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Following up: Questions and Talk Moves in Preservice Teachers' Mathematics Classroom Conversations

Hege Myklebust*
Western Norway University of Applied Sciences, NORWAY

Maru Alamirew Guadie
Western Norway University of Applied Sciences, NORWAY

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Abstract: Our research aim is to describe how Preservice Teachers (PSTs) can rehearse and prepare for leading productive talks in mathematics and other subjects. Based on literature and previous research on what constitutes productive talks, we focus on questions and talk moves in this case study, where we follow three groups of PSTs during their practicum, practicing conducting productive talks in mathematics. Our research questions are: What kinds of questions do PSTs ask? What kinds of talk moves do they use? How do these questions and talk moves contribute to the PSTs breaking the IRE (Initiation–Response–Evaluation) pattern and moving towards more productive mathematics talks with complex exchanges of questions and responses? And furthermore: How can we use these findings to improve teacher education in this field? We find that leading productive talks in the mathematics classroom is a challenging task, but there is variation between our three groups in what they struggle with. In accordance with previous research, we also find that the third turn in the exchange, following up after a question and a response is a crucial point in the conversation. One recommendation for teacher education is that video filming and analysing classroom talks might help PSTs to become conscious of and improve on this point. Further research is needed both on long term effect of such practice and focus, and on other ways to improve classroom talks in mathematics and other subjects.

Keywords: *Dialogic teaching, mathematics classroom conversations, preservice teachers, question types, talk moves.*

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Introduction

Several decades of international research suggests that a dialogical pedagogy where classroom conversations with substantial contributions from both students and teachers can enhance learning and at the same time develop students' ability to argue, reason and think (Alexander, 2017; Hardman, 2019; Michaels & O'Connor, 2015; Nystrand, 1997; Resnick et al., 2018). Even so, studies show that the most common form of classroom talk still is the IRE-exchange (Initiation–Response–Evaluation), where the teacher asks a question (I) with the intent to check if the student can (re)produce the correct answer, the student responds (R), and the teacher evaluates the response (E) (Hardman, 2019; Lehesvuori, 2013; Wilkinson et al., 2017). Chapin et al. (2009) described talk as productive in mathematics classes when it is used to strengthen students' mathematical thinking and reasoning. Leading such productive talks requires complex competencies, and in our research project, we introduce the preservice teachers (PSTs) to the theories of dialogic teaching and give them study tasks to rehearse their skills, with a long-term aim to develop teacher education in this area.

Hardman (2019) states:

> Despite the growing body of evidence showing that a dialogic pedagogy can improve student learning outcomes and social-emotional well-being, research into its implementation suggests teachers have found it difficult in practice and that it is rarely observed in the classroom (Hardman, 2019, p. 152).

Hardman points out that the main problem seems to be finding ways of following up a student response in such a way that the student is encouraged to expand or explain their thinking, rather than just recite someone else's thinking. We wish to draw attention to this problem by studying PSTs' first efforts to lead productive mathematics classroom

* **Corresponding author:**
Hege Myklebust, Western Norway University of Applied Sciences, Norway. ✉ maru.guadie@hvl.no

conversation. Teacher educators do not expect first-year students to master productive talks from their first attempt but aim to encourage them to break the IRE pattern and take steps towards more productive classroom talks.

It seems that conducting such productive talks is seen as inherently difficult by many teachers, and to implement new ways of talking with students, it is necessary to break the task down into smaller elements which can be rehearsed and practised. This is what we are working on in the research project *Arbeidskravprosjektet* [the study task project] at Western Norway University of Applied Sciences, where we focus on leading classroom talks inspired by *dialogic teaching* (Alexander, 2017, 2020), *dialogic education* (Cui & Teo, 2021), *accountable talk* (Michaels et al., 2008), and similar theories (Kim & Wilkinson, 2019). The project is a collaboration between the subjects of mathematics, Norwegian, and pedagogy, where the Preservice teachers (PSTs) are given study tasks to plan, rehearse and practice dialogic education in the subjects.

The talk moves and question types on which we focus here are chosen because previous research have pointed to them as important for productive classroom conversation, and they are presented to the PSTs in their mathematics textbook (Solem et al., 2017) and in their mathematics classes. In their classes at the teacher education institution before their practicum, the PSTs are also taught about productive talks and breaking the IRE pattern.

This study aims to answer the following research questions: What kinds of questions do PSTs ask? What kinds of talk moves do they use? How do these questions and talk moves contribute to the PSTs breaking the IRE pattern and moving towards more productive mathematics talks with complex exchanges of questions and responses? And furthermore: How can we use these findings to improve teacher education in this field?

Even though there is a lot of research on the benefits of dialogic education, not much attention has been paid to the process of enabling new teachers to facilitate such education. We believe teacher education needs to address this and our study can contribute with some understanding of the challenges and experiences of PSTs preparing for their future work as dialogic educators.

Literature Review

One of the first attempts to create a system for analysis of classroom discourse was made in 1975 (Sinclair & Coulthard, 1992). They launched the "Birmingham Discourse Analysis System" as grounds for both analysing classroom discourse and as a tool for planning lessons. They suggest a rank scale of analytical units "in which a unit at a given rank […] is made up of one or more units of the rank below […] and combines with other units at the same rank to make one unit at the rank above" (Sinclair & Coulthard, 1992, p. 2). They suggest this rank scale for analysis of discourse: Lesson – transaction – exchange – move – act. In a lesson, there may be several transactions (chunks of discourse on the same theme), each made up of exchanges (defined as two or more utterances), which again can be made up of several moves (like initiation, response, and feedback). Within one move, however, several acts may be done, like stating a fact and asking a question, and more). Their work has later been known especially for describing the IRF structure:

> We now express the structure of exchanges in terms of moves. A typical exchange in the classroom consists of an *initiation* by the teacher, followed by a *response* from the pupil, followed by *feedback,* to the pupil's response from the teacher (Sinclair & Coulthard, 1992, p. 8).

This is later perhaps better known as an IRE exchange of Initiation, Response, and Evaluation, signalling that the most common feedback is an evaluation of the student answer (Mehan, 1979), and we will use this term from now on. This exchange pattern, if used without further follow-up, leaves students with few opportunities to question or explore ideas to develop their thoughts.

An increasing number of researchers and teaching developers worldwide have criticised the role of the IRE structure in classroom practice, even if it has also been defended (Dahl, 2021). As an alternative, dialogic teaching has been developed, which capitalises on the power of talk to further students' thinking, learning, and problem solving (see for instance the review by Kim & Wilkinson, 2019). According to Alexander (2017), the dialogic approach aims to engage students in sustained stretches of talk that enable speakers and listeners to explore and build on their own and others' ideas to accumulate knowledge and understanding. Dialogic teaching reflects the view that knowledge and understanding come from testing evidence, analysing ideas, and exploring values rather than unquestioningly accepting somebody else's certainties (Alexander, 2017).

In this vein, many researchers have paid attention to classroom talk moves (Chapin et al., 2009; Cui & Teo, 2021; Kim & Wilkinson, 2019; Michaels et al., 2008). Talk moves are generally used to involve students in the subject of the conversation and stimulate their ability to think, understand, and engage. Chapin et al. (2009) proposed five productive talk moves:

- Revoicing: rephrasing a student's contribution in a tentative yet clear way to highlight an important idea and reveal a misunderstanding. Revoicing helps students identify the most important elements of a conversation and select the key points to remember and rephrase to increase their understanding. 'Do you mean…?', 'You are saying that…?'

- Repeating: asking students to paraphrase someone else's contribution or add emphasis to important ideas. This move helps reiterate important ideas and slow the conversation to offer processing time. 'Can you repeat what Julie said about…?', 'Did you hear what Ali just said?'.
- Reasoning: asking students to apply their own reasoning to someone else's contribution, thereby encouraging students to justify or elaborate on their own thinking, provide evidence, and create new connections. 'Can you explain that further?', 'Do you agree or disagree and why?', 'What evidence did you use?'
- Adding on: inviting students to participate in the discussion by building on the ideas of others and prompting students for further participation. This move gives students a chance to connect to other students' thinking. 'Does anyone have something else to add?', 'Can you say something more about Gemma's idea?'
- Using waiting time: allowing time for students to organise their thinking and provide more considered responses. 'Take some time to think', 'I'll let everyone get a chance to think before anyone speaks'.

Talk moves can take different forms, but they are often questions from the teacher to students. Teachers constantly ask questions in class, be it verbally or in written form (e.g. exercises, assessments, and homework), but the key factor is asking quality questions for the right reasons at the right time (Walsh & Sattes, 2005). Teachers should recognise what they wish students to become aware of and how to stimulate this awareness (Ulleberg & Solem, 2018).

Although efforts have been made to categorise types of questions, there is a danger of these being either too simplified and unnuanced or too complicated to be of use to teachers (Solem et al., 2017). Ulleberg and Solem (2018) therefore developed the question model in Figure 1, which can be used in all stages of classroom talk: before, during, and after. The model should be sufficiently simple to be of use for teachers and PSTs, but sufficiently complex that it challenges and invites reflections about practice (Solem et al., 2017, p. 22).

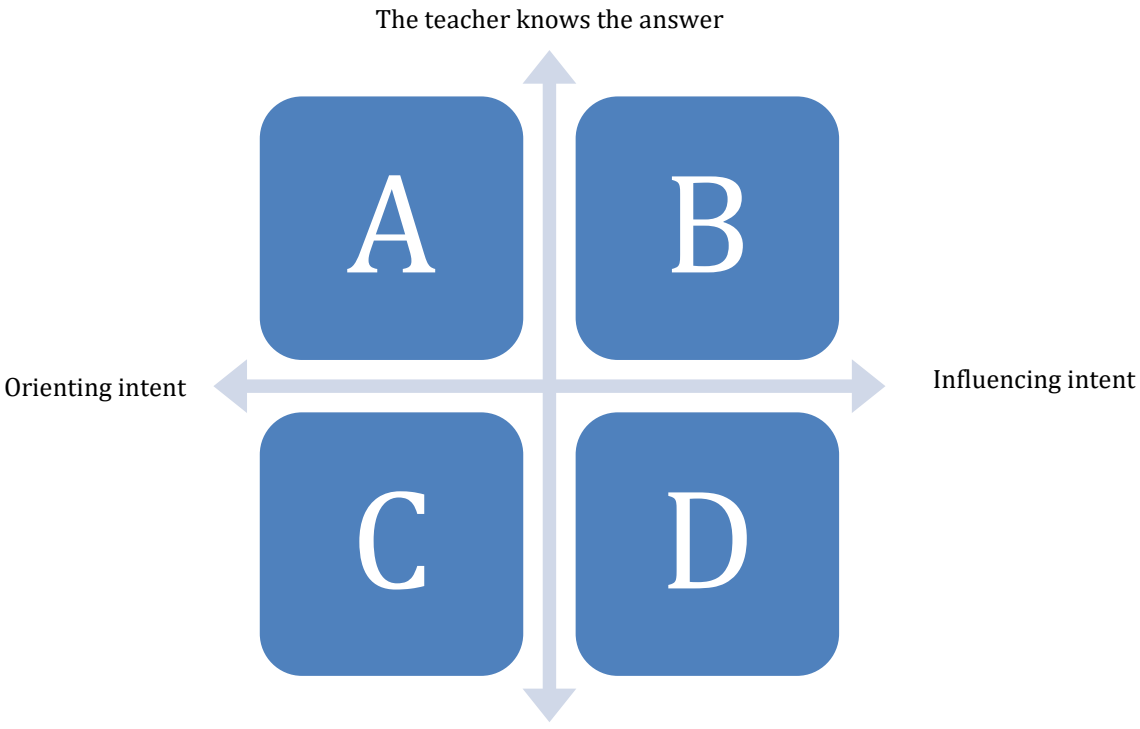

Figure 1. Question Model (Ulleberg & Solem, 2018)

On the vertical axis of the question model, the focus is on the teachers' relationship to the answer, whether they know what the student will (or should) answer to the question they are posing or not. On the horizontal axis, the focus is on the intention or purpose behind the question. On the left-hand side of the axis, the teacher's intention behind the question is to orient themselves about what students remember, know, and make sense of the topic or challenge and what strategies they use. On the right-hand side, the teacher's intention when asking a question is to influence or push students' thinking by asking questions that encourage them to think further, explore, explain, justify, and discover new connections.

As shown in Figure 1, the model is divided into four areas. Area A covers questions typical in an IRE exchange, where the teacher knows what answer to expect to the questions posed and the reason for asking is to check whether students

have understood or can remember the correct answer. Area B covers questions that aim to influence and challenge students' thinking in a certain direction. The teacher wants students to discover connections and patterns and learn to argue and justify. Area C is characterised by the teacher wanting to be oriented about students' thinking and strategies as they answer the question. Not knowing what the students might answer, the teacher is interested in how they think and argue. Area D covers the questions that challenge students to think further and influence them to explore a task without directing them. The reflections can take unexpected directions and move towards an explorative endeavour where the teacher does not know what the student might answer.

The model is directed towards movements in classroom talk, as the four areas of the model are dynamically connected. A question's quality cannot be measured by categorisation alone; it is entirely dependent on the situation and the teacher's intention in each situation. The model functions as a reminder for the teacher to pose questions from different areas to create dynamics in the conversation, analyse and investigate their own teaching after the talk has been carried out, search for patterns in their teaching, expand their repertoire, and look for lost possibilities (Ulleberg & Solem, 2018).

Previous studies of classroom talks concerning questions and talk moves are mostly done with experienced teachers, not PSTs, and therefore they are not directly comparable with ours, but they are still relevant in the discussion of these pedagogical choices. Eckert and Nilsson (2017) focus on the talk move revoicing as an important part of an interactive approach to teaching. They find that revoicing can be done as active or inactive revoicing, having different effects on the classroom interaction. Mahmud's (2019) study of the talk move wait time in mathematics classroom concludes that there are a number of positive results gained by increasing wait time in oral questioning in mathematics, and that it increases the students' ability to think (Mahmud, 2019). In a review study of effective questioning in mathematics, Shahrill (2013) comprises what different studies find are effective questioning strategies for productive mathematics talks and combine this with the importance of wait time (Shahrill, 2013). In an ongoing study Östman (2019, preliminary results) study teachers' probing questions in mathematical classrooms connected to their practice of encouraging students to explain their thinking. She also mentions wait time as crucial, but scarce, and that revoicing is used in 50 % of the teachers' follow-up after probing questions (Östman, 2019). In a narrative review of mathematics understanding and whole-class dialogue, Dahl (2021) concludes that no single dialogic tool or specific question type will fit all situations, but that the use of questions and follow-ups need to be carefully considered in each situation. In this article she aims to nuance the critique against the IRE exchange (Dahl, 2021).

Methodology

Research Design

The study task project is designed as an educational design research (McKenney & Reeves, 2012) in which we practise a way to teach PSTs about leading productive classroom talk by giving them the study task described below. Then, after evaluating and reflecting on this, we adjust the task before retrying it on the next year's PSTs. This article is a case study, where we describe in detail how one iteration of the study task is conducted by three groups of PSTs in one class.

Sample and Data Collection

The material for this study is collected from the second iteration of the task, using a class of first-year PSTs for lower secondary schools. The study task project takes place on a small campus of the Western Norway University of Applied Sciences, with only two classes each year, one for each of the two varieties of the Norwegian teacher education; 1–7 and 5–10 (the numbers refer to the grades you are trained to teach at). The study task project is directed at the 1–7, so this is the class chosen for this case. The class at the time consisted of 17 PSTs, making up a total of five practice groups. One group had students missing for the rehearsal part of the task, and one failed to hand in the different parts of the task in time. The three groups selected for this study were the ones who managed to complete the entire task and hand in all the material. The groups are in this article represented by the PSTs who conduct the talks in the films, three female PSTs, hereafter referred to as PST_3, PST_6 and PST_10 – the labels given to the PSTs while anonymizing the data.

PST_3 and her group have their practicum in a third-grade class. She conducts her practice talk with a group of six third-grade students in a separate room. They choose an activity in which the teacher shows the students a piece of paper with different geometrical figures. In the rehearsal they use a black-and-white print of four geometrical figures (rectangle, square, triangle, and a trapezium). In the practice, they use the same figure with different colours.

PST_6 and her group hold their practicum in a fourth-grade class and conduct their practice in a smaller group of children, four boys and two girls sitting around a table. They have chosen an activity in which a hidden figure (a green dinosaur) is gradually revealed. This is the same activity as they use in their rehearsal. In practice, they run another activity first, so some of the students are already tired and restless at the start of the conversation.

PST_10 and her group hold their practicum in a second-grade class of 10 students. In the rehearsal, they discuss a figure comprising different geometrical figures, while in the practice, a hidden figure is gradually revealed from behind a notebook. This makes it difficult to compare the two situations, as the activity has changed.

The data material for this study consists of the material (films and written documents) produced and handed in by the PSTs as part of the study task. There are three sets of data, as a result of the three different part tasks: The PSTs are required to plan and rehearse a mathematics conversation about geometry, with the other PSTs playing the roles of the students. The rehearsal is filmed and handed in (1). The group then analyses the rehearsed conversation to look for points to improve, before practicing a similar conversation with actual students in their practicum schools. This conversation is also filmed and handed in (2), and the students analyse the film to look for 'golden moments' in the conversation when the potential for productive talk was either used or lost. They then reflect on how and why the moments were used or lost in a written text handed in (3).

Our data material, then, is collected from three practicum groups of PSTs. It consists of three video clips of their rehearsals where the PSTs act as students, three video clips of their practices with actual students, and to triangulate the data, we used the written group reflection texts as reference points in the discussion about the later iterations of the study task project and perceived learning outcome.

The PSTs and parents of the children on the video clips all signed consent forms agreeing that the material may be used for research, and the project has been reported to the Norwegian Centre for Research Data.

Analysing of Data

We transcribed the video clips, using standard written Norwegian (nynorsk) with the addition of pauses marked in number of seconds. We did not need any more specific transcription protocol because our analysis was going to be of the content, not of other elements of the talk. We did a qualitative content analysis (Titscher et al., 2000, p. 62) in two steps. First, we studied what questions and talk moves were used, by coding the transcriptions using categories from the literature reported in the literature review: 1) Question types asked by the PST (Ulleberg & Solem, 2018), 2) Talk moves made by the PST (Chapin et al., 2009).

Category 1) Question types are based on the model by Ulleberg and Solem (2018, see Figure 1), where four basic types of questions are described, and these types make up the subcategories:

- A – teacher knows the answer, orienting intent
- B – teacher knows the answer, influencing intent
- C – teacher does not know the answer – orienting intent
- D – teacher does not know the answer – influencing intent

Category 2) Talk moves are described by Chapin et al. (2009), who suggest these as "effective for making progress toward achieving our instructional goal of supporting mathematical thinking and learning" (Chapin et al., 2009, p. 12). The five moves make up our subcategories:

- Revoicing (When the teacher revoices the student's response, often in a clearer or more subject-specific way – with the intent to clarify, specify and repeat)
- Repeating (When the teacher repeats or asks another student to repeat a response in order to make a point redundant and keep everyone following)
- Reasoning (When the teacher asks a student to explain their thinking)
- Adding on (When the teacher asks the same student or another student to elaborate or add on to a response)
- Using waiting time (When the teacher waits longer than what often seems "natural" in order to make the students think, letting more students think before the fastest one's answer)

In step two we looked at what kind of exchanges could be found in the discourse. Sinclair and Coulthard (1992) described the IRF (IRE) exchange, and that several exchanges on the same theme can be characterized as a transaction. We were interested in whether or not the PSTs managed to break the IRE pattern, and who were active in the different transactions. We therefore categorized the transactions into two main groups: single use of the IRE exchange, versus what we call complex exchange, meaning transactions on the same theme, stretching across more than one IRE exchange. The next step on Sinclair and Coulthard's rank scale is *move* (discursive move, not to be confused with the talk moves in step 1). Sinclair and Coulthard name Initiation, Response and Feedback on this level. We made our own subcategories based on who the contributors are and what *discursive moves* (DM) they make in our material:

- *Teacher Initiation* (the start of a new exchange, often a question from the teacher)
- *Student Response* (a student's response to a question or other initiation from the teacher)
- *Follow-up* (when the teacher follows up a student's response with a comment/new question or probes for further comments)

- *Follow-up response* (When a student responds to a teacher's follow-up)
- *Evaluation* (when the teacher evaluates the response from the student)
- *Echo* (when the teacher simply echoes the response from the student seemingly without intent = inactive revoicing)
- *Student question* (When a student asks a question)
- *Teacher response* (When the teacher responds to a student question)
- *Student–student response* (when a student responds to something another student has said)

We used NVivo software to code the conversations, both researchers did the coding separately at first, with several operational discussions during the process. A single utterance from a PST may then have several codes. It can, for instance, be a follow-up discursive move, a C-question, and a 'reasoning' talk move simultaneously, as in the utterance in italics below:

> PST_3: Which one is the quadrilateral here, then?
>
> Students: The green one! The yellow one!
>
> PST_3*: The green one? How can you tell that it is a quadrilateral, then?*

Validity and reliability measures were that the definitions of the categories are mainly taken directly from the literature, so there should be little room for errors and misunderstandings. Both researchers individually coded all the conversations, before discussing each coding and calibrating, and several operational discussions took place during the coding process. The coding is also transparent, as it can be checked by the reader in Tables 4 and 5.

Findings/Results

In the following, for each of the three PSTs, we show a table of the IRE exchanges and complex exchanges in the two situations. Thereafter, a chart showing the number of question types, talk moves and discursive moves in the two situations is displayed. We then include two of the longest and most complex exchanges to show the manner of the analysis and serve as examples for the discussion that follows.

Table 1. Overview of Video Clips for PST_3

PST_3	**Rehearsal film**	**Practice film**
Length (minutes)	8:45	12:38
IRE exchanges	7	24
Complex exchanges	8	10

What the group discusses between the rehearsal and practice is unknown, but as Table 1 shows, they have many more single IRE exchanges in the practice than in the rehearsal, even though the film is not that much longer. In the rehearsal film, PST_3 has an even distribution between complex and IRE exchanges. The complex exchanges in the practice film have an average of 9–10 turns, and PST_3 keeps the same students engaged in conversation for longer stretches of time (this can be said to be an improvement).

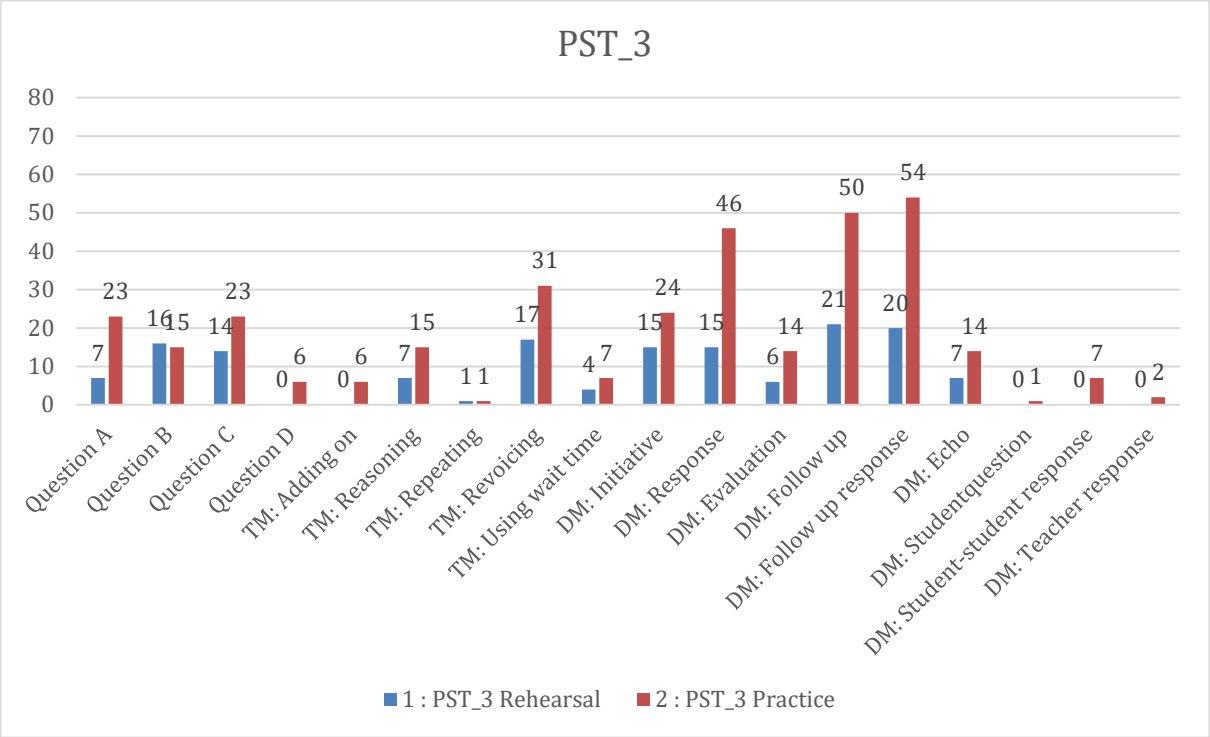

Figure 2. Number of Codings in the Practice and Rehearsal Conversations for PST_3

Figure 2 shows that PST_3 uses question types B and C evenly in her rehearsal conversation, however, in her practice, question types A and C are more often used, and she even uses question type D six times. She uses follow-up considerably: she has twice as many follow-ups as initiations in her practice, close to that in the rehearsal. The practice shows some examples of students discussing among themselves (student–student response). Her main talk move strategy in the practice is revoicing, but she also increases her use of reasoning and wait time from the rehearsal to the practice.

Table 2. Overview of Video Clips for PST_6

PST_6	**Rehearsal film**	**Practice film**
Length (minutes)	9:09	23:60
IRE exchanges	20	36
Complex exchanges	12	21

As shown in Table 2, both the rehearsal and the practice for PST_6 are dominated by short, mostly IRE exchanges, but even the complex exchanges are shorter than those of PST_3 and PST_10.

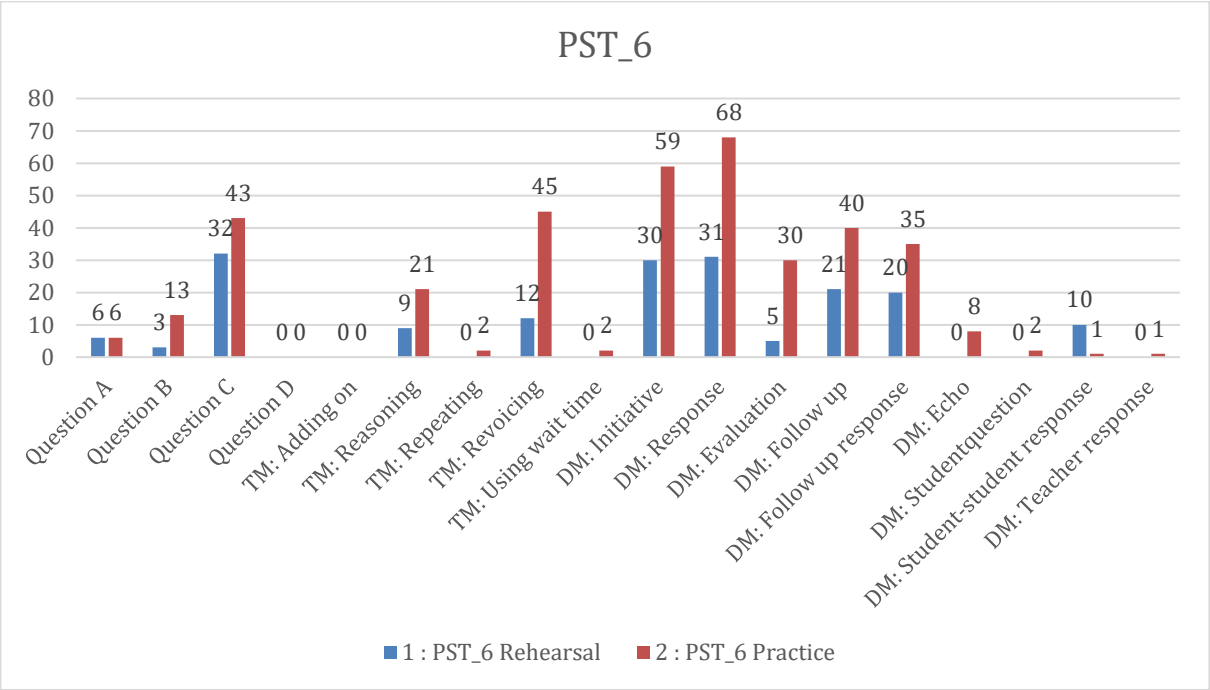

Figure 3. Number of Codings in the Practice and Rehearsal Conversations for PST_6

Figure 3 shows that PST_6 has a long practice conversation (over 23 minutes), which might explain most of the increase in the number of codings in all the categories. She adopts question type C as her main questioning strategy in both situations, with the tendency even clearer in the practice conversation. She has numerous initiatives, but only follows up on around half of the student responses (both in the practice and in the rehearsal). In her rehearsal, the other PSTs acting as students sometimes discuss among themselves (student–student response), but that happens less frequently in the practice conversation. She uses revoicing much more in the practice than in the rehearsal (this is the most dominant of the talk moves). She does not use wait time as much as the other two PSTs do; however, like PST_3, she also increases the use of the reasoning-move from the rehearsal to the practice.

Table 3. Overview of Video Clips for PST_10

PST_10	**Rehearsal film**	**Practice film**
Length (minutes)	11:03	12:15
IRE exchanges	4	2
Complex exchanges	2	5

As shown in Table 3, PST_10 has two almost equally long conversations in the two situations. Her conversations differ from those of PST_3 and PST_6, particularly in that she has so few different exchanges, keeping each transaction going longer.

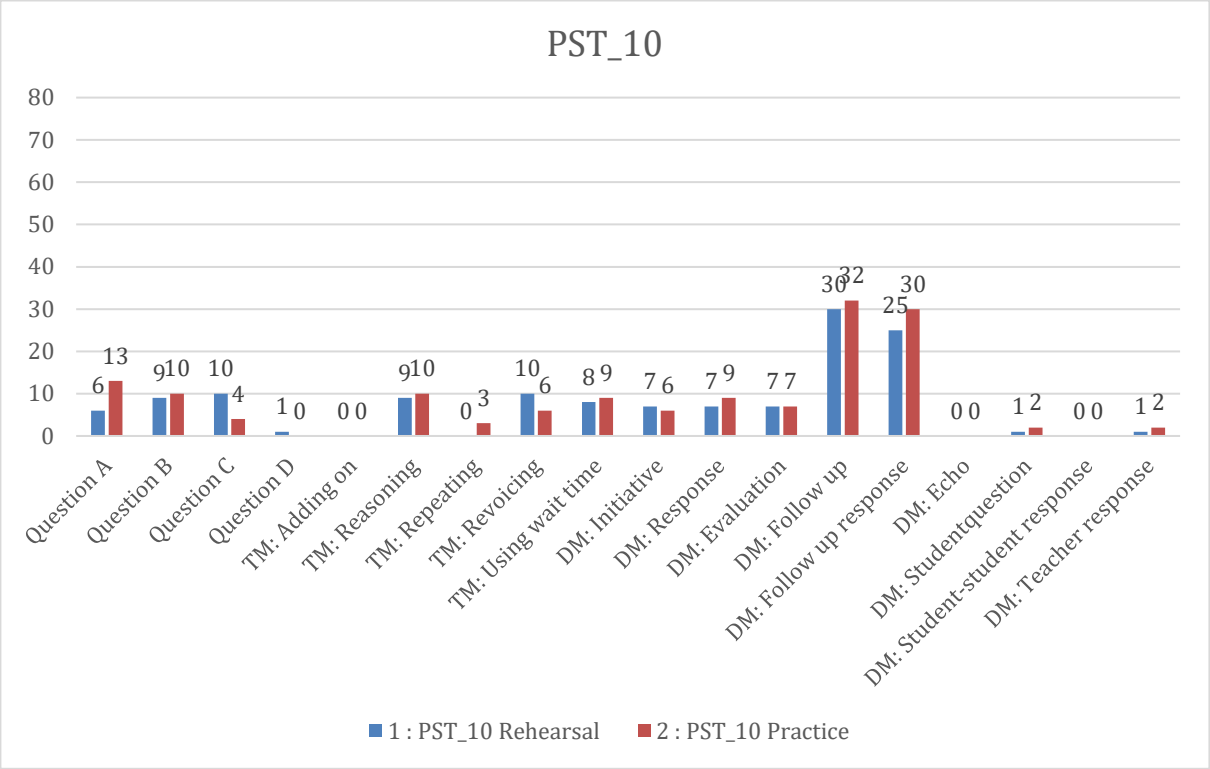

Figure 4. Number of Codings in the Practice and Rehearsal Conversations for PST_10

Figure 4 shows that PST_10 has an even distribution of question types, but with an increase in type A questions in the practice. She has only a few initiatives, but more follow-ups. She does not use echo among her discursive moves at all. She uses the revoicing talk move, but more active revoicing than the other two PSTs, and her main talk move strategy is to press for reasoning. She uses wait time more distinctly than the other two PSTs.

Examples of the Coded Transactions of PST_10

As mentioned above, the conversations of PST_10 differ from those of the other two PSTs in that she has so few exchanges (only two IRE exchanges and five complex exchanges in her practice). The first two complex exchanges are also short, meaning that most of her practice conversation is spent on the two longer complex exchanges. There is little discussion among the students; as the teacher, she controls the conversation and gives each student a turn to talk. However, she does retain the focus on the same topic for long stretches of time, engaging several students in a discussion about the same topic. Here, we present excerpts from the two long complex exchanges as well as our coding and comments.

The PST is holding up a notebook, from the edge of which an orange cardboard figure is just visible. She asks, 'What can this be?' She receives several responses from different students (each of these are coded as separate exchanges). The excerpt in Table 4 starts as the PST decides to challenge the students to talk more about the properties of the figure. We have omitted parts of the transaction where the topic is off task, marked by a row with […] in it.

Table 4 includes a column with our coding, the abbreviations there meaning:

Q: Question type

TM: Talk move

DM: Discursive move

Table 4. First Coded Transaction

Turn	Conversation	Coding	Comment
1	PST_10: But if I say: Can it be a quadrilateral?	DM: Initiative Q: B	The PST challenges more or less imaginative suggestions about what the figure might be by asking a specific question: Can it be a quadrilateral? All you can see at this point is two sides, one angle and the side of the notebook making up the third side

Table 4. Continued

Turn	Conversation	Coding	Comment
2	Students: No!	DM: Response	The students obviously cannot see a quadrilateral
3	PST_10: What? Why do you say no?	DM: Follow-up Q: C TM: Reasoning	She keeps challenging them, pressing for reasons why they have dismissed the idea of a quadrilateral
4	Students: [it's…] [It could be, but…]	DM: Follow-up response	The students start to question their dismissal
5	PST_10: But not the part that's showing now?	DM: Follow-up Q: B TM: Revoicing	She helps them put their doubts into words
6	Students: No	DM: Follow-up response	They agree with her revoicing
7	PST_10: Wow. How can we figure it out, then? Is there something we can count?	DM: Follow-up Q: B TM: Reasoning	She keeps pressing for reasoning, helping them understand what she is after by hinting heavily
[…]			
	PST_10: […]. But can you see here? (She is pointing back and forth between the two visible sides of the hidden figure)	DM: Follow-up Q: B	She returns the focus to the properties of the figure
8	Several students at the same time: Two-side! Two-side!	DM: Follow-up response	In Norwegian, the proper names for a triangle and a quadrilateral are 'three-side' and 'four-side' (literally). The same pattern can be used for a pentagon ('five-side') and so forth, but even in Norwegian, there is no such thing as a 'two-side'
9	PST_10: You are saying something about sides. Where is a side, then?	DM: Follow-up Q: B	Instead of correcting the students' overgeneralisation, she encourages the students to show her what they are thinking
10	Girl_3: (Points to the angle) I think it's there.	DM: Follow-up response	The student responds hesitantly, suddenly not so sure about what a side is
11	PST_10: Yeah, you mean the angle?	DM: Follow-up Q: A TM: Revoicing	The PST again refrains from correcting the student, but instead revoices, using the proper mathematical term
12	Girl_3: Yes	DM: Follow-up response	
13	PST_10: Mm. Shush, Boy_2. Because there are many… (Boy_4 has his hand up). Where do you, Boy_4, think there is a side?	DM: Follow-up Q: B	She keeps the focus on the properties of the figure, asking another student to identify a side
[…]			
	PST_10: Because it's like this… often we think that… sides and angles are the same thing…	DM: Follow-up	Her tone is hesitant, maybe she is uncertain of how to best lead the students to the conclusion she wishes them to reach. The students quickly catch her hints

Table 4. Continued

Turn	Conversation	Coding	Comment
14	Student: But they're not!	DM: Follow-up response	
15	PST_10: But where is a side, then? Come over here, Boy_3	DM: Follow-up Q: A	She asks the question about sides again, more directly this time
16	Boy_3 (gets up and walks over, pointing to the top side) It's one of these	DM: Follow-up response	Boy_3 answers by showing rather than using words
17	PST_10: Yes, look! Can you see that? (Boy_3 is stroking his finger back and forth along the side). Is edge another word for side? Can you see that? Thank you, Boy_3	DM: Evaluation DM: Follow-up Q: A Q: C TM: Using waiting time	She gives a positive evaluation of Boy_3's response, ensuring everybody sees. Boy_3 proudly stays by her side, pointing to the successfully located side
18	PST_10: Can you help me count the sides, then? Boy_5 too? OK, so we have: One! (Points to the top side, the students counting along with her). Two! (Points to the slanted side) and three! (Points to the side made up of the side of the notepad). OK, so the orange bit that is showing, how many sides did it have?	DM: Follow-up Q: A	She has finally established the concept of sides and can now proceed to counting them. She uses wait time, counting slowly, ensuring all the students follow, repeating the A question at the end
19	Students: Three!	DM: Follow-up response	The students answer the factual question correctly
20	PST_10: Yes! So that means that this CANNOT be a quadrilateral? How many sides are in a quadrilateral ('four-side') then?	DM: Evaluation DM: Follow-up Q: A	She can now conclude the question she asked initially (can this be a quadrilateral) and ask a control question
21	Students: Four!	DM: Follow-up response	They answer correctly
22	PST_10: Oh! So, it's kind of in the name?	DM: Follow-up Q: A	She states her conclusion in the form of a question
23	Students: Yes! Yep! That's true!	DM: Follow-up response	The students seem proud to have contributed to her conclusion

The transaction is still not finished. The PST continues the talk about sides and angles for 21 more turns before the students become so tired that the transaction collapses. After an intermission with some off-topic talk, PST_10 picks it up again, as she has pulled out some more of the figure from the notebook (Table 5).

Table 5. Second Coded Transaction

Turn	Conversation	Coding	Comment
1	PST_10: Are there any more sides?	DM: Initiative Q: A	The PST returns the focus to the properties of the figure
2	Students: Yes!	DM: Response	
3	Girl_2: We have two new sides	DM: Response	One of the students ventures a specific answer, using the concept of sides that has recently been established.
4	PST_10 Two? Come and count, Girl_2!	DM: Follow-up Q: A TM: Revoicing/ reasoning	She revoices the answer of two in a questioning tone, at the same time challenging the student to show what she was thinking
5	Girl_2 (gets up and counts with her back to the class): One – two – three – four – five – six!	DM: Follow-up response	
6	PST_10: Come over here! (Pulls on the sleeve of Girl_2 so that she is side by side with her). I'll let you do it one more time, so that they can see on this side, too	DM: Follow-up TM: Using waiting time	Using wait time to ensure everyone is following
7	Girl_2 (points to the sides as she counts): One – two – three… (she gets a bit uncertain as to which ones she has counted already and changes the order she's counting in) four – five – six	DM: Follow-up response	
8	PST_10: Yes, here we see…	DM: Follow-up	She starts to comment, but the girl starts over
9	Girl_2: One – two – three – four – five – six	DM: Follow-up response	
10	PST_10: Yes, now I'll show you. She counts (pointing, counting slowly) one – two – three – four – five – six	DM: Follow-up TM: Using wait time	Once again, she repeats and uses time
11	PST_10: But I wonder about something. You guys in class 2A, because I know you know a whole lot. How can we tell… because we say one, two, right (pointing to two sides), how do we know that a side starts? How can we tell? (Pointing to the angle). It is just like you were showing us earlier, Girl_3! Can you tell us what you pointed to before?	DM: Follow-up Q: B TM: Reasoning	It appears she wants the students to draw a conclusion about the connection between sides and angles, but it is difficult to know how to ask the questions
12	Girl_3: Eh… the angles?	DM: Follow-up response	
13	PST_10: The angles! So that… There's an angle (pointing). Then, there's the side (lets her finger slide along the side). And then there's another angle (points). And then we know to count another side, just like you did earlier, Girl_2 (points to Girl_2 who is at the side of her chair, uneasy, wiggling her head.	DM: Follow-up TM: Revoicing	She voices her point, crediting Girl_2 for making the contribution
14	PST_10: Are we having fun now, or what!?		She seems unsure of how to continue, and the students are getting restless, so she exclaims enthusiastically, and the second graders agree.

Discussion

In this section, we discuss the three research questions with the corresponding analysis categories separately, before discussing the learning outcome for the PSTs and possible implications on later iterations of the study task as well as on teacher education generally. Finally, we draw on the PSTs' reflections as well as our analysis of the conversations.

Types of Questions

As stated in the Literature Review, Ulleberg and Solem's (2018) model of question types is useful for teachers to both plan their conversations and reflect on their questioning practice. It can also help in analysing and discussing the questions used by PSTs in practicing classroom mathematics talks. The choice of question type depends on the intention of the teacher (Solem et al., 2017, p. 24). Although subcategory A questions often lead to single IRE exchanges, they can also serve a purpose in more productive talks, like Dahl (2021) points out. For example, the first coded transaction shows that subcategory A questions can be used with intent, as in turn 11 (to use and enhance the correct mathematical term while revoicing the student's answer) and in turn 15 (to ensure the students understand and agree on what the side of a geometrical figure is). Our PSTs use all the types of questions in the different categories, but there is no clear pattern for what type of question leads to what type of talk; it depends on the follow-up (or lack thereof) to the student's response. This corresponds with the findings of Dahl, who concludes her narrative review of mathematics understanding in whole-class discussions with the claim that

> There is no one dialogue tool or specific type of question of evaluative response that will work in every situation – or consequently should be avoided or recommended – not even dialogue forms which are or look like IRE. […] In other words, it is the teacher's responsibility to lead whole-class conversations in a direction that both builds on the students' thinking, but also actively leads the class in a fertile direction (Dahl, 2021, p. 32, our translation from Danish).

However, questions from subcategories A and C (orienting intent) dominate in our material, while questions from subcategories B and D are less often used (influencing intent) and subcategory D (where the teacher does not know what the student might answer but has an influencing intent) is least frequently used in our material. As questions with an influencing intent require the teacher to know where they want the student to go and how to influence their reasoning appropriately, questions with an orienting intent may be easier for first-year PSTs to use (e.g., asking for correct answers or about how the students reached their answers).

The most used question type overall is type C: a question with an orienting intent, where the teacher does not know what the student might answer. Some variation of 'What do you see?' is the most common question. While this is a good introductory question for a conversation about geometrical figures and shapes with first- to fourth-grade students, the productiveness of the conversation depends on how it is followed up, like Hardman (2019) points out. The conversations led by PST_6 are particularly dominated by this type of question. In her rehearsal talk, she asks 32 type C questions (compared with six A and three B questions), whereas in the practice she asks 43 type C questions (compared with six A and 13 B questions). PST_10 also starts with a C-question ('What can this be?'); however, after a few suggestions, she quickly follows up with a conversation about the properties of the figure being discussed, thereby breaking the IRE pattern. Shahrill (2013) has done a review of literature on what counts as effective teacher questioning in mathematics, and even if she concludes that "Research findings have shown that effective questioning skills have been linked with students' achievement in mathematics" (Shahrill, 2013, p. 230), she also points to the importance of wait time to enable students to think before answering. Other researchers studying types of questions have also concluded that it rather is the teacher's follow-up than the question type that determines the quality of the conversation. Östman (2019) is studying the use of probing questions in mathematics classrooms, and her preliminary results also point towards the responsive talk moves revoicing and wait time as crucial (Östman, 2019).

Talk Moves

A central point of Alexander's (2017) dialogic teaching is that the teacher should have a repertoire of ways to teach dialogically, including talk moves, which help respond to and facilitate students' contributions to the conversation as well as follow up their responses, breaking the IRE pattern. However, it takes practice to get the hang of using these in expedient ways in each situation. According to Michaels and O'Connor (2015), "Teachers must use tools in strategic sequence. This takes practice and requires attending to and becoming familiar with the materials that the tool acts upon, as well as understanding the larger problem or purpose" (p. 337). Our PSTs, especially PST_3 and PST_6, favour the talk move of revoicing. While revoicing includes rephrasing a student's contribution in a tentative yet clearer way (e.g., 'So you're saying that …?' and 'Do you mean that …?'; Chapin et al., 2009), it is also used to simply repeat the student's contribution, this is what Eckert and Nilsson (2017) call inactive revoicing: "Inactive revoicing takes the form of word-by-word revoicing, without indicating the teacher's intention or interpretation" (Eckert & Nilsson, 2017, p. 38). In our material, this seems to be used more as a strategy to buy time rather than to clarify the students' thoughts. Here is an example of that, from the practice with PST_3:

PST_3: What do you think about when I say 'geometrical figures'?

Girl_2: Hmmm… quadrilateral.

PST_3: Quadrilateral?

Boy_2: Symmetry.

PST_3: Symmetry

Girl_2: Round

PST_3: Round

Yes? Yes, now I've brought a piece of paper here, with four different figures (turns the piece of paper over). Can anyone see which figures are here? (The boys on her left side raise their hands, and then the rest of them raise their hands, too). Boy_3?

Boy_3: Rectangle

PST_3: Rectangle

Girl_2: Quadrilateral

PST_3: Quadrilateral. Where is a quadrilateral here, then?

Students: The green one. The yellow one.

PST_3: The green one? How did you figure out that those are quadrilaterals, then?

This is an example in which the PST uses the talk move of revoicing inactively. She simply repeats what each student says. As this is at the beginning of the talk, she may be trying to invite the students into the conversation without provoking resistance. Towards the end of the excerpt, she does, however, challenge the students to explain how they see the shapes they claim to see, adding a reasoning talk move to her inactive revoicing. The revoicing talk move used more actively can be found in turns 7–12 in the first coded transaction. PST_10 revoices the student's contribution actively by using the specific term where the student has just pointed. In this way, she recognises that the student has provided the right answer but gives her a new word to use. Later in the conversation, we again find the PST using revoicing actively (see the second coded transaction) in relation to the contributions from Girl_2 and Girl_3. First, she lets Girl_2 count the sides several times and revoices by counting again, slowly and pointedly, so that everyone can see. Then, she asks Girl_3 to repeat something she has already mentioned, letting Girl_3 contribute before revoicing it in a clearer, more scientific way.

The second coded transaction also shows another talk move, namely, using wait time. Using wait time is important to enable all students to participate not only in the talk, but also in the thinking. However, it is difficult to achieve: "Wait time, the most researched of all talk moves, is a notoriously difficult talk tool to pick up" (Michaels & O'Connor, 2015, p. 337). PST_10 is good at using this difficult tool. She lets Girl_2 count the sides first once, with her back to half the class, then again so that everyone can see, and a last time she herself repeats it, ensuring that everyone follows. She also uses it to revoice the point about the angles from Girl_3. She speaks slowly and stops to point, emphasising the point to the students, all the while crediting Girl_3 for making the contribution. We earlier saw that PST_10 asks considerably fewer questions than her classmates. Compared with PST_3, for instance, whose film is only a minute longer, PST_10 asks 27 questions in approximately the same time as PST_3 asks 69. This is because she uses more time between each question than the others. Our findings here are in concurrence with other research on this important talk move. Walsh and Sattes (2005) stated that a common mistake is to ask too many questions too fast and leave insufficient time for the students to think before they answer. Many other researchers have also been concerned with the talk move of using wait time. We already mentioned that researchers who initially study question types often conclude with the importance of wait time (Dahl, 2021; Shahrill, 2013). Others, like Mahmud (2019), study the use of wait time specifically. He concludes unequivocally:

> In conclusion, all the findings of the study on the role of wait time in the process of oral questioning in mathematics teaching should inform teachers of the importance of practicing wait time in the oral questioning process as a means of improving students' mathematics learning (Mahmud, 2019, p. 696).

Another important talk move is reasoning, where the teacher should encourage students to explain their thinking, argue for their point of view, or examine the grounds for any controversial or uncertain claim. In these talks about geometry, the most common question pressing for reasoning is a variety of 'how can you tell?' In the excerpts above, we find this in several places (see turns 3 and 7 of the first coded transaction and turns 4 and 11 of the second coded transaction).

Exchanges/Transactions

Even after learning about dialogic teaching, talk moves, and question types, the PSTs struggle to engage the students in complex exchanges. It is easy to 'fall back' into the IRE pattern, and after a successful IRE exchange move on rather than probe more deeply into the students' thinking and risk getting into matters where the PSTs themselves feel uncertain. Indeed, our study shows that the PSTs actually have more single IRE exchanges in their practices than in their rehearsal talks, this is at least true for PST_3 and PST_6. There may be several reasons for this. The students are first-year students with limited teaching experience, and Ulleberg and Solem (2018) underline the importance of solid mathematical and didactical knowledge to be "able to lead classroom talk in which the students are invited and stimulated to engage in mathematising" (Ulleberg & Solem, 2018, p. 18). Another reason may be that the rehearsal does not fully prepare the PSTs for the practice with actual students in the classroom. The responses from the students are also unpredictable, and inexperienced PSTs might become stressed by dealing with 'real life' children.

Like Dahl (2021) points out, also the IRE-exchange has its place in a productive classroom conversation, and several of the single IRE exchanges in the practices are at the beginning of the talks. They might be interpreted as attempts to include more of the students in the talk before moving to 'deeper' layers of the conversation. As the talk progresses from the initial rounds of IRE exchanges, the complex exchanges lengthen. For PST_3's group, in the rehearsal, the other PSTs acting as students answer obligingly and logically to anything the 'teacher' asks; by contrast, in the practices, the answers from the actual students are far more unpredictable, as in the excerpt below:

PST_3: Rectangle. Why should that one goes out, then?

Boy_2: It shouldn't!

PST_3: What might be the reason for that one going out?

Boy_3: Can't we just take them all out?

PST_3 (shushing): What might be reasons for the rectangle going out?

Boy_2: It's too large for life!

The students are not always willing to cooperate and might respond with an answer that is difficult for a PST to handle. Even so, Ulleberg and Solem (2018) stress the importance of listening to the students' answers: "Listening to the students' answers is crucial for teaching and, paying attention to the input from students is a central foundation for the questioning" (Ulleberg & Solem, 2018, p. 17). We can see from PST_10's conversations in tables 4 and 5 that she listens to and builds on the contributions of the students.

Improving Teacher Education

Our study shows that leading productive mathematics classroom talks is a challenging task for aspiring teachers, concurring with previous research on this topic (Alexander, 2017, 2020; Cui & Teo, 2021; Michaels et al., 2008). The PSTs in our study had received lectures about dialogic teaching, oral skills, and teaching geometry before their practicum period, but still struggled to lead productive mathematics talks in practice. Typical problems included the lack of follow-up by PSTs, lack of cooperation from students, and failure to frame the conversation. In terms of the latter, the PSTs start the talk with a minimum of introduction and end it without summing up. Any experienced teacher will have learned through their everyday work that such framing is an important part of a productive talk. For example, PST_3 ends her practice conversation like this:

PST_3: No. Okay. How about this one? The triangle? Are there any shapes you think about with this one? (She turns the piece of paper slowly, so everyone can see) It doesn't have to be anything in the room.

(Students give several more or less serious answers at the same time)

PST_3: Okay, that's all! (Gets up and puts her things together)

However, although the IRE pattern of classroom talk is frequently used in our material (even more in the practices than in the rehearsals), all three PSTs do show promising signs of emerging dialogic teaching, as in the first coded transaction from PST_10. They all use the talk move of reasoning in the practice talks, and both PST_3 and PST_6 show good progress in using more revoicing, reasoning, and wait time in the practice than in the rehearsal. Regarding question types, PST_3 and PST_6 use more B and C questions, PST_3 and PST_10 use more A questions, and PST_3 even uses D questions in the practice. In the written reflections, the PSTs expressed that their perceived learning outcome was good and that they felt better prepared to meet classroom conversations after completing the rehearsal (our translations from Norwegian):

> I think it was a good rehearsal; it only gets more important to have these conversations. I would think that this is something you never finish learning, too, so that's why it's good to rehearse a lot (PST_3).

> It was exciting and instructive to conduct a mathematics conversation with fellow students. At first, it was a bit awkward to lead a conversation with people my own age, but I quickly forgot about that. I felt like I managed to see all the students and ask them what they saw or didn't see. Everyone got to answer what they thought (PST_6).
>
> Watching the film was, as expected, a bit unpleasant at the beginning, hearing my own voice. But I feel it fell into place, and by the end I was focusing only on the questions and not on how my hair looked or how I moved my arms in a 'stupid' way. I found it incredibly instructive to hear how I asked questions and answered the 'students', but not least to see how I made eye contact with the 'students' (PST_10).

Our impression after reading the written reflections is that the PSTs still lack some understanding about what might help them lead more productive mathematics talks in the future. For instance, some struggle to explain what makes a 'golden moment':

> When A says 'No, I changed my mind, I think this one is the odd one out' (the trapezoid). That was very unexpected on my part; I thought everyone would agree that the triangle was the odd one out because that's the only figure with three sides (PST_3).
>
> 'If we part the rectangle in two, we get two squares or two triangles', a student said. The fact that the student was able to see that, I thought of as a golden moment (PST_3).

It is not clear what makes PST_3 see these as particularly golden moments, and she does not explain any further in her text. The same goes for PST_6:

> There was a disagreement between the students about whether a 'twenty-side' could be called a geometrical figure. The teacher was good and let Girl_3 count and point to the sides. She found that the figure had twenty sides. Here, the teacher could have asked more clearly why the student thought that that would make it a geometrical figure and listen to her reasoning. This didn't happen in this case, because she rather led the conversation over to the student of the opposite opinion (PST_6).

It is unclear whether the PST writing this reflection thinks that a 'twenty-side' is a geometrical figure or what would have come out of a conversation about this. We also find well-founded reflections about what could have made the conversations better:

> The PST asks the students: 'How can we tell where a new side starts?' Instead of letting the students think about this, the PST added that it was what Girl_3 had talked about earlier in the conversation. The students remembered that Girl_3 had mentioned angles, and that was probably the right answer, so they 'didn't have to' think about why we can use the angles to separate the sides. That's why we think an alternative development should have focused on more thinking time for the students and let them have the opportunity to explain. In this clip, the PST is the one explaining why sides and angles are connected; ideally, this explanation should have come from a student, and in an improved conversation this would have been the case (PST_10).

The PSTs all refer to the question model we used in our analysis and presented to them in their textbooks. They analyse their own conversations by categorising the questions they ask, but their texts show that they sometimes have trouble with this. For example, PST_3 frequently categorises questions that we would claim to be category A as category C:

> OK, do you remember what we call it? E [Initial of fellow PST acting as student]? What do we call that shape? (C. The teacher does not know what the student will answer but asks to orient herself about whether the students are following (PST_3).

Conclusion

Leading productive talks in the classroom, in mathematics as well as in other subjects, is a challenging task for both experienced teachers and preservice teachers. Especially difficult is following up students' responses in a manner that encourages them to expand and explain their thinking. Succeeding with such dialogic teaching requires practice and attention, and a place to start could be by focusing on and rehearsing asking different types of questions and making talk moves designed to encourage students to participate and engage in complex exchanges that go beyond the traditional IRE exchange. By rehearsing and analysing situations such as this, teacher education can strengthen PSTs' ability to recognise and use such golden moments that appear during a mathematics conversation as well as understand when and how to build on students' contributions to the conversation, thus strengthening students' thinking skills and ability to engage in productive conversations about content knowledge.

Recommendations

This study could have implications for both teacher educators and future researchers. Our study show that leading productive talks is a challenging task, and for practitioners in teacher education, a recommendation could be to prepare PSTs for dialogic education by asking them to film their own conversations and transcribe and analyse 'golden moments' used and lost. In addition, the PSTs could look specifically at their framing of the conversations and follow-up

moves. We found that following up student responses seemed to be particularly challenging, and this is a crucial point for achieving more productive mathematics classroom talks. Our study highlights the importance of teacher education focusing on how PSTs can rehearse and prepare for leading productive talks in mathematics and other subjects. There should be progress from one study task to the next and over the years of teacher education. Future research could look more closely into different ways of strengthening the PSTs' ability to lead dialogic education – while we have focused on questions and talk moves, there is a need for more knowledge about how both these and other teaching practices can be trained and enhanced.

Limitations

The inherent element of subjective interpretation in this kind of qualitative research is a limitation, as other researchers might disagree with our choices of categories and coding. This study only examines three groups of PSTs in one of the iterations of the study task project and the possibilities for generalisation are thus limited.

Ethics Statements

The participants provided their written informed consent to participate in this study, both the PSTs and the parents of the children in the films from the practicum. The study has been approved by both the Norwegian Centre for Research Data and the Western Norway University of Applied Sciences.

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