating that all participants are aware of what the group members refer to and what the member means by pointing to the $5x$. This is what Garfinkel (1967) called common-sense understanding. In this regard, the utterance contributes to the sense-making of the mathematical expression in terms of the negative 3 exponent. After the common-sense understanding of the expression $[(5x)]^{-3}$, a decision is made that everything must go down and be placed in the denominator.
3. In Line 6, (L3), the immediate question is, “What must go down?”. Although L3 only says “Yes but,” it shows agreement about the going down; however, the “but” suggests a clarification of what exactly must go down. L3’s contribution shifts the organisation of the conversation towards focusing on “that which must go down,” making it a key point in the sense-making process. This way of speaking is what learners often pick up in everyday language used in the mathematics classroom.
4. L2 demonstrated this in Line 7 through the indexical utterance, “then it must,” indicating that it must go down and be written in the denominator, giving a more definite conclusion of “what must go down.” A further clarification about “what must go down” is provided by L2 in Line 7. Here, L2 acknowledges that the negative exponent must go down and then become positive. This reflects an understanding that $x^{-3} = x^{-(3)/1}$, meaning that taking it down makes the exponent positive—similar to thinking of $5x^{-3} = 1/(5x^3)$.
5. In Line 8, L2 elaborates on what is meant by “becoming positive.”
6. In Line 9, L1 responds to what L2 said and demonstrated by labelling “that is wrong” in an indexical way. The response of L1 extends the idea of “what is positive,” reading the expression as $(5 \times x^{-3})$, showing that the -3 exponent is associated with x , not 5. Therefore, the statement “the positive number stays on top” is made.
7. In Line 11, L2’ replies with “Yes...,” which serves as a reflexive gesture, building an account of previous actions or statements. This reflexivity in sense-making can be observed through practical action and reasoning, leading to a practical outcome. Throughout the conversation, L2 takes on the role of co-conversationist simply by saying “Yes,” acknowledging that the discussion and mathematical understanding are progressing correctly, as seen in Line 11.
8. In Line 12, L1’ attempts to clarify his own explanation, steering the conversation back a step; however, it is halted by the co-conversationist’s brief “No.” Line 13 marks the first clarification during the sense-making process. Later, in Line 16, L3 identifies what is wrong, showing a deeper conceptual understanding of the mathematical statement.
9. In Line 18, L2 also determines what is wrong, indicating a deeper grasp of the mathematical idea. By saying “So,” L2 agrees that this is incorrect, further supporting the sense-making process. Identifying errors provides learners with immediate feedback on their understanding, often roles expected of teachers.

In mathematical sense-making conversations, learners often act as both teacher and student to reach shared understanding.

10. L1's reaction in Line 19 involves deciding whether the statement is always, sometimes, or never true, which shows agreement with the discoveries made earlier. L1 demonstrates this understanding by ticking the correct block.
11. In Line 20, L2 reflects on the statement's recording, recognising it was not correct and explaining what it should have indicated. In Line 21, L1 then takes on the role of co-conversationist, affirming with "Yes."
12. L1 continues the discussion by clarifying "never true" as the correct answer, and this is acknowledged by L2 in Line 23. In Line 24, L2 interrupts L1 before he can explain why it is "never true." The turn-taking here appears competitive, showing a form of dominance. However, in Line 26, after a pause, L1 resumes reading from the coefficient 5, whereas L2 begins with x . Although L2 wishes to contribute more actively, L1's handling of " x " as a side remark does not diminish L2's input, as L2 is given the chance to agree in Line 27. Following that, in Line 28, L1 offers a more complete explanation of what must be done.

DISCUSSION

Understanding the use of mathematical concepts is closely linked to the mathematical discourse employed by the teacher. From the analysis, it is evident that the mathematical discourse used by the teacher is communicated to the learners to facilitate their understanding. According to Celce-Murcia (2008), classroom discourse refers to the language teachers and learners use to express thoughts through written words and conversation. Therefore, as shown in the analysis, mathematical discourse encourages learners to demonstrate their understanding of mathematical concepts as they engage in mathematical reasoning.

The transcript illustrates how learners approached the problem by discussing and negotiating mathematical concepts. For instance, the debate over whether the negative exponent should affect the entire expression or only part of it highlights the learners' process of refining their understanding. The conversation also illustrates the role of reflexivity and indexicality in making sense of the problem, as learners used contextual cues and prior knowledge to guide their reasoning.

Furthermore, the study shows that facilitated conversations can greatly enhance learners' engagement with mathematical problems. By emphasising deep, collaborative discussions, teachers can help students develop a more nuanced understanding of mathematical concepts and improve their problem-solving skills. The findings suggest that incorporating problems that encourage deeper thinking into the curriculum, along with effective facilitation, can support learners in building a stronger conceptual foundation and improving their overall mathematical reasoning. The notion of facilitation among teachers is a challenging skill to act out in class. The natural objective of a teacher and teaching is to reach some mathematical object; hence, probing becomes very difficult.

The analysis highlights the crucial role of conversational dynamics in mathematical sense-making within educational settings. The transcript reveals how learners actively participate in a collaborative process of negotiating mathematical ideas, employing reflexivity and indexicality to refine their understanding of expressions involving negative exponents. The discussion underscores the importance of effective facilitation in guiding learners through complex problem-solving processes, demonstrating that well-structured discourse can significantly enhance conceptual understanding. The findings advocate for integrating problems that promote deeper thinking into mathematics teaching to foster critical thinking and collaborative learning. Educators are encouraged to adopt facilitation strategies that promote meaningful dialogue and to receive professional development in discourse practices to optimise teaching effectiveness. Future research should further explore how various facilitation techniques and problem types influence learner outcomes, providing valuable insights for enhancing mathematics education.

CONCLUSION

This study concludes that learners' mathematical sense-making is deeply rooted in contextual understanding, prior knowledge, and the dynamics of structured peer interaction. The analysis of the learners' conversations

revealed three key components: (1) contextual influence, where learners' problem-solving strategies were shaped by their familiarity with the problem context and existing knowledge; (2) indexical understanding, as learners relied on conversational cues and situational references to articulate mathematical ideas; and (3) structured interaction, where learners engaged in negotiation, clarification, and consensus-building, resembling authentic mathematical discourse. The discussion confirms that such discourse-based interaction supports not only procedural fluency but also conceptual depth in learners' understanding. The reflective and collaborative dialogue observed during the problem-solving process demonstrates how learners assume both teaching and learning roles, enhancing mutual understanding and correcting misconceptions through peer feedback. These findings underscore the importance of equipping teachers with strategies to guide and scaffold meaningful mathematical conversations. When effectively facilitated, classroom discourse helps learners navigate complex mathematical ideas and fosters critical thinking. Therefore, mathematics education should integrate open-ended, thinking-rich tasks and emphasise dialogic teaching approaches to promote deeper engagement and understanding. Future research should examine the effects of various discourse facilitation techniques on learners' metacognitive engagement and long-term conceptual growth. Additionally, exploring how discourse practices differ across diverse cultural and classroom contexts can offer broader insights for global mathematics education reform.

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