Entailments of questions and questioning practices in ambitious mathematics teaching

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The work of teaching mathematics is complex and involves numerous problems and challenges for teachers to handle. Questioning is a slice of mathematics teaching that is both common and challenging. In this paper, we use the context of collective planning in a Norwegian professional development initiative as a space for investigating questions and questioning practices in ambitious mathematics teaching. Based on analysis of nine co-planning sessions, which were carried out over the course of two years, we suggest that questioning practices involve considerations of: 1) what types of questions to ask, 2) purpose of questions and questioning, and 3) timing of questioning. Based on our conceptual framework, we propose a fourth logical entailment relating to the positionality of students, and we suggest that further research is needed to explore this entailment.

Keywords: Questioning, planning, mathematics teaching, interactions.

Introduction

More than a century ago, in her seminal study of questions as a measure of effective teaching, Stevens (1912) investigated if the number of questions asked by teachers could serve as a proxy for efficiency in instruction. Interestingly, she found that it was also necessary to consider the quality of questions. Based on observations across different subjects, Stevens identified three elements of questioning that indicate quality: questions have to stimulate reflection, they must be adapted to students' experience, and questions must aim at moving students' thinking forward. Despite an increasing number of studies of teacher questions and questioning practices, Gall (1970, p. 707) introduced her review of research on the use of questions in teaching by stating that even though everyone agrees that questions are important in teaching, "researchers still do not know much about them. What educational objectives can questions help students to achieve? What are the criteria of an effective question and how can effective questions be identified?" As evident from the review of Gall, as well as from other reviews of research on questions and questioning in (mathematics) education, studies tend to highlight either how questions are used in the classroom (e.g., Gall, 1970), or what constitutes effective questions and questioning practices (e.g., Shahrill, 2013; Wilen & Clegg, 1986). In other words, studies often have a similar focus to the seminal study of Stevens (1912).

Following recent discussions in Thematic Working Group 19 (TWG19), this study attempts to shift focus from *what teachers do* to consider teaching as a *work to be done*. Instead of focusing on activities performed by teachers – and their effects on student learning — we follow Ball (2017) in our attempt to investigate what constitutes the special work of teaching mathematics, and we seek to explore and understand the entailments of this work. In particular, we focus on questioning practices, which constitutes a slice of the work of teaching. Whereas Stevens (1912) focused on questioning in

recitation, we focus on questioning in discussions within the context of ambitious mathematics teaching when we approach the following research question:

What can be entailed by questions and questioning practices in ambitious mathematics teaching?

Our use of the word 'entail' indicates that something is logically involved or necessitated, and it points toward a view of teaching as work, which implies that it is something to be done, or task(s) to be undertaken (Work, n.d., para. 3). When we use the term 'questions and questioning practices', we follow Enright et al. (2016), who use the term with reference to a collection of practices that are carried out within the teaching profession.

Conceptual framework

This study draws on a conceptualization of teaching as instructional interactions that are collaboratively constructed between teacher and students around a particular content, and situated in broader environments (Cohen et al., 2003). Mathematics teaching can never be considered as transmission of content in isolation, but it is "co-constructed in classrooms through a dynamic interplay of relationships, situated in broad socio-political, historical, economic, cultural, community, and family environments" (Ball, 2017, p. 15). In addition, we draw on the notion of teaching as work, as described by Ball (2017) and Lampert (2010). Following their interpretation of the work of teaching, we consider teaching as a complex work that entails many demands and dilemmas that teachers must manage. A study of the work of teaching mathematics, in this sense, thus involves efforts to identify and understand these demands and dilemmas, rather than describing what teachers do and attempting to make sense of these actions.

Our study also draws on a conceptualization of ambitious mathematics teaching where students' emerging mathematical thinking and sensemaking is at the forefront. Ambitious mathematics teaching aims at positioning students as sense-makers and provide equitable access to learning. To achieve these aims, ambitious mathematics teaching typically includes facilitation of mathematical discussions that elicit and build on students' thinking (Kazemi & Hintz, 2014). The study draws on data from a larger project, called Mastering Ambitious Mathematics teaching (MAM). This project is organized around cycles of enactment and investigation, and it is inspired by similar projects in the United States (e.g., Lampert et al., 2013).

Methods

Thirty Norwegian elementary teachers participated in the project. In the cycles, teachers were divided into four groups. We analyze data from one group of eight teachers in the present study. The groups participated in 12 sessions over a period of two years, and nine sessions were organized around learning cycles that include the following phases: 1) *Preparation* that involved reading and watching videos; 2) *Collective analysis* guided by a teacher educator around principles and practices central to the instructional activity; 3) *Co-planning* of the instructional activity; 4) *Rehearsal* where one or two teachers tried out the activity with colleagues acting as students; 5) *Enactment* of the instructional activity by the same teacher with a group of students (age 11–12); 6) *Collective analysis* that included reflections on how the principles and practices had worked out. We anticipated that experienced

demands and dilemmas would become most visible in the planning phase, so our focus here is therefore on the third phase of the learning cycles.

We analyzed nine co-planning sessions using Sportscode video analysis software, which allowed for direct coding on the videos. Initial deductive coding followed an adapted version of the discussion planning framework of Boerst et al. (2011). We then conducted inductive coding of the segments that were coded as *questioning* in the initial coding phase, with an emphasis on trying to identify tasks that are entailed in the work. Instead of asking what teachers did, and what they discussed in the planning sessions, we asked what kinds of problems, dilemmas, or decisions they were faced with. Three categories emerged from the inductive coding, and these are presented and discussed below.

Entailments of questions and questioning practices

In the following, we present excerpts from our data material to illustrate and discuss the proposed categories of entailments.

Considering type of question to ask

In the planning sessions, we observed several instances where the group engaged in discussion of what questions they could ask students. This is not surprising, as questions abound in mathematics lessons; when teachers want to guide students in a certain direction, they often try to use questions instead of teaching by telling.

In the second session, when the teachers planned an activity using quick images, they discussed the challenge of stimulating the students to identify a certain pattern. One teacher suggested that they could ask: "How can you use the 4 times table to get the first number? In other words, how can you get 5 as an answer when you have to use the 4 times table." Another teacher commented that this is hard for students, both to visualize and discuss. One of the teacher educators in the group interrupted,

> TE1: Yes, but let's try to come up with a really good question that helps the students understand where we want to go, shall we? Because this is really where we are at, right. If we want them to discuss this, which we might not want to eventually, but if we want them to discuss this…

This was one of several instances where the teachers discussed how to use questioning to guide the students in a particular direction, which is a task that is entailed in the work. In this case, the teachers wanted to help the students discover the pattern of $4n + 1$. From the teacher educator's reference to "a really good question", and from the overall discussion, it appears that the aim here was to identify a particular question that could work as a prompt to stimulate exploration through discussion, rather than to check students' understanding, as in recitation.

Although the primary focus in this discussion seemed to be on finding the best question to ask, we notice that there is also an embedded focus on purpose. This leads to the next, and tightly related, kind of entailment that teachers are faced with in questioning practices.

Considering purpose of questions and questioning

Another entailment is thus to consider the purpose of questions and questioning practices. For instance, teachers can consider how to formulate a question to stimulate students' thinking. We noticed that this is also at play in the above discussion of the type of question to ask. In another

session, the teachers discussed how they wanted students to discover connections between a string of tasks, but they hesitated to ask the students straight away if they could see any connections. One teacher reflected, "So, we want to tell them: I want you to consider these numbers now. Do you see any connection between them?" Then she added, "Is it wrong to be so direct about it?" The teacher educator affirmed that they could ask students directly if they could see any connections, but this challenge of how direct they should be, and what kind of questions they should ask, persisted.

As the teachers continued to discuss this, the issue of whether to use an open question came up.

T1: When we say, in the context of 4000 divided by 160, we could ask: Do you see a connection with the previous task? 400 divided by 16.
T2: Should we say that?
T1: Well, if we say that, they have to consider it for a while, and then they will notice that both are multiplied by 10. And, what do you think happens there?
T3: That is kind of more open. If you consider these expressions, what do you think about?

Although this appears to be another example of considering what type of question to ask, we notice an underlying challenge relating to purpose here. The task of deciding on a type of question to ask is thus entailed by considering the purpose of stimulating students' thinking, which is important in ambitious mathematics teaching. Sometimes teachers consider using an open question to allow for more creativity and exploration, but, at other times, they might consider using a more closed and directive question to check on students' understanding. This choice depends on the purpose.

Considering order and timing of questioning

A third entailment of questions and questioning practices relates to timing. In direct response to the discussion above, T2 asked: "But do you think we should say that first? Should we begin by asking if they see a connection, or should we let them think for a little while first, before we hook them on?" This points at two considerations that need to be made in questioning practices: one concerning the *order* of questions, and another concerning the *timing* in the sense of finding the exact right moment to ask a question. If the overall aim of an activity is to stimulate exploration, which is prominent in ambitious mathematics teaching, teachers might want to start by asking a more open question, before asking for connections more directly. T2 seemed to be conscious about this challenge. When one of the other teachers moved on without responding, he continued to press for reflections about this: "But should we ask them: Do you see a connection with the previous task? Or should we allow them to think a little bit on their own first, to see if someone actually discovers it … before we hook them on?" On the one hand, we notice that this comment is indicative of a challenge concerning the order of questions. On the other hand, there appears to be an entailed issue concerning timing, both with respect to timing of the questions in the overall trajectory of the class, but there is also an entailed challenge of how long to wait before providing the students with a more directed question.

The discussion of order and timing above relates to a situation that the teacher controls. Deciding what question to ask first or how long students may think before posing a more directive question, are both examples of issues that teachers can consider beforehand, as they plan the lesson. However, in a classroom with real students, unexpected situations often occur. For instance, a student might

immediately come up with a solution that ends the discussion prematurely. This kind of situation was discussed in the third session, where the teachers planned an activity on quick images (see Figure 1).

TE1: What do we ask if this [pattern] comes up quickly?
T1: This relates to our previous discussion about how 9 can be represented in different ways. So it might be a good idea to bring up that one in addition, showing that they are almost similar. Perhaps put this [pattern] below the other one.
TE1: But what if someone says 3 times 9? Yeah, that was nice. Then the discussion is kind of over. What kind of questions do we ask then, in order to move on?

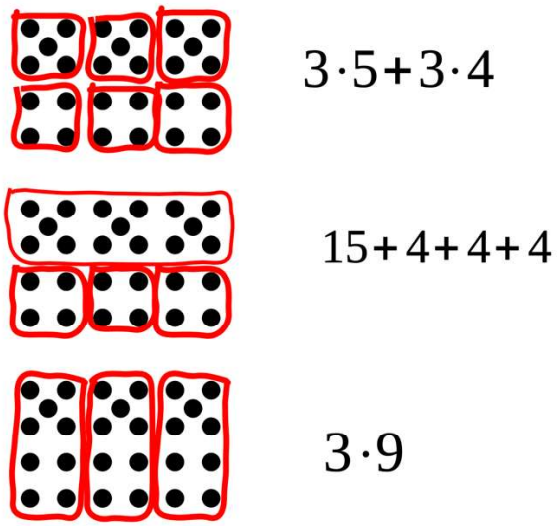

Figure 1: Reconstruction of some of the teachers' annotations on the quick images discussed

This question was followed by a pause in the conversation, indicating that it was considered a dilemma by the teachers. One of the teachers followed up, suggesting that they could prompt the students to explain their thinking, and show the others how they see the 9 in this representation. This suggestion corresponds with the literature on cognitively guided instruction (e.g., Carpenter et al., 2015), and points at eliciting students' thinking. The initial issue of timing in questioning is thus related to the more foundational question about purpose of questions and questioning practices.

Discussion

In her review of research on questioning, Gall (1970) emphasized the *type* of questions being asked, and Stevens (1912) focused on type of questions as well as the number of questions that were asked. Early studies of questioning in teaching had less emphasis, however, on the *purpose* and functions of questions, and they did not emphasize *timing* of teacher questioning. Yet, we can recognize some of these as underlying perspectives in many studies of teacher questioning. Another important difference between our study and other studies of teacher questioning is that most other studies focus on what teachers *do* – what types of questions they ask, what purpose their questioning has, and how their timing of questioning influences students' learning – and not on the entailments of the work of questioning. In the following, we discuss results from our study in relation to previous research, and in relation to our conceptual framework. Analyses of what teachers do often end up in evaluation of their performance, attempts to explain why they performed in a certain way, or in efforts to measure the effects of their performance on students' learning. As opposed to this, analysis of teaching as

work tends to focus on understanding the complexity and entailments of teaching and its demands. Such analysis thus contributes to unpacking and conceptualizing the work of teaching, and it may also contribute to developing a much-needed professional language to describe this work.

Every review of questioning in teaching that we have seen involves a focus on types of questions that teachers ask. In her review of the use of questions in teaching, Gall (1970) notes that studies have used different taxonomies for classifying types of questions. She highlights Bloom's taxonomy as the one that "best represents the commonalities that exist among the systems" (p. 710). Later reviews, both in general education and in mathematics education, also highlight the importance of considering cognitive levels of questions (e.g., Shahrill, 2013; Wilen & Clegg, 1986). With respect to the instructional triangle, considering the type of question to ask relates to what is described in the triangle as interactions between teachers and students. In ambitious mathematics teaching, deciding on the type of question to ask is particularly important. Whereas use of questions might be appropriate to check on students' understanding, it can be challenging to decide on a good question to prompt discussion.

Considering the purpose and function is another entailment of questions and questioning practices, and Enright et al. (2016) unpacked this entailment in their attempt to develop a typology of questions by instructional function — also by applying the instructional triangle as conceptual framework. Whereas teachers in the context of planning would typically consider the purpose of questions and questioning, the entailments that teachers are faced with inside of the instructional interactions would often be more related to considering the functions of questions. Consideration of purpose and functions of questions would often be located along the axis of interactions between teachers and content, for instance when considering purpose in relation to the learning goal for the lesson. However, purpose and function of questions might also involve considerations around what types of interactions between students and content that teachers wish to facilitate. For instance, teachers might decide to use open questions or why-questions when they aim at facilitating a discussion, whereas more closed questions or what-questions might lead to recitation. Ambitious mathematics teaching aims at facilitating discussions that elicit and build on students' mathematical thinking (Kazemi & Hintz, 2014), and our analysis illustrates some of the challenges teachers are faced with when trying to build on students' thinking without being too directive. This balancing of drawing on students' thinking while at the same time leading a class toward a mathematical goal may constitute a dilemma.

Entailments of considering order and timing of questions might involve similar considerations as those teachers have to make in the context of purpose and function. One aspect of timing that has frequently been described in research on questions and questioning is wait time (e.g., Shahrill, 2013; Wilen & Clegg, 1986), and this was also visible in the planning discussions we analyzed. Considering what is the appropriate time to pose a question has been less focused on in previous research, but it is also something teachers need to consider when interacting with students. Our analysis also indicates that considerations of order and timing of questions and questioning might constitute a task of teaching that is particularly pressing in the context of ambitious mathematics teaching. As one of the teachers noted, a student might come up with a response that are perceived by the class to end the discussion, and the teacher is then faced with a considerable challenge of coming up with a follow-up question or prompt to move the discussion forward.

All three entailments of questions and questioning practices that we have identified thus appear to fit well within the instructional triangle, and we have discussed above how these entailments are particularly pressing in the context of ambitious mathematics teaching. What we did not observe in our analysis of planning sessions, and what we have not seen much of in other studies, are considerations around interactions with environments with respect to questions and questioning practices. Recent studies of the work of teaching mathematics that build on the conceptual frames of the instructional triangle have explored interactions with environment in terms of considering identity and positioning of students. For instance, in her discussion of what constitutes the mathematical work of teaching, Ball (2017, p. 17) states:

> Central to bear in mind is an inherent fact of teaching, namely, that teachers are always communicating, relating, and making sense across differences, including differences in age, gender identities, race and ethnicity, culture and religion, language, and experience. This important dimension of difference in identity and positionality means that a fundamental part of the work of teaching is being aware of and oriented to learning about and coordinating others' perspectives.

Thus, a logical entailment of questions and questioning practices would be to also consider identity and positioning. As can be seen from the quote above, such considerations tap into interactions with environments and is a fundamental — but often overlooked — part of the work of teaching mathematics. There are a couple of possible reasons why positionality did not emerge as a category from our analysis. On the one hand, it might be a feature of the project. The teachers in the MAM project engaged in cycles of planning and enactment in a context where they did not know the students. When planning the activities, they had to make assumptions about students, since they did not know what students they would encounter before the enactment phase. In a context when teachers do not know their students, they might not be expected to consider positionality, which requires knowledge of students and their identities. On the other hand, the lack of emphasis on positionality in planning of these instructional activities might also indicate a general lack of emphasis on positionality among (these) Norwegian mathematics teachers. If that is the case, it is even more important to emphasize this — both as a fundamental part of the work of teaching mathematics, and as a fundamental part of questions and questioning practices in mathematics teaching. We believe that considering *positionality* might constitute a fourth entailment of questions and questioning practices in mathematics teaching, and we call for future studies to investigate it. This is particularly important in the context of ambitious mathematics teaching, which aims at positioning students as sense-makers and provide equitable access to learning mathematics (Kazemi & Hintz, 2014). There is thus a need to explore what this might look like in questions and questioning practices.

Conclusion

Questions and questioning practices in teaching have been studied for more than a century. Whereas much research has focused on how teachers use questions and the effects of these questioning practices on student learning, we propose to instead focus on trying to understand what might be entailed in questions and questioning practices — considered as a slice of the professional work of teaching mathematics. From our analysis of teacher planning sessions, we identified three entailments that relate to considering what *types* of questions to ask, the *purpose* of asking questions, and the

timing of questioning, which includes considering both the order of questions and deciding on the right moment to ask questions. In addition, we suggest that a fourth entailment is also involved in questions and questioning practices: considering *positionality* of students through questioning practices. This involves attending carefully to how teachers' questions and questioning practices can contribute to providing equitable access for all students and thus serve as part of an overall effort toward justice and inclusion — in school, but also in the society at large.

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