AN EXPLORATION OF TEACHERS' WHY-QUESTIONS IN THE MATHEMATICS CLASSROOM

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Teacher's why-question can press students toward justification, make sense of mathematical structure, and make students' thinking visible to others. However, the productivity of why-questions hinges on their underlying purpose. In this brief report, we illustrate our framework of underlying purpose of why-question by examining 152 why-questions from 49 classroom videos (grade 4th-8th). While a particular question can appear similar in content, the expected student responses ranged significantly and thus we argue for two implications. First, as researchers, coarsely defining question types by categories such as "why" may be insufficient to tie a teacher move to a particular functional purpose. Second, if we want why-questions to cue students to provide mathematical domain explanations (justifications), there is a need to better understand what classroom/discourse factors lead to productive why-question use.

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The questions that a teacher poses to students can shape mathematics classrooms in terms of opportunities for students to reason mathematically (e.g., Boaler & Brodie, 2004; Franke, et al. 2009; Sahin & Kulm, 2008). One particularly powerful type of question is the why-question which is often associated with higher order questioning (Kawanaka, & Stigler, 1999) which can serve to press students towards justification (e.g., Conner, et al., 2014), make sense of important mathematical structures (e.g., Jones & Bush, 1996), and make students' thinking available for the teacher and other students (e.g., Sahin & Kulm, 2008). However, the productivity of such questions hinges on their underlying purpose. The same question, "Why?," can lead to a substantially different level of student engagement in varying classrooms.

In a larger project classifying teacher prompts (Melhuish, et al., 2020), we discovered that why-questions were particularly anomalous when compared to other moves that can be productive in engaging students in rich mathematical discourse and reasoning. When we created profiles of various types of classes via a cluster analysis of teaching moves, we found that "why" questions did not serve as a marker differentiating classes that were more focused on mathematical reasoning from classrooms where the teacher did the majority of the mathematical work (Author, year). In fact, the "generic why" prompt was the most prevalent of any of our codes and spanned the majority of the lessons in the project. As a result, we conjectured that why-questions were likely serving substantially different roles for different teachers.

In this paper, we share an analysis of the why-questions found in a corpus of 64 video-taped mathematics lessons spanning grades 4-8. For each instance, we considered the nature of the why prompt, conjectured an instructional purpose, and considered how the students responded to the request. As a result of this analysis, we developed a framework to classify the mathematical why's of instruction. We share this framework and discuss the implications for instruction.

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Problematizing Why-Questions

The mathematics classroom reflects a community of a teacher and students where norms shape the overall activity (e.g., Cobb, 2002). And so, we argue there is a need to go beyond categorizing teacher questions based on linguistic form, but to situate their meaning in the larger classroom domain and likely functional outcome. This is especially true for "why-questions" which have often been differentiated from other types of requests because of their context-sensitivity (Cox, 2019). We define a why-question as "some proposition *P* along with the request that *P* be explained" (Temple, 1988, p. 141). Often these questions will be of the form "Why *P*?" such as "Why did you add five to the nine?"; however, such a request for explanation could be asked with an implicit why such as, "How come you added five to the nine?" Thus, why-questions can be operationalized as any prompt for an explanation that could be formulated into a "Why *P*?" question without changing the intended meaning.

Why Questions are Context-Dependent

Temple (1998) elaborated that the "assumption that lies behind the [why-question] seems to combine a *motive* for asking the question in this way with an *expectation* about the sort of answer that is likely to be given" (p 150). The motive may not be immediately apparent as why-questions are particularly context-sensitive (Cox, 2019; van Fraassen; 1980) relating to both contrast (why this and not that) and domain sensitivity (what is an acceptable explanation in the relevant domain). Take the example from above. Depending on contrast, this question could be implicitly asking why "five" was added (rather than another number) or why the numbers were "added" (rather than another operation). Further, why-questions are domain dependent where adequate explanation depends on the relevant domain. While all of the why-questions in this project are in the context of a mathematics classroom, it is quite likely that the domain of explanation could vary based on norms (such as a procedure or conceptual focus).

Why-Questions as Implicit Requests for a Mathematical Justification

In mathematics education literature, why-questions are often treated as serving a particular motive: requesting a justification or proof which we call a *domain explanation.* A proof or justification can be thought of as a mathematical argument for why a particular mathematical claim is true using accepted premises, structures, and modes of argument (Stylianides, 2007). If we consider tools focused on teaching, we find "why" often plays this role explicitly or implicitly such as in EQUIP where teacher questions are categorized as *why*, *how*, *what*, or *other* (Reinholz & Shah, 2019) or Conner et al.'s (2014) collective argumentation framework where the questions: "Why?" or "Why doesn't that work?" are used to exemplify a request for a justification. Similarly, educators like Jones and Bush (1996) illustrate that why-questions are fundamentally linked to exploring mathematical structure. However, we conjecture that why-questions may not always be linked to the expectation of a mathematical domain explanation.

Why Questions are Not Always Requests for a Domain Explanation

While some philosophical (Sandborg, 1998) and empirical attempts (Stacey & Vincent, 2008) have been made to operationalize explanation in the domain of mathematics, they tend to stem from mathematician communities or mathematical text. Such explorations are likely to idealize mathematical explanation in ways that do not fully account for the types of explanations requested during conversation in a K-12 classroom. The literature about why-questions outside of the classroom point to a number of ways they are used in conversation including: serving the role of critiquing (Bolden & Robinson, 2011), rhetorical (Larrivée & Levillain, 2019), requesting a fact or process (Faye, 1999), or requesting an opinion (Mishra, & Jain, 2014). Further, the work on mathematical domain explanations (Sandborg, 1998; Stacey & Vincent, 2008) focus on

mathematical claims rather than why a student did a particular thing, a second-person perspective (Roessler, 2014) likely to exist in a classroom. Such why-questions in mathematics classrooms could reflect legal (why are we allowed to do that?) and strategic (why did you make that choice?) decisions (Chazan & Sandow, 2010).

The Project and Analyzing Why-Questions

In this report, we share an analysis of the why-questions teachers ask in mathematics lessons. Our data corpus includes 64 lessons (49 which had why-questions) from distinct teachers spanning two school districts in the United States. In district 1, a midsized urban district in the Pacific Northwest, we selected a stratified random sample of 33 4th and 5th grade lessons based on their Mathematical Quality of Instruction (Hill, 2014) score. In the second district in the Southwest, a large urban district, we included 31 middle school (5th-8th grade) mathematics. For each video, two coders identified any instance of a "generic why" – that is a why question coming from the teacher-to-student(s). The coders met and reconciled any differences. From this process, we identified a set of 152 instances of why-questions. For each why-question, a member of the research team wrote a memo containing context leading up to the why, a transcript of the why-question, and the student response. From the first twenty videos, two researchers took notes describing the evidenced purpose of the why-questions eventually leading to a framework including a number of dimensions: type of why (why, why not, why or why not; strategic, legal, peer-evaluation, or claim), conjectured expected student response (elaborated below), focal mathematical object, and who introduced the mathematical object (teacher, student, peer, class). The initial framework and categories were tested and refined based on the remaining data.

The Why of the Whys in the Mathematics Classroom

An overview of expected student responses can be found in Table 1. Notice that of the why-question, 55% aligned with an expected response in the mathematical domain—evidencing that why-questions do often serve the motive implicitly assigned to them of seeking a mathematical justification. However, 45% of the why-questions did not appear to seek mathematical-explanations reflecting substantial variation.

Table 1: Expected Student Responses

Non-Explanation (32%)		Non-Domain Explanation (13%)		Domain Explanation (Justification) (55%)			
No response (Rhetorical)	3%	Explain the process of arriving at an answer or step	6%	Argue for representational or numerical equivalence	9%	Argue that a mathematical claim (propositional) is true or false	8%
Correct an error or mistake	13 %	Explain a strategic choice or efficiency of approach	3%	Argue that an instantiation meets a definition	14 %	Argue for the Reasonableness of an Answer	3%
Refer to a rule/fact	16 %	Explain a linguistic or task context choice/feature	4%	Argue that a strategy is appropriate conceptually	15 %	Critique or debate a peer's contribution	7%

Table 2 illustrates several examples to contextualize some of these variations. The first example illustrates a why-question whose purpose aligns with students generating a mathematical explanation (justification) -- which is consistent with the implicit treatment of why

questions in the literature. In the second example, we see a teacher asking students to provide a fact that makes a procedural option invalid (a legal request). In the third example, the why-question does not seem to be requesting an explanation but rather is serving the purpose to notify the student of a mistake.

Table 2: Illustrative Examples

Description and context	Interpretation
The teacher asked whether each piece of a given shape is equal to 1/4 and students said, "No." So, the teacher said, "why not?" It was followed by the student's explanation, "because they are not even, these don't make a square."	**Type:** why not & claim **Expected response:** argue an instantiation meets a definition **Focal object:** concept
During whole class discussion, the teacher asked whether they can add 5/7 and 2/3 and students said "No." So, the teacher asked, "why not?" A student answered, "because they don't have the same denominator."	**Type:** why not & legal **Expected response:** refer to a rule/fact **Focal object:** procedure
Students are working in small groups on a problem involving elephants eating 150lbs per day, determining how much they eat in April. The teacher asks one of the groups, "So why did you divide these two numbers?" The student then attempts to explain their process, to which the teacher responds, "Are you sure you want to divide, though?"	**Type:** why & strategic **Expected Response:** correct a mistake **Focal object:** strategy to solve a problem

Discussion

In this brief report, we share our analysis of why-questions spanning a diverse set of mathematics classrooms. We found that the context-sensitivity of why-questions is apparent in the mathematics classroom discourse. While a particular question can appear similar in form, the expected student responses ranged significantly. With these results in mind, we argue for a few implications. First, as researchers, coarsely defining question types by categories such as "why" may be insufficient to tie a teacher-move to a particular purpose. Second, if we want why-questions to lead to students providing mathematical domain explanations (justifications), there is a need to better understand the necessary components for a why-question to be productive. Finally, the ambiguity of why-question can also lead to situations where students interpret why-questions as different from the teacher's intent. Such mismatches could lead to student responses being assessed as incorrect or incomplete (on exams or in conversation). As educators, we should be attentive to the very valid alternative way students can understand these types of questions, which this data suggests has its roots in how teachers likely vary in their intentions while using the same linguistic form.

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References

Boaler, J., & Brodie, K. (2004). The importance of depth and breadth in the analyses of teaching: A framework for analyzing teacher questions. Proceedings of the 26th meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education. Toronto, Ontario, Canada.

Bolden, G. B., & Robinson, J. D. (2011). Soliciting accounts with why-interrogatives in conversation. *Journal of Communication*, *61*(1), 94-119.

Chazan, D., & Sandow, D. (2011). Connecting Research to Teaching: Why Did You Do That?: Reasoning in Algebra Classrooms. *The Mathematics Teacher*, *104*(6), 460-464.

Cobb, P. (2002). Reasoning with tools and inscriptions. *Journal of the Learning Sciences*, *11*(2-3), 187-215.

Conner, A., Singletary, L. M., Smith, R. C., Wagner, P. A., & Francisco, R. T. (2014). Teacher support for collective argumentation: A framework for examining how teachers support students' engagement in mathematical activities. *Educational Studies in Mathematics*, *86*(3), 401-429.

Cox, R. (2019). How why-interrogatives work. *Synthese*, 1-38.

Franke, M. L., Webb, N. M., Chan, A. G., Ing, M., Freund, D., & Battey, D. (2009). Teacher questioning to elicit students' mathematical thinking in elementary school classrooms. *Journal of Teacher Education*, *60*(4), 380-392.

Hill, H. C. (2014). Mathematical Quality of Instruction (MQI): 4-point version. *Ann Arbor, MI: University of Michigan Learning Mathematics for Teaching Project*.

Jones, D., & Bush, W. S. (1996). Mathematical structures: answering the" why" questions. *The Mathematics Teacher*, *89*(9), 716-722.

Kawanaka, T., & Stigler, J. W. (1999). Teachers' use of questions in eighth-grade mathematics classrooms in Germany, Japan, and the United States. *Mathematical thinking and learning*, *1*(4), 255-278.

Larrivée, P., & Levillain, P. (2019) The real use of "special questions": a comparative corpus analysis. *CLUB*, 93

Melhuish, K., Strickland, S. Ellis, B., Han, S., Pham, A. & Thanheiser, E. (2020). Profiling productive mathematical teaching moves in 4th-8th mathematics classrooms. In A.I. Sacristán, J.C. Cortés-Zavala & P.M. Ruiz-Arias, (Eds.). Mathematics Education Across Cultures: Proceedings of the 42nd Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education, Mexico (pp. 2017 – 2025)..

Mishra, A., & Jain, S. K. (2014). An Approach for Computing Sentiment Polarity Analysis of Complex Why-type Questions on Product Review Sites. *Res. Comput. Sci.*, *84*, 65-76.

Reinholz, D. L., & Shah, N. (2018). Equity analytics: A methodological approach for quantifying participation patterns in mathematics classroom discourse. *Journal for Research in Mathematics Education*, *49*(2), 140-177.

Roessler, J. (2014). Reason explanation and the second-person perspective. *Philosophical Explorations*, *17*(3), 346-357.

Sahin, A., & Kulm, G. (2008). Sixth grade mathematics teachers' intentions and use of probing, guiding, and factual questions. *Journal of mathematics teacher education*, *11*(3), 221-241.

Sandborg, D. (1998). Mathematical explanation and the theory of why-questions. *The British journal for the philosophy of science*, *49*(4), 603-624.

Stacey, Kaye, and Jill Vincent. "Modes of reasoning in explanations in Australian eighth-grade mathematics textbooks." *Educational Studies in Mathematics* 72.3 (2009): 271-288.

Stylianides, A. L. (2007). Proof and proving in school mathematics. *Journal for research in Mathematics Education*, *38*(3), 289-321.

Temple, D. (1988). The contrast theory of why-questions. *Philosophy of Science*, *55*(1), 141-151.

van Fraassen, B. (1980). The scientific image. Oxford: Clarendon Press.