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# ORCHESTRATING MATHEMATICAL THINKING: A CORRELATIONAL AND DISCOURSE ANALYSIS OF TEACHER QUESTIONING STRATEGIES AND THEIR IMPACT ON PROBLEM-SOLVING PROFICIENCY IN PRIMARY 4 CLASSROOMS

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**Abstract**

The quality of teacher-student discourse is a critical mediator of mathematical learning, with teacher questioning being its most potent tool. In primary mathematics, where the foundation for higher-order thinking is laid, a preponderance of low-cognitive demand questions (focused on recall and procedure) persists, potentially stifling the development of genuine problem-solving skills. Understanding the specific relationship between questioning patterns and student problem-solving behaviors is essential for effective teacher professional development.

The cognitive landscape of a mathematics classroom is profoundly shaped by the teacher's questioning habits. A shift towards a greater ratio of high-cognitive demand questions, particularly those that probe reasoning and generate alternatives, is strongly associated with the development of sophisticated problem-solving competencies. Professional development must move beyond advocating for "more questions" to fostering a repertoire of strategic, discourse-eliciting questions and the pedagogical skills to sustain productive talk.

**Keywords:** Teacher questioning, mathematical discourse, problem-solving, primary mathematics, classroom observation, cognitive demand, professional development.

## Introduction

Problem-solving is the heart of mathematics. It is not merely an application of learned procedures but a complex cognitive process involving exploration, conjecture, reasoning, and justification. The *Principles to Actions* (NCTM, 2014) explicitly identifies facilitating "meaningful mathematical discourse" as one of eight

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essential teaching practices, with questioning being the primary lever teachers have to orchestrate such discourse. In primary classrooms, teacher talk dominates, and the types of questions asked establish the intellectual norms—signaling whether mathematics is about memorizing fixed answers or about sense-making, argumentation, and creative thinking.

Extant research distinguishes between low-level questions (requiring recall of facts or execution of a known procedure) and high-level questions (requiring analysis, synthesis, evaluation, or metacognition). While high-level questioning is consistently linked to improved student achievement in correlational studies, observational data indicate that low-level questions predominate in many mathematics classrooms globally. This creates a concerning gap between pedagogical ideals and classroom reality. Furthermore, less is known about the *specific mechanisms* through which different *types* of high-level questions (e.g., those that probe conceptual understanding vs. those that elicit multiple strategies) influence distinct facets of problem-solving, such as strategy diversity or explanatory rigor.

This study is grounded in sociocultural theory, viewing learning as a process of enculturation into a community's discursive practices. The teacher, as the discourse leader, models and scaffolds the kinds of questions students should eventually internalize as their own metacognitive tools. The study addresses three specific limitations in the literature: (1) the need for fine-grained analysis linking specific question *functions* to student outcomes, rather than just broad cognitive level; (2) the lack of multi-classroom observational studies that account for the nested nature of data (students within classrooms); and (3) the paucity of research that connects observed questioning patterns directly to student performance on non-routine problem-solving tasks, as opposed to standardized computation tests.

Therefore, this study is guided by the following research questions:

1. What is the distribution of cognitive demand (low vs. high) and functional typology (focusing, probing, generating) of teacher questions in Primary 4 mathematics classrooms?
2. To what extent does the frequency and nature of high-cognitive demand teacher questions predict student performance and strategy use on a problem-solving assessment, after accounting for prior achievement?
3. What are the observable characteristics of mathematical discourse in classrooms with differing profiles of teacher questioning?

We hypothesize that a higher frequency of high-cognitive demand questions, particularly probing and generating types, will be significantly associated with higher student problem-solving scores, greater strategy diversity, and more collaborative and explanatory discourse.

**Methods**

A naturalistic, correlational mixed-methods design was employed. The study combined systematic quantitative observation and coding of teacher talk with qualitative discourse analysis of classroom interactions and quantitative analysis of student problem-solving outputs.

The study was conducted in eight intact Primary 4 classrooms across four public schools, selected for demographic diversity (urban/suburban). Each classroom was taught by a different, fully certified teacher (6 female, 2 male), with teaching experience ranging from 5 to 20 years. The total student sample was 192 (average 24 per class). All teachers were implementing the same national mathematics curriculum.

Data collection occurred over a 10-week period in the second semester.

1. Classroom Observations: Each classroom was video-recorded for 10 consecutive whole-class mathematics lessons (focused on the topics of fractions and decimals, known to involve conceptual challenges). The main instructional segment (approximately 30 minutes) of each lesson was transcribed verbatim.
2. Student Problem-Solving Assessment (PPSA): After the observation period, all students completed a 45-minute, 5-item performance assessment. Tasks were non-routine and required explanation (e.g., "Two ropes are each cut into 5 equal pieces. One rope was longer to start with. Does each piece from the longer rope have to be longer than each piece from the shorter rope? Explain your reasoning using words, pictures, or numbers.").
3. Prior Achievement Data: End-of-Term 1 standardized mathematics scores were collected as a covariate.
4. Teacher Stimulated-Recall Interviews: Following the observation cycle, each teacher viewed selected video clips of their own lessons and participated in a semi-structured interview to discuss their questioning intent and perceptions of student responses.

1. **Teacher Question Coding Scheme:**

○ Cognitive Demand: Adapted from the *Task Analysis Guide* (Boston & Smith, 2009).

▪ Low: Recall facts, definitions, or procedures (e.g., "What is the denominator?", "What is 7 x 8?").

▪ High: Require explanation, justification, connection, or strategic thinking (e.g., "How do you know it's equivalent?", "Why can't you just add the denominators?", "Could you solve this a different way?").

○ Functional Typology: Adapted from Boaler & Brodie (2004).

▪ Focusing: Direct student attention to specific information or steps.

▪ Probing: Elicit deeper explanation, justification, or meaning.

▪ Generating: Encourage multiple approaches, conjectures, or generalizations.

2. **Student Problem-Solving Coding:**

○ Overall Score: Holistic rubric (0-4 points per task) assessing understanding, strategy, and communication.

○ Strategy Diversity: Count of distinct, valid strategies employed across tasks.

○ Explanatory Justification: Binary code for presence of a written justification beyond a numeric answer.

**3. Discourse Features:**

For qualitative analysis, transcripts from high-questioning and low-questioning classrooms were analyzed for patterns in turn-taking, uptake of student ideas, and use of exploratory talk (Mercer, 1995).

• Quantitative: Descriptive statistics summarized question distributions. Two-level Hierarchical Linear Modeling (HLM) was used to account for students nested within classrooms. Level-1 (student) predictors included prior achievement. Level-2 (classroom) predictors included the proportion of high-level questions and proportion of probing/generating questions. The outcome variables were PPSA total score and strategy diversity.

• Qualitative: Discourse analysis was conducted on selected contrasting episodes (e.g., a teacher using a series of probing questions vs. a teacher funneling students toward a predetermined answer). Interview data were analyzed thematically to understand teacher rationale and awareness.

## 3. Results

A total of 2,847 teacher questions were coded. Overall, 68.5% were low-cognitive demand. The proportion of high-level questions varied significantly by teacher, from 18% in the lowest classroom to 55% in the highest. Among high-level questions, probing questions were most common (60%), followed by generating (25%) and focusing (15%).

**HLM Results:**

After controlling for prior achievement at the student level, the classroom-level proportion of high-level questions was a significant positive predictor of the class average PPSA score ($\gamma = 0.51$, SE = 0.18, $p < .01$). This means a 10% increase in high-level questions was associated with a 0.51 standard deviation increase in predicted problem-solving scores. The proportion of *probing* questions specifically was the strongest predictor of strategy diversity ($\gamma = 0.63$, SE = 0.21, $p < .01$). **Student Work Analysis:** Classes with teachers in the top quartile of high-level questioning had students who used an average of 2.1 distinct strategies across the PPSA, compared to 1.2 in the bottom quartile ($p < .001$). Written justifications were present in 71% of responses from high-questioning classrooms vs. 28% in low-questioning classrooms.

- **Classrooms with High Frequencies of Probing/Generating Questions:** Discourse was characterized by extended student turns, teacher "revoicing" of student ideas ("So, you're saying that..."), and questions that built on previous answers ("Does Jamal's method work for the next problem too?"). Students more frequently challenged or added to peers' ideas.
- **Classrooms Dominated by Low-Level Questions:** Discourse followed an Initiation-Response-Evaluation (IRE) pattern. Teacher talk was characterized by "funneling"—rapid-fire questions leading students to a specific answer. Student responses were short, and incorrect answers were often quickly bypassed rather than explored.
- **Teacher Interview Insights:** Teachers with high-level profiles spoke of "uncovering student thinking" and saw their role as a "facilitator." Those with low-level profiles expressed concerns about time and curriculum coverage, viewing questions primarily as a tool to check for procedural understanding.

The study reveals a strong, positive relationship between the cognitive level of teacher questions and students' problem-solving proficiency. Merely asking more questions is not enough; the strategic use of probing and generating questions

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appears to create a discourse environment that cultivates strategic flexibility, perseverance, and the disposition to explain and justify mathematical reasoning.

**Discussion**

The findings provide robust empirical support for the theoretical importance of high-cognitive demand questioning in primary mathematics. The significant between-teacher variability highlights that questioning is a *learned practice* subject to improvement, not a fixed trait. The results move the field beyond simple advocacy for "asking better questions" by demonstrating the specific, measurable impact such questions have on the complex skill of problem-solving.

The power of probing questions lies in their ability to make student thinking visible, both to the teacher and to the students themselves. This visibility allows for formative feedback and encourages metacognition. Generating questions, by valuing multiple pathways, signal that mathematics is a subject of creativity and inquiry, not just one right answer. These questioning strategies operationalize a Vygotskian perspective, where the teacher's language scaffolds the development of students' internal cognitive tools for reasoning. The HLM results underscore that the classroom discourse climate, shaped by the teacher, is a significant factor in individual student outcomes.

1. **From Monitoring to Eliciting:** PD must help teachers shift their questioning purpose from monitoring answer correctness to eliciting and exploring reasoning.
2. **Building a Strategic Repertoire:** Teachers need a toolkit of reliable, high-level question stems (e.g., "What is the same and what is different about these methods?", "How could you convince someone who disagrees?") and practice in deploying them in the flow of instruction.
3. **Responding to Student Ideas:** PD must focus not just on asking the question, but on how to skillfully respond to student answers—using wait time, revoicing, and connecting ideas to build coherent discussions.
4. **Video-Based Reflection:** Using videos of their own teaching (as in the stimulated-recall interviews) is a powerful tool for developing teacher awareness of their questioning patterns.

The correlational design limits causal claims; it is possible that more capable problem-solving classes elicit higher-level questions from their teachers. The observational period, while extensive, captured only one unit of instruction. The study did not measure the impact of student-generated questions. Future research should: a) design intervention studies where teachers are trained in specific questioning strategies, with pre/post measures of student problem-solving; b) investigate the longitudinal development of teacher questioning skill; and c) explore the interplay between task design (the problems posed) and question quality, as rich tasks may be a necessary condition for meaningful questions to emerge.

**Conclusion**

This study confirms that the questions primary mathematics teachers ask are not merely instructional embellishments; they are fundamental architects of the cognitive and discursive space in which students learn. A deliberate shift towards a culture of high-level questioning—particularly probing and generating questions—is a viable and powerful strategy for transforming primary mathematics classrooms into incubators for problem-solvers. By mastering the art of questioning, teachers do not give students the answers; they give them the tools to find their own.

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