Journal of Mathematics Education
2025, Vol. 18, No. 1, 51-65

https://doi.org/10.26711/007577152790184

A Growth Storyline for Centering Children's Mathematical Thinking: A Grade 5 Case

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This case study illustrates one teacher's growth storyline over 3 years, with special attention to how and the extent to which she centered children's thinking in her instructional practices of noticing and questioning. Data were drawn from interviews and observations of Ms. B, who was a fifth-grade teacher during Years 1–2 of the study and a mathematics coach during Year 3. Overall, we found that children's thinking became increasingly centered in Ms. B's practice. Growth was incremental, but a strong catalyst came in the form of an "AHA moment"—she shifted her questioning goals from immediately getting children to correct answers and advanced strategies to understanding their existing thinking. Through multiple vignettes of Ms. B's growth, we provide illustrations of what centering children's thinking can look like when teachers are in the process of developing competency. Also shared are tensions teachers are likely to face, such as (a) uncertainty and discomfort with what it means to make sense of and center children's thinking and (b) conflict with existing practices that do not typically involve understanding children's thinking. Implications for practice and future research are considered.

Keywords: children's mathematical thinking, teacher learning, responsive teaching, noticing, questioning

This study is grounded in a vision of teaching that is responsive to children's mathematical thinking. In this vision, children's thinking about mathematical ideas is centered over teachers' ideas, and teachers consistently use children's thinking to decide what mathematics to pursue and how to pursue it during instruction (Bishop, 2021; Richards & Robertson, 2016). In other words, teachers not only attend to what children say and do, but they also honor children's thinking by exploring and building on it. Children are thereby provided with opportunities to engage in mathematics as a sensemaking activity, generate their own strategies (vs. practice teacher-demonstrated strategies), and develop trust in their own thinking (Battista, 2017).

Teaching that is responsive to children's thinking has widespread support in research and policy documents (National Council of Teachers of

Mathematics, 2014; National Research Council, 2001), but achieving competency is a challenging and long-term endeavor (Goldsmith et al., 2014). Research has provided snapshots of this type of teaching, but longitudinal illustrations are limited. In this study, we used a longitudinal lens to investigate one teacher's story as she grew in her ability to center children's thinking over 3 years, first as a teacher and then as a mathematics coach. We describe and illustrate her growth storyline as she moved toward teaching that is responsive to children's thinking.

Conceptual Background

Competency in teaching that is responsive to children's thinking depends on teachers' ability to consistently center children's thinking. This centering plays a role in numerous instructional practices, and we focused specifically on two foundational practices: noticing and questioning of children's mathematical thinking.

Teacher noticing refers to how teachers attend to and make sense of events in complex instructional environments. Research on this instructional practice has dramatically increased in the past two decades as has appreciation for the complexity and importance of teacher noticing as a core practice (e.g., König et al., 2022; Schack et al., 2017). However, teacher noticing is not uniform in nature. Noticing can have many foci, and high-quality instruction requires that teachers engage in many types of noticing. In this paper, consistent with our emphasis on centering children's thinking, we focus on professional noticing of children's mathematical thinking. This type of noticing involves attending to details in children's strategies, interpreting those details to identify the understandings they reflect, and then deciding how to respond on the basis of those understandings (Jacobs et al., 2010). Teacher noticing itself is an invisible practice, but it is also foundational for teachers' visible practices, such as posing questions.

Teacher questioning refers to teachers' contributions when interacting with one or more children, and it occurs throughout instruction, including in one-on-one conversations, small group work, and whole-class discussions. We use the term "questioning" broadly, such that teachers' contributions may be in the form of questions, statements, or series of exchanges. Questioning, in its many forms, has long been a focus of study, with research consistently highlighting its critical role in high-quality instruction (e.g., Boaler & Brodie, 2004; Chapin & O'Connor, 2007). We focus on a particular type of questioning—questioning designed to center children's thinking, such as eliciting, exploring, supporting, or extending children's thinking (Fraivillig et al., 1999; Franke et al., 2009). When teachers use this type of questioning, they do not follow a script and instead customize their questions to individual children and the details in what they say and do. For instance, a teacher might ask a child how they are making sense of a problem, how particular parts of

their representation link to what is happening in a story context, or how they decided on specific problem-solving steps in their strategy (Jacobs & Empson, 2016). This type of questioning centers children's thinking, which is in contrast to the well-known I-R-E (initiate-respond-evaluate) questioning pattern in which children talk, but the desired talk is determined by the teacher (Mehan, 1979).

Teacher noticing and questioning of children's thinking are foundational to teaching that is responsive to children's thinking, and they are intertwined. Teachers need to notice children's thinking prior to being able to pose questions grounded in that thinking. In this paper, we illustrate one teacher's growth storyline by highlighting her centering of children's thinking in her practices of noticing and questioning.

Methods

In this case study, we investigated how one teacher, Ms. B, noticed and questioned children's thinking over 3 years. The study took place in the context of a larger project—*Responsive Teaching in Elementary Mathematics* (RTEM)—which focused on the teaching and learning of fractions in upper elementary grades (Jacobs et al., 2019). We describe this context before presenting details of the current study.

RTEM Context

In the RTEM project, 92 teachers of grades 3–5 participated in professional development (PD) designed to develop competency in teaching that is responsive to children's thinking. Teachers came from three neighboring school districts in the southern United States, and they were divided into three PD cohorts of about 30 teachers each. Over 3 years, teachers completed more than 150 hours of face-to-face workshops and Collaborative Inquiry sessions between workshops. *Collaborative Inquiry* sessions were face-to-face conversations among pairs of teachers, guided by an online module. Prior to a session, the two teachers posed a common problem to their classes, and then during the session, engaged with each other about the details of children's thinking in written work from their classes and in video (or written work) provided in the module (Pynes et al., 2020).

The PD included a variety of activities to help teachers learn to center children's thinking. For instance, teachers engaged with research-based frameworks of children's thinking for problem solving (Carpenter et al., 2015; Empson & Levi, 2011), and they considered children's thinking linked to various types of story problems. Special attention was given to equal sharing problems given their foundational role in fraction instruction (e.g., *4 children equally share 10 cookies, how much cookie can each child get?*). Teachers also engaged with research-based frameworks of instructional practices, such as noticing children's thinking (Jacobs et al., 2010) and questioning children's

thinking (Franke et al., 2009; Jacobs & Empson, 2016). Further, teachers had opportunities to collaboratively work on their noticing and questioning in real time (when interacting with children) and with time for reflection (when exploring video and written work).

Participant

Ms. B had just completed her second year of teaching when she was selected as a case study teacher during the first week of PD. During Years 1–2, she taught fifth grade, and, during Year 3, she served as a school-based mathematics coach, mentoring other teachers by providing workshops and modeling or co-teaching lessons. Our analysis focused mostly on Ms. B's teaching, but we purposefully included her coaching to gain insight into how prominent children's thinking was in the instructional vision guiding her mentoring. Ms. B worked in a district that had a long history of supporting teaching that centered children's thinking, and the student population was essentially split between White (48%) and Hispanic (45%) students, with 61% of students qualifying for free or reduced-cost lunch, and 33% classified as Limited English Proficiency.

Data Sources

Data included field notes from 7 observations and audio-recordings of 19 semi-structured interviews (each about 30 minutes). Table 1 provides an overview of the timing for these data sources, and each is described below.

Table 1

Data Sources for Ms. B Across 3 Years

		Teacher		Coach
		Year 1	*Year 2*	*Year 3*
Observations (*N* = 7)		2	3	2
Interviews (*N* = 19)	*Linked to Observations*	2	3[a]	2
	Linked to Professional Practice	2	2	2
	Linked to Collaborative Inquiry Sessions	2	2	2

[a] Field notes for one observation in Year 2 were supplemented with a videorecording.

Observations and Post-Observation Interviews

For each teaching observation, Ms. B was observed teaching a fraction lesson that included at least one equal sharing problem of her choosing. Post-observation interviews focused on lesson details, with special attention to children's thinking in written work generated for the equal sharing problem. For her coaching observations, Ms. B was observed in a one-on-one mentoring session and in a district-wide meeting with other coaches. Post-observation interviews focused on what happened in the observation, with special attention to mentoring implications.

Professional Practice Interviews

When Ms. B was a classroom teacher, professional practice interviews addressed a lesson that involved any fraction story problem of her choosing. Focus was on details of children's thinking in their written work as well as Ms. B's decision making when selecting the story problem(s) for the lesson and children's written work for the whole-class discussion. When Ms. B was a coach, one professional practice interview focused on her perspectives comparing teaching and coaching and the other on her planning of a school-wide PD.

Collaborative Inquiry Interviews

The Collaborative Inquiry interviews focused on how Ms. B and her partner interacted and what they learned during the sessions. Details of children's thinking were addressed in relation to written work from their classrooms and the video (or written work) presented in the online module.

Analysis

We analyzed the observations and interviews to understand and characterize Ms. B's growth storyline. Given our vision of teaching, we specifically focused on how and the extent to which Ms. B centered children's thinking, with special attention to noticing and questioning children's thinking.

To construct Ms. B's growth storyline, we first identified instances of noticing and questioning children's thinking throughout the data. An instance was determined by a focus on an individual child's thinking, and it could be a single comment or a series of interactions. We then descriptively characterized what was happening in each instance in relation to the centering of children's thinking. Next, we focused on data from Years 1–2 when Ms. B was a teacher. We looked chronologically across instances to identify overall shifts in her instructional practice. By shifts, we mean increased centering of children's thinking in either quantity or depth. We then similarly considered the role that centering children's thinking played in her coaching in Year 3. Throughout analysis, we noted clear examples to serve as illustrations.

Trustworthiness of the findings was enhanced in three main ways (Tisdell et al., 2025). First, data were triangulated across a variety of data

sources—observations and different types of interviews. Second, triangulation also occurred across researchers through an iterative process of collaborative identification and characterization of instances and shifts. Third, data were collected over 3 years, which allowed for extensive engagement with Ms. B.

Findings

We present a longitudinal view of a teacher who grew to center children's thinking in her noticing and questioning. Ms. B immediately embraced RTEM's overall vision of teaching that is responsive to children's thinking. However, implementation took time and sometimes created tensions because Ms. B needed to develop new practices and confront existing practices that were inconsistent. Over the 3 years, Ms. B gradually shifted to increasingly center children's thinking, and we share this growth storyline chronologically.

Teaching Early in the PD

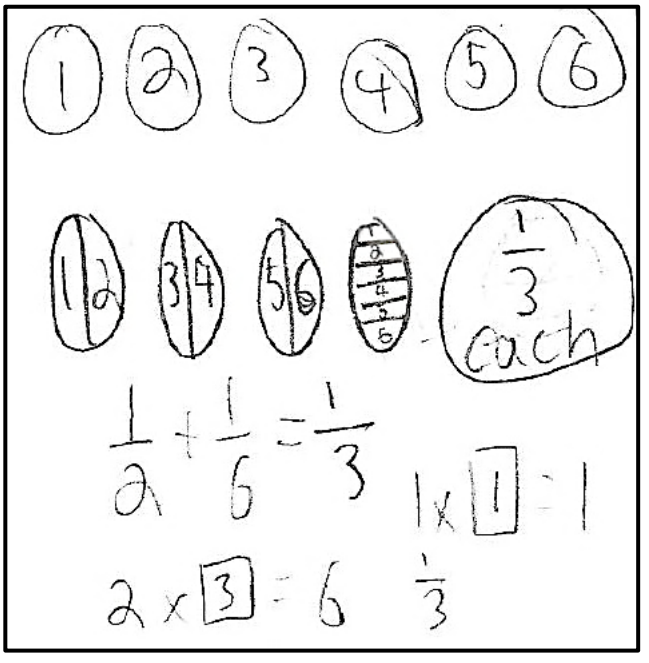
Ms. B's initial focus on children's thinking was narrow in scope. Rather than working to understand the thinking underlying children's strategies, she focused on what children did *not* do, typically intervening to fix incorrect strategies or press toward advanced strategies. For instance, consider Ms. B's rationale for selecting Jasper's strategy (Figure 1) for a whole-class discussion of this equal sharing problem: *6 children want to share 4 submarine sandwiches at the park, so that everyone gets the same amount. How much can each child have?*

Jasper used a common direct modeling strategy for equal sharing problems (Empson & Levi, 2011). He represented the 6 children and 4 sandwiches with circles, partitioned the first 3 sandwiches into halves and the last sandwich into sixths (although the 6 pieces were not equal in size), distributed pieces to children by numbering the pieces, and correctly determined that each child received 1/2 and 1/6 sandwich. He then struggled to combine 1/2 and 1/6 into a single amount, generating an incorrect answer of 1/3.

Despite his incorrect answer, Jasper had a valid model depicting the correct amount of sandwich per child and many other mathematically significant details. However, when Ms. B shared her reasoning for selecting Jasper's strategy for discussion, she minimized his sensemaking and instead focused on highlighting and fixing his partitioning and equation errors:

> I wanted to talk about how he split up his circle and just talk about how, is there another way to draw them, besides circles? And would it be easier to split up a rectangle? And talk about those pieces, and are they equal? Are they not equal? And then obviously Jasper's equations.

Figure 1
Jasper's Strategy for 6 Children Equally Sharing 4 Sandwiches



Ms. B's deficit focus was challenged by what she was learning in the PD, and although she appreciated the benefits of centering children's thinking, she struggled with implementation. For instance, she struggled with being patient with children's current strategies and understandings since she wanted them to advance quickly: "I feel like the first word problem…we have to get them to where they're [advanced]. And like tomorrow—during the discussion tomorrow—they have to get that!" She also struggled making sense of children's thinking, such as when she looked at children's written work:

> I've really been trying to take [written work] home and look through the work, and I don't know fully what I'm looking at yet. I'm trying, but I know there are some things that I'm still missing.

Centering children's thinking was even more uncomfortable during instructional interactions: "I think it just scares me that during discussion, it's all about listening and engagement, and that's like ahhhh!" However, toward the end of Year 1, Ms. B had an "AHA moment" that changed everything.

AHA Moment

Toward the end of Year 1, Ms. B shared a new realization that deeply affected her practice—her AHA Moment about questioning goals:

> The biggest thing I learned from [the PD] was not asking questions to get them to the answer so I could move them up a strategy, but to understand their thinking ... That literally changed my world. It changed everything.

Working to shift her questioning to understand, rather than change, children's thinking allowed Ms. B to increasingly center children's thinking. Note that this shift did not mean that Ms. B ignored incorrect answers or needed areas of strategy advancement. Instead, she developed a deeper appreciation for how understanding children's existing thinking could enhance her efforts to advance that thinking:

> When you start noticing their thinking, and not trying to push them to the answer, and then having good discussions on their thinking…it's easier to move them, whereas before I think I was so focused on them getting the right answer so that I could move them up a strategy.

Learning to question to understand children's thinking took time, but Ms. B recognized benefits even from her early efforts. For instance, she shared a story about Tasha who typically generated invalid strategies or no strategies at all during the whole first semester. Ms. B explained how she had been working to shift her questioning to try to understand Tasha's thinking:

> I've been asking her about her thinking and how she's thinking about it. I don't even think I've really given her any extra attention or anything like that. I have just simply, when she's at that breaking point of not understanding, I've asked her about her thinking.

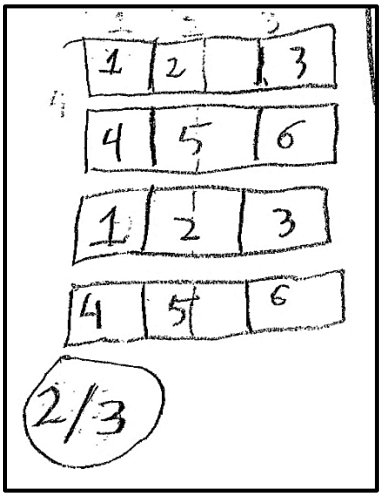
As a result, Tasha's recent problem solving had included some valid strategies, correct answers, and even explanations of her thinking. Ms. B shared her amazement at the effect of this seemingly minor shift in her questioning: "It blew my mind! Where did that come from? … Questioning their thinking, even in discussion, has been a life changer for me." In the next section, we elaborate on how, over time, Ms. B built on her AHA moment about questioning goals, further centering children's thinking in her noticing and questioning.

Teaching After the AHA Moment: Centering Children's Thinking

After her AHA Moment, Ms. B chose to work with a coach on adjusting her questioning to better understand children's underlying thinking. Further, her excitement about the details in children's strategies grew and were visible in

her noticing and questioning. Consider her comments about Milo's strategy (Figure 2) for this equal sharing problem: *6 friends wanted to have some granola bars for a snack. They had 4 granola bars to share equally. How much granola bar can each friend have?*

Figure 2
Milo's Strategy for 6 Friends Equally Sharing 4 Granola Bars



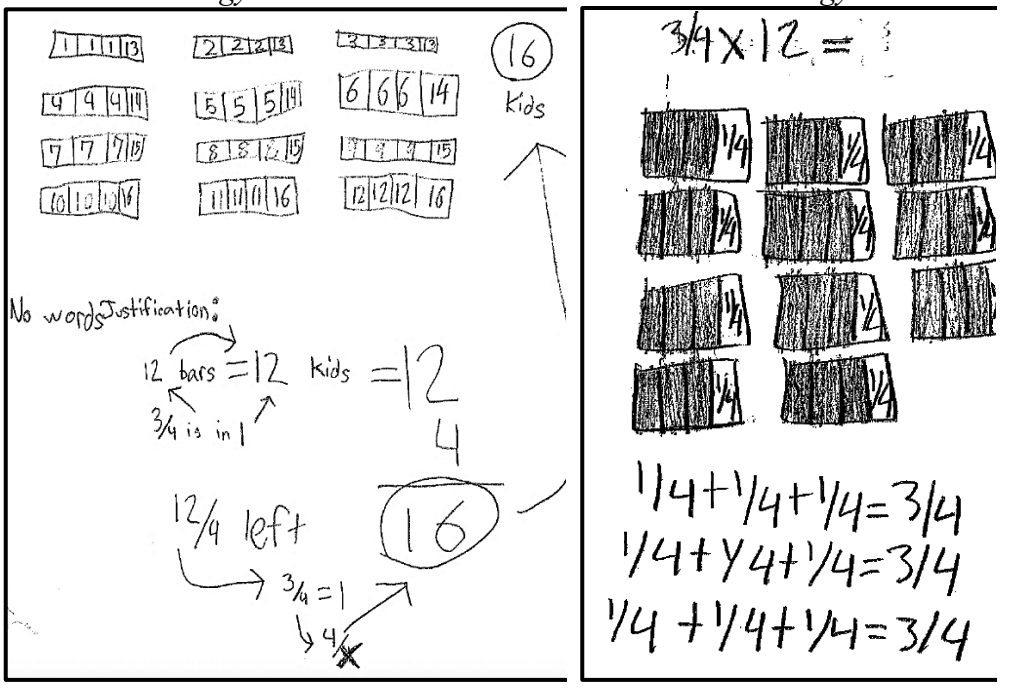
Ms. B excitedly noticed that Milo had partitioned each granola bar into thirds (unlike the rest of the class which had generally partitioned using sixths), and he had also revised his partitioning during problem solving:

> I really like to dive in and think about it and look at what the kids did. And like one of my kids, Milo—he was my only kid to divide [4 granola bars] into thirds. And I was like—that was so cool! He thought about it! He first divided it into fourths and then he went back and said, "Wait a second, I can do it with thirds."

We share another set of vignettes to illustrate how Ms. B's centering of children's thinking in her noticing and questioning occurred across strategies regardless of their stage of completion. Consider her comments about two children's strategies—one with a correct answer and one without an answer—for this measurement division problem: *Divine has 12 giant chocolate bars to share with the kids on her soccer team. She wants to give each person 3/4 of a bar of chocolate. How many kids will she be able to give chocolate to before she runs out?* (Figure 3).

Figure 3
Children's Strategies for 12 Giant Chocolate Bars Divided into Servings of 3/4 Chocolate Bar

Dominic's Strategy *Alexandra's Strategy*



Dominic and Alexandra both represented the chocolate bars and partitioned them into fourths, but Alexandra had a miscount, representing only 11 chocolate bars instead of 12. Both children distributed 3 one-fourth pieces of chocolate from each chocolate bar before collecting the extra one-fourth piece from each chocolate bar to continue distributing servings of three-fourths. Dominic distributed by numbering each piece with the number of the kid who would receive that piece, and he correctly determined that 16 kids could receive chocolate bars. Alexandra shaded the first three-fourths in each bar as one serving before using equations to represent the extra one-fourths as three-fourth servings (1/4 + 1/4 + 1/4 = 3/4). She did not complete her distribution, provide a final answer, or clarify her unfinished equation (3/4 × 12 = __).

These two strategies contrasted with a more common strategy in Ms. B's class in which children continuously distributed pieces, so that the first kid received the first three pieces in the first chocolate bar, the second kid received the last piece in the first chocolate bar and the first two pieces in the second chocolate bar, and so on. Thus, Ms. B shared her curiosity about Dominic's distribution:

> I thought it was interesting that he did 1, 1, 1, and then 2, 2, 2 in the next whole, and then 3, 3, 3, and then 4, 4, 4 in the fourth whole, and then went back at the end, and counted all the ones left over.

Ms. B then built on her noticing of Dominic's distribution details to make sense of the bottom part of his strategy in which he determined the number of kids who would get chocolate:

> He's saying 3/4 is in 1 whole bar, and then below that, he said 12/4 is left. So, like he knew that 12/4 were left over cause 1/4 in each bar was left over, so he knew 12/4 was left over. And then if 3/4 [chocolate bar] equals 1 [serving] then that's 12 kids. 12/4 left over and there's 4 three-fourths in 12 [fourths], so 12 plus 4 is 16 [kids].

Ms. B noticed and made sense of details in Dominic's unconventional representation, and she also wanted to understand more about his thinking. She proposed this follow-up question for him: "How did you know that there were 4 three-fourths in 12/4?" Unlike her typical questioning prior to her AHA Moment, Ms. B did not immediately try to advance Dominic's strategy to, for instance, a more conventional representation, but instead delved deeper into his existing strategy to elicit his understanding of a mathematically significant relationship he had generated—the relationship between 12 fourths and 4 three-fourth servings.

Ms. B demonstrated a similar focus on strategy details when talking about Alexandra's strategy that was incomplete and had some minor errors. Notably, Ms. B recognized, but did not emphasize, these errors, nor did she share how she planned to correct them, as she might have before her AHA moment. Instead, she appreciated how the equations captured the combining of 3 one-fourths into additional servings, as that step was new for Alexandra:

> Her equation [for the problem] is wrong, but the fact that she went through and remembered to count the [extra] 1/4s and then added [the 1/4s] to 3/4 at the bottom is absolutely huge. Like huge for her!

Ms. B also used details in Alexandra's partial strategy as a starting point to delve deeper into her existing strategy: "You have it right here. Now we just have to figure out how to interpret it." These short vignettes provide a glimpse into how Ms. B's noticing and questioning reflected her increasing centering of children's thinking.

Coaching Other Teachers

Ms. B's shift to centering children's thinking in her own teaching provided the inspiration for her mentoring—she wanted other teachers to make the same shift. For instance, although Ms. B had initially struggled to make sense of children's thinking in their written work, she now felt more confident in her ability to do so: "That's been the biggest growing for me over the past 2 years, how to look at your students' work." As a coach, Ms. B identified noticing children's thinking in written work as a mentoring focus:

> Asking teachers, "What do you see?" Helping teachers to notice what they see in their students' work…Analyze what kids are doing, their thinking. This has been my go-to—noticing student work.

She worked with individual teachers, encouraging them to notice children's thinking: "For the first 2 weeks, I just want you to notice. I want you to be able to come to me and say here are some things I notice about my kids' work." She also worked with grade-level teams. Teachers brought written work to their planning sessions, and together they noticed children's thinking—they discussed details of what children did, interpreted what those details indicated about children's understandings, and considered what they might do next. Inspired by her own AHA moment about questioning goals, Ms. B invited teachers to generate follow-up questions to *understand* children's thinking, not to move them to correct answers or advanced strategies.

Ms. B also modeled questioning in teachers' classrooms, and teachers often commented on the effectiveness of her questions, inquiring how she generated them. Ms. B typically responded by highlighting her centering of children's thinking:

> That continuum of going back to the problem, then generally asking [children] what they did, and then asking them more specific questions about why they did what they did, and then finally asking them questions to extend their thinking.

Accompanying this commitment to centering children's thinking was an appreciation for the tensions along this journey, especially given teachers' limited time, "It's harder than it seems for teachers to just start exploring students' ideas."

Concluding Thoughts

This case study presented one teacher's growth storyline as she worked toward competency with teaching that is responsive to children's mathematical thinking. Special attention was paid to how she centered

children's thinking in her noticing and questioning. Our use of a longitudinal lens, with multiple vignettes, addressed an under-researched area, and we highlight three main contributions.

First, we provided illustrations of what centering children's thinking can look like when teachers are in the process of developing competency. For instance, Ms. B showed increasing curiosity about the details of children's thinking in their strategies as well as an increasing ability to make sense of them. She also showed increasing use of these details as a starting point for follow-up questions rather than formulating follow-up questions only to achieve correct answers or desired strategies.

Second, we identified a pivotal AHA moment in Ms. B's growth storyline—appreciation of the need to shift her questioning goals from getting children to correct answers and advanced strategies to understanding children's existing thinking. This seemingly small shift was a catalyst for Ms. B's growth, and she regularly referenced this AHA moment during Years 2–3.

Third, we identified several tensions teachers are likely to face when learning to center children's thinking. For instance, Ms. B experienced uncertainty and discomfort with what it meant to make sense of and center children's thinking. She also experienced conflict between her intentions to understand children's thinking and the pressure she felt to fix errors and move to advanced strategies.

All three contributions not only enhance our understanding of developing competency in teaching that is responsive to children's thinking, but they also have practical implications. For instance, PD facilitators could share Ms. B's illustrations, her AHA moment about questioning goals, and the tensions she faced. Sharing this information could help teachers imagine how they could center children's thinking in their own classrooms and appreciate the complexity in doing so. Additional longitudinal research is also needed to explore the growth storylines of a larger number of teachers to provide other illustrations and to potentially reveal important variations in these storylines. Finally, we note that the development of centering children's thinking is an incremental, multi-year journey (see also, Goldsmith et al., 2014), yet the journey is worthwhile because the benefits are far-reaching and generative (Franke et al., 2001). When teachers learn how to center children's thinking, they have regular opportunities to learn from the thinking of children in their classrooms, and thus children's thinking can provide a constant source of PD throughout teachers' careers.

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Author Note
This research was supported in part by the National Science Foundation (DRL–1316653 and 1712560). The opinions expressed do not necessarily reflect the position, policy, or endorsement of the supporting agency. We would like to thank Ms. B for her collaboration and for sharing her journey with us.