Hähkiöniemi, Markus; Lehesvuori, Sami; Nieminen, Pasi; Hiltunen, Jenna; Jokiranta, Kaisa

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THREE DIMENSIONS OF DIALOGICITY IN DIALOGIC ARGUMENTATION

MARKUS HÄHKIÖNIEMI,
SAMI LEHESVUORI,
PASI NIEMINEN,
JENNA HILTUNEN,
KAISA JOKIRANTA

Abstract

Three dimensions of dialogicity are emphasised in the literature: dialogic teacher talk, students' dialogic moves and organising for dialogic teaching. In this article, we examine these dimensions and the interplay between them in supporting dialogic argumentation in the context of whole-class discussions in mathematics and physics. Three seemingly different seventh-grade lessons were selected for further analysis from the database of a research project on dialogic argumentation. In this paper, we focus on whole-class discussions after a group assignment. The lessons were video recorded with multiple cameras and transcribed. We characterised dialogic features of teacher talk, more general teacher decisions and organising for dialogic teaching, as well as students' dialogic and justifying moves. In addition, we examined how these were connected. According to the results, the three dimensions of dialogicity played out differently in the lessons. Furthermore, the results give insights into the interplay of the three dialogicity dimensions and students' justifying moves in dialogic argumentation.

Keywords

argumentation, dialogue, mathematics, physics, whole-class discussion

Introduction

Several studies have provided evidence that whole-class discussion (e.g. Evans & Dawson, 2017; Zaccarelli, Schindler, Borko, & Osborne, 2018) and particularly argumentation (see, e.g., the reviews by Asterhan & Schwarz, 2016, and Nussbaum, 2008) may enhance the learning of mathematics and science. It is stressed that dialogicity is an essential element in high-quality, whole-class discussion, although the concept of dialogicity has slightly different meaning or emphasis in different studies (see the recent handbook Wegerif et al., 2019). Three dimensions of dialogicity have been emphasised: dialogic teacher talk (Bansal, 2018; Lehesvuori, Hähkiöniemi, Jokiranta, Nieminen, Hiltunen, & Viiri, 2017; Lehesvuori, Ramnarain & Viiri, 2018; Mortimer & Scott, 2003), students' engagement with each other's ideas through dialogic moves (Asterhan & Schwarz, 2009; Webb et al., 2014) and general organising for dialogic teaching (Alexander, 2004; Stein, Engle, Smith, & Hughes, 2008). A common feature in these dimensions is the openness to diverse viewpoints instead of focusing only on one. Thus, dialogicity emphasises the mutual consideration of various voices (Bakhtin, 1986). Although it is possible to consider all communication dialogic, often, a monologic mode assuming only one valid perspective is differentiated from the dialogic mode, assuming more than one perspective that should be considered (Wells, 2007). Correspondingly, O'Connor and Michaels (2007) differentiate between a structural and ideological sense of dialogue in the same way that Mortimer and Scott (2003) differentiate between interaction and dialogue. In this study, we consider dialogicity in the latter sense.

Argumentation brings another perspective to whole-class discussion. Conner, Singletary, Smith, Wagner and Francisco (2014) define collective argumentation in mathematics as "any instance where students and teachers make a mathematical claim and provide evidence to support it" (p. 404). This definition is in line with Krummheuer (1995), who considers collective argumentation a social phenomenon in which students and teacher together present rationales for their actions. These definitions highlight the role of justifying claims in argumentation. Justifying is also an essential part of argumentation in other argumentation frameworks (e.g. Toulmin, 1958). The role of dialogicity in the above definitions is not so clear. Also in those studies using the expression dialogic argumentation, the role of dialogicity is often left implicit (Nielsen, 2013). Nielsen (2013) synthetises in his review that often dialogic argumentation in science education is seen as "a specialised way of arguing in which the participants not just defend their own claims, but also engage constructively with the argumentation of their peers"

(p. 373). We take this as the definition of dialogic argumentation in our study. Dialogic argumentation thus includes participants justifying claims and engaging with each other's arguments. The three dimensions of dialogicity are relevant in dialogic argumentation, as the teacher talk must be open for multiple viewpoints, students must engage with each other's ideas through dialogic moves and the lesson must be organised so that there are opportunities for the dialogic interchange of ideas. Argumentation and dialogicity often overlap. However, argumentation without dialogicity may exist, for example when a teacher presents a justification, and dialogicity may exist without argumentation when different ideas are presented and challenged without justifying any of the ideas.

As argued above, the role of dialogicity in argumentation includes several dimensions: dialogic teacher talk, students' dialogic moves and organising for dialogic teaching. While previous studies have considered all these dimensions, more research is needed to examine all these dimensions together. Furthermore, we must understand more thoroughly how the dimensions are connected and how they together support dialogic argumentation. Accordingly, the aim of this study is to examine these issues regarding the case of three lessons that had different characteristics of whole-class dialogic argumentation. The following research questions guided this study: (1) How do dialogic teacher talk, students' dialogic moves and organising for dialogic teaching play out in the three lessons? (2) How do dialogic teacher talk, students' dialogic moves and organising for dialogic teaching affect each other and dialogic argumentation in the three lessons?

Dialogic teacher talk, students' dialogic moves and organising for dialogic teaching

One dimension of dialogicity is considering the dialogicity of teacher talk or communicative approach. Mortimer and Scott (2003) differentiate between dialogic and authoritative approaches. According to them, in a dialogic approach, the teacher is open to various points of views, whereas in an authoritative approach, the teacher focusses only on the scientific perspective and ignores students' views. Several studies have used Mortimer and Scott's framework to analyse teacher talk (Bansal, 2018; Lehesvuori et al., 2018; Lehesvuori et al., 2017). Following Mortimer and Scott, researchers have considered dialogic teacher talk, including, for example, eliciting students' views through open-ended questions, receiving students' ideas without judging them, asking follow-up questions and prompting student contributions (e.g. Lehesvuori et al., 2018; Sedova, Sedlacek, & Svaricek; 2016).

Another dimension of dialogicity is that between students' ideas. According to Webb et al. (2014), in productive classroom dialogue, students should voice their own ideas and engage with others' ideas. According to their results, students' engagement with others' ideas and provision of detailed explanations related to student achievement. The idea of engaging with others' ideas is also present in the idea of explorative talk by Mercer, Dawes, Wegerif and Sams (2004). Similarly, building on Bakhtin's concept of voice, Segal and Lefstein (2016) emphasise that, for realising voice, students should express their own ideas and be heeded by others. This also points to the need for students to engage with each other's ideas. Moreover, according to Scott, Mortimer and Aguiar (2006), there are different kinds of dialogic discourse, depending on how high the interanimation of students' ideas is. If the interanimation is high, students not only present various ideas, but also explore and work on the ideas (Scott et al., 2006). This again emphasises dialogicity in the sense of students engaging with each other's ideas. Similarly, Asterhan and Schwarz (2009) have studied how students react to each other's ideas. They created categories for dialogical moves, which are divided into argumentative (claims, request for claims, simple agreements, supports, challenges, rebuttals, simple oppositions and concessions) and nonargumentative (elaborations, requests for information and information providing). Other categorisations containing similar elements have been created. For example, Chen, Hand and Park (2016) created categories of information seeking, elaborating, challenging, defending, supporting and rejecting.

The third dimension of dialogicity is organising for dialogic teaching. This dimension includes the more general organisation of a lesson, designing appropriate learning tasks and making decisions during the lesson to create opportunities for dialogic interaction. Alexander (2004) presented principles that characterise dialogic teaching: collectivity, reciprocality, supportivity, cumulativity and purposefulness. According to Alexander (2004), several wider contextual and organisational conditions support dialogic teaching. Alexander mentions, for example choosing between whole-class teaching or different group work modes and planning appropriate tasks. One of the important conditions in supporting dialogicity is the learning task. Discussable tasks are challenging and open in the sense that there are multiple possible ways of thinking about them (Asterhan & Schwarz, 2016). Jackson, Garrison, Wilson, Gibbons and Shahan (2013) found that maintaining the cognitive demand of a task correlated positively with the quality of the whole-class discussion. Besides setting up challenging tasks, teachers can prepare and make purposeful decisions to orchestrate productive whole-class discussion after students have worked on a problem in groups (Stein et al.,

2008). Stein et al. (2008) discuss five practices concerning how teachers can do this: anticipating students' ideas, monitoring students' thinking during group work, selecting particular student works to be discussed with the whole class, sequencing the discussed student works in a specific order and connecting students' ideas in the whole-class discussion.

In dialogic argumentation conducted in a whole-class setting, all the three dimensions of dialogicity are present. The teacher plans the whole-class discussion to follow relevant activities and organises the discussion in particular ways. Besides creating opportunities for dialogic teaching, the teacher must use this opportunity through using dialogic teacher talk that is open to students' ideas. After all, everything depends on how the students present their ideas and engage with the other students' ideas.

Methods

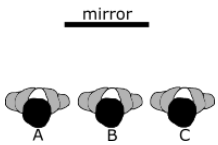
Context

The reported research is part of a two-year longitudinal study in which six Finnish mathematics and science teachers implemented argumentation tasks in mathematics and physics. Each teacher taught the same students in both subjects. The classes were followed from the beginning of the seventh grade until the end of the eighth grade. Each teacher implemented about one task per month during the autumn and spring semesters in mathematics and during either the autumn or the spring semester in physics. The teachers participated in meetings with the researchers before a lesson to prepare for it and after the lesson to reflect on it. Each lesson included some form of group work on the argumentation task and whole-class discussion.

For this sub-study, we selected three lessons, particularly the whole-class discussions at the end of each lesson for further analysis. The reason for selecting the lessons was that the lessons appeared to have differences in how actively students reacted to each other's ideas in the whole-class discussion and how rich the discussion was, contentwise. The observed differences were later confirmed when actually analysing the data.

Lesson A was a seventh-grade physics lesson about image formation in a plane mirror. This was the first argumentation lesson in physics by Teacher 1. Lesson B was a seventh-grade mathematics lesson about comparing fractions. This was the second argumentation lesson in mathematics by Teacher 2. Lesson C was a seventh-grade mathematics lesson about the circumference and area of polygons. This was the sixth argumentation lesson in mathematics by Teacher 2. More details of the lessons are provided in Table 1.

Table 1
Overview of the Lessons Discussed in This Paper

Lesson	**Task**
Lesson A (teacher 1, first physics lesson)	Select an option that is true. a) A sees only himself. b) Only B sees all the persons. c) A and C see only each other. d) B is the only one who sees himself. 
Lesson B (teacher 2, second mathematics lesson)	Students first selected individually which of the two fractions is the largest (e.g. 12/23 or 11/24), then discussed in groups and then with the whole class. This was repeated five times with different fraction pairs.
Lesson C (teacher 2, sixth mathematics lesson)	The area of a square made with four sticks is 1. How small of a polygon can you construct with 12 sticks? Explain how you know the area of your polygon. 

Data collection

The lessons were video recorded with a handheld video camera that followed the teacher from the back of the classroom. The camera was connected to a wireless microphone on the teacher. In addition, each student group had a small wide-angle GoPro camera attached to their desk. Students' written productions were also collected.

Data analysis

The video data was transcribed, and the transcripts were analysed together with videos. Only the whole-class discussions following a group work activity were analysed. First, we coded students' turns as dialogic and justifying moves (Table 2) using the coding scheme of Hähkiöniemi, Hiltunen, Jokiranta, Kilpelä, Lehesvuori and Nieminen (2019). Students' dialogic moves capture students' engagement with each other's ideas, and justifying moves account for if the students' support their claims and whether they make their reasoning explicit. Dialogic and justifying moves are coded independently, and thus, the same student turn can include both. Using two independent coders, we achieved good inter-rater reliability for identifying dialogic and justifying moves as well as differentiating between subtypes (Cohen's Kappa coefficients ranging from 0.77 to 0.86), as reported in Hähkiöniemi et al. (2019).

Table 2
Students' Dialogic and Justifying Moves

Student move	Description
Dialogic moves	
Questioning	Student asks a question about an idea presented by someone else.
Challenging	Student points out a deficiency in another student's idea.
Elaborating	Student analyses, develops or clarifies another student's idea.
Commenting	Student comments or takes a stand on another student's idea without questioning, challenging or elaborating.
Responding	Student responds to another student's question without questioning, challenging, elaborating or commenting.
Justifying moves	
Articulating reasoning (AR)	Student explicitly explains why a claim can be concluded from what is known. In other words, a student explains the line of reasoning leading to a claim, making the reasoning visible.
Describing support (DS)	Student presents facts, calculations, observations, figures etc. to support the claim without articulating reasoning. The support must be related to the content of the lesson.

Subsequently, we started to analyse teacher talk. We analysed whether teacher talk was dialogic in the sense of being open to several perspectives (Mortimer & Scott, 2003; Lehesvuori et al., 2017; Lehesvuori et al., 2018). Furthermore, we analysed what kind of dialogic features teacher talk had. We were sensitive to all kinds of features that appear in the data, although we already were familiar with several features prescribed in previous research (e.g. neutrality towards students' responses, asking open questions, prompting students to tell more, requesting alternative ideas, requesting elaboration, extended wait time).

Then, we examined how the lesson was organised for dialogic teaching. We analysed what kind of phases the lessons had, what kind of opportunities the lesson phases included for dialogic argumentation, what kind of characteristics the tasks had and what kind of opportunities the task characteristics created for dialogic argumentation. In addition, we analysed what kind of organising decisions the teacher performed during the lesson to create opportunities for dialogic argumentation. Finally, we characterised how the dialogic features of teacher talk, more general teacher decision making and organising as well as students' dialogic and justifying moves were connected.

Results

The frequencies of students' dialogic and justifying moves in the whole-class discussions in the three lessons are presented in Table 3. Lesson A contained many dialogic moves but no articulating reasoning. On the contrary, lesson B contained some dialogic moves, most of them being commenting, but many justifying moves that included articulating reasoning. Lesson C contained many dialogic moves and an instance of articulating reasoning. In the following, we elaborate on the dialogic argumentation in the lessons.

Table 3
Frequencies of Students' Dialogic and Justifying Moves in the Lessons

		Lesson A	Lesson B	Lesson C
Dialogic moves	Questioning	1	1	8
	Challenging	10	0	9
	Elaborating	3	5	11
	Commenting	8	9	24
	Responding	1	1	2
Justifying moves	Articulating reasoning	0	7	1
	Describing support	8	7	8

Lesson A

In lesson A, the teacher started the whole-class discussion with the solution from a group who proposed, "Everyone sees everyone, but only b was closest to that". This answer has two parts. Besides answering option b, the group added an incorrect statement that "everyone sees everyone". After the group stated their answer, the teacher asked others to comment on it, but only some vague comments were given. The following excerpt begins when the teacher again asked for comments for the group's solution. Students' dialogic and justifying moves are indicated in the excerpt.

Turn	Speaker	Transcript	Codes
1	Teacher	*You hear what Student 1 and Student 2 just said. Is there something to it?* […]	
3	Student 3	*Well, Student 1 could have, or your group could have opened up their answer a bit more. I did not fully understand it.*	Commenting
4	Teacher	*So they say that everyone sees everyone in the case of that figure.*	
5	Student 4	*It is not true. It does not see.*	Commenting
6	Student 5	*It doesn't work because C does not see himself when he, like, looks from that angle* [moves hand forward from himself].	Challenging & DS
7	Student 6	*I don't see myself.*	Commenting
8	Student 1	*Yeah, but does he look straight ahead or towards the mirror?*	Challenging
9	Student 4	*He cannot see it in the mirror if he looks at the mirror.*	Commenting
10	Student 3	*He sees at most half of himself.*	Challenging
11	Student 7	*The angle of the rays goes in a way that it is not physically possible* […]	Challenging & DS
14	Student 3	*I think he sees half of himself (teacher raises his finger, puts it slowly down and remains silent)* […]	Challenging
17	Student 7	*But I cannot see half of myself from here [points at a window]*	Challenging & DS
18	Student 1	*But he sure sees the others through the mirror.*	Challenging
19	Student 4	*Yeah, but he cannot see himself.*	Challenging
20	Student 3	*He cannot see himself from anywhere.*	Challenging
21	Student 4	*Everyone else, yes.*	continues
22	Student 1	*Oh, I see! (the debate continues for few turns)* […]	Commenting
27	Teacher	*All righty! Then, group 2! Now, Student 8! You may now say your answer* [acknowledges Student 8's previous effort when teacher interrupted, as it wasn't time then to explain one's own responses]	

The excerpt shows that students reacted actively to others' ideas and particularly challenged the presented solution. The discussion expanded suddenly after the teacher's turn 3, as many students objected to the group whose solution was under discussion. Finally, in turn 21, Student 1 indicated that the other students had a relevant point. The number of students' dialogic moves was high in this excerpt, which suggests that the students were engaging with each other's ideas. However, the students' justifying moves did not

include articulating reasoning. There were three moves in which students described support (DS) for refuting the presented claim. Otherwise, the students only pointed out a deficiency in the solution without presenting support related to the content of the activity. Even the three DSs were very general, without going into details. For example, it was not discussed how light reflects from the mirror.

In the above excerpt, teacher talk was dialogic, as the teacher did not evaluate the solution but transferred the evaluation demand to the other groups. The teacher also persisted in requesting more comments when the discussion did not really start. In addition, in turn 3, the teacher gently highlighted the part of the proposed answer which could easily be objected to. Thus, the teacher focused students' attention to a point that launched an active discussion. Subsequently, the teacher remained silent and, with that, gave room for student dialogue. The teacher's giving plenty of room for student dialogue seemed to enable many challenges. However, simultaneously, the teacher did not press students to be more precise in their arguments (e.g. by asking what the angles of the rays mean in turn 11). To do this, the teacher could have stopped the flow of students' dialogic moves and focused on one move. Thus, the teacher gave plenty of space for students' dialogic moves at the cost of not pressing students to articulate their reasoning.

Regarding organising dialogic teaching at a more general level, the lesson was divided in phases in which students first discussed in small groups, the groups wrote their arguments on an interactive electronic wall, the groups got acquainted with other groups' arguments and the whole class discussed the arguments. This organisation of the lesson gave students space first to have a dialogue in smaller groups as well as think about other groups' solution before the whole-class discussion started. In addition, the task was designeds so that several of the statements a–d are partly true and none of them completely answers the question of who sees whom. All these aspects of lesson planning may have contributed to dialogicity. In addition, the teacher decided to begin the whole-class discussion from a solution that included an incorrect part. This increased the potential for dialogicity. In the beginning of the whole-class discussion, the teacher reminded the students about the rules of discussing. In addition, the teacher prevented a student from presenting another solution when the discussion on another solution was continuing.

Lesson B

Lesson B contained five whole-class discussions after five tasks. The following excerpt contains a whole-class discussion after the students had selected their opinion on which one of the fractions 12/23 and 11/24 is larger.

Turn	Speaker	Transcript	Codes
1	Teacher	*Why, in your opinion, is 12/23 bigger than 11/24?*	
2	Student 1	*Well, because it is bigger because 12 is half or over half of 23, whereas 11 is less than half of 24. So 12 is more than one-half of 23.*	AR
3	Teacher	*Yeah. How about here?*	
4	Student	*Same opinion.*	Commenting
5	Teacher	*Is it exactly the same?*	
6	Student	*Same.*	
7	Teacher	*How about Student 2; do you agree?*	
8	Student 2	*I think about combining those previous right answers of the previous tasks. So, here, you need smaller amounts of numbers to fill it, and you also have less of those numbers. So, okay, I will explain better. You have a smaller amount of numbers in the denominator, and thus, you need a smaller number of nominators to make it one whole, and now, you have even more of the nominators. […]*	AR
19	Teacher	*What do the other people say about a thing like that?*	
20	Student	*It is basically the same thing.*	Commenting
21	Student	*It is what we tried to explain.*	Commenting

This whole-class discussion contained only a couple of students' dialogic moves. Furthermore, the commenting moves do not indicate as deep engagement with other students' ideas as challenging, elaborating and questioning. The excerpt contained two different articulated reasoning and both were complete and mathematically correct. Thus, the students' arguments were much more detailed than in lesson A. The difference to lesson A is that the justifying moves were not dialogic moves. Moreover, the justifying moves were not presented as a reaction to other students' ideas.

The teacher talk was dialogic, as the teacher was neutral towards students' arguments and asked for other opinions. The teacher's neutrality towards the presented argument supported the obtaining of the few dialogic moves and the second, different argument for the same claim. The teacher also tried to elicit more comparison (turn 5) when a student shared the same opinion. In addition, the teacher asked other students to comment (turn 19) on the presented argument.

Concerning organising dialogic teaching at a more general level, the lesson was divided into small subsections. In each subsection, students were given a new task that was discussed both in small groups and with the whole class. This gave several possibilities for students to engage in dialogue with others.

Meanwhile, groups were rather large, as the students were divided into three groups based on which of the fractions they thought to be larger or if they thought them to be equal. This may have affected the students' interest in the whole-class discussion, as they already had engaged in discussion with a large group and perhaps had already achieved a consensus. In this lesson, the task clearly had only one correct answer, which may have also affected the need for dialogue. However, even though there is only one correct answer, the fractions can be compared in multiple ways. This increased the probability of having different ways of reasoning articulated, which happened in the above excerpt. In this case, the presence of two articulated reasoning was supported also by the teacher's decision to let Student 2, who is known as being very good in mathematics, answer only after other students.

Lesson C

The whole-class discussion in lesson C started with a short discussion on a clear and easy solution (5 squares). After this, there was a long discussion on a solution presented in Figure 1. At first, students gave only some surface-level comments, such as "good idea to use half squares". Then, the teacher started to calculate the sticks.

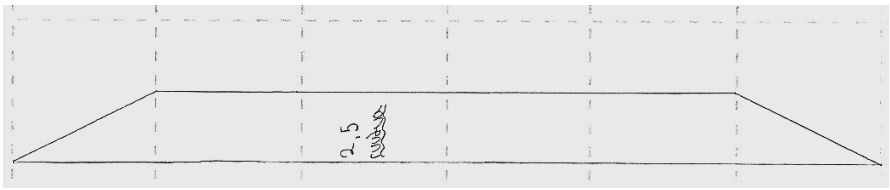


Figure 1
The solution under discussion. Students have written '2.5 squares' on their drawing.

Turn	Speaker	Transcript	Codes
1	Teacher	*I think I will calculate [the number of sticks], just for an example.* […] *These are pretty clear. One, two, three, four, five, six* [places the diagonal stick on top of the drawing so that it does not cover the whole line]. *Oh.*	
2	Student	*Nine, ten, eleven.*	
3	Student 1	*How about that* [in audible].	Commenting
4–11	Student 2	*But the squares or, like, the squares go like that with everyone else.* […] *Also, in the others' work, the stick does not cover the whole square.*	Commenting

12	Teacher	*Let's see, let's see, let's see, let's see.*	
16	Student 3	*But you could do it, if you would move a little those [sticks] so they would be touching each other, and then it would still have the same size.*	Elaborating
17	Student 2	*But then, it would be more difficult to calculate* [the area of the polygon] *because then the one* [the right-most part] *would not be a half square.*	Challenging & DS

Students started to pay attention to the fact that the diagonal sticks were not long enough. The teacher did not give a final word on this, and the discussion continued as Student 3 elaborated on the solution, proposing a way to adjust the construction. Student 2 challenged the elaboration by pointing out that it would be difficult to calculate the area. Student 2 also described support for this by saying that one part of the polygon would not be half a square, meaning probably that then, the diagonal sticks do not reach the vertical grid line.

After the above excerpt, students commented on each other's ideas. Then, the teacher started to focus the discussion on the exact value of the area. The teacher asked many questions and made other statements: "But is it true that it is two and a half squares?", "How much is it if it is less than two and a half squares?", "We should be exact on how many squares it is.", "For example, the first polygon was five squares. But is this two and a half squares?" and "Instead of yelling opinions, I am interested in hearing why". Students continued to voice opinions, suggest elaborations, challenge ideas and ask questions. Finally, Student 1 asked for a turn, and the teacher reminded the class about discussion rules. After this, Student 1 elaborated the solution so that, for the first time, someone proposed adjusting the polygon so that the exact area can be concluded (Figure 2).

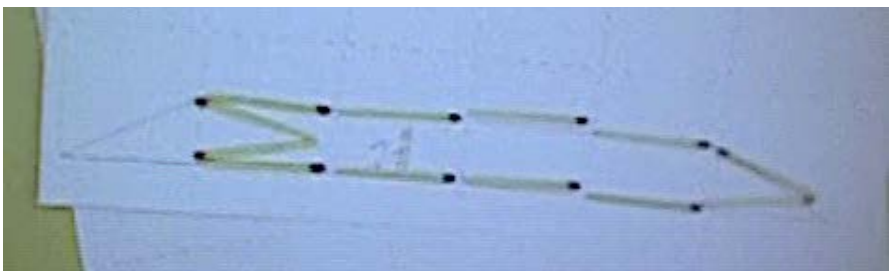


Figure 2
Student 1's elaboration of the solution.

Turn	Speaker	Transcript	Codes
79	Teacher	*About discussing. So. You don't have to ask for a turn from me. But you have to look to see if someone is in the middle of something, you let him/her explain and then, when there is an appropriate moment, you speak. Student 1 had something.*	
80	Student 1	*If you put two of those...*	
81	Teacher	*Everyone else, listen. Let's always listen to the one who is speaking. Yes.*	
82	Student 1	*There are two sticks towards the left and do the right side the same, and then, when you put them together* [mimics moving the triangle on the right to the left], *it would be two squares only.*	Elaborating & DS
83	Student 2	*What?*	
84	Student 4	*Would you show us that?* [Teacher walks to a corner of the room.]	Questioning
85	Student 1	*If this is* [inaudible] *towards the inside* [the two diagonal sticks on the left in Figure 2]. *And you build the same on the right* [the two diagonal sticks on the right in Figure 2]. *And then, if you put them together, you get two squares.*	Elaborating & DS
86	Student 4	*Wait.*	
87	Student 2	*Well, yes, in principle, yeah.*	Commenting
88	Student 5	*Is it two squares?*	Questioning
89	Student 3	*No.*	Commenting
90	Student 6	*It's still two and a half squares.*	Commenting
91	Student 4	*Student 1, if you do that to both sides, you will get a half square of them altogether, and then it would two squares. No, it isn't. Then, it would be. Wait. It is. It is.*	Elaborating & DS
92	Student 5	*It's two squares. No. Three.*	Commenting
93	Student 4	*No, it is two squares. It is two squares. Student 1 knows how to calculate. No, he doesn't know. It would be one and a half. It would one and a half. Student 1 doesn't know how to calculate. It is one and a half squares.*	continues
94	Student 5	*No, it would probably be two squares, because—*	Elaborating & DS
95	Teacher	*Hey, hey, hey, don't talk over each other. Student 5 is talking here.*	
96	Student 5	*If those on the middle, the whole ones, would be one square, and then those on the side would be, in principle, or they would be or if you calculate like this, then those, when they have been turned inside, they would be a half square in principle. Or, it would be totally, like, I can't explain.*	continues

97	Student 7	*It would be two.*	Commenting
98	Student 1	*Well, I suppose you mean one and a half squares from these [in the middle], and then if you move this* [shows moving the triangle on the right to fill in the triangle-shaped hole on the left in Figure 2]*, it would be two squares.*	Elaborating & AR

In turn 82, Student 1 described support for his claim (combining these two) but did not articulate his reasoning. Then, there were several students' dialogic moves. The teacher walked to the corner of the room and let the students discuss. In turn 95, the teacher prevented students from talking over each other and reminded them about discussion rules. After this, Student 5 tried to justify the value of the area but did not manage to articulate her reasoning. Nevertheless, Student 1 elaborated student 5's justification and articulated his reasoning with the help of gestures (turn 98).

In this whole-class discussion, several students' dialogic moves indicated that students were engaging with each other's ideas. In addition, there were several justifying moves, including articulating reasoning. Furthermore, reasoning was finally articulated because of the students' preceding dialogic moves. Thus, dialogicity supported the existence of articulated reasoning. Another sign for dialogicity supporting argumentation is that the justifying moves were simultaneously dialogic moves.

In lesson C, teacher talk was dialogic, as the teacher elicited students' ideas, received students' ideas neutrally and asked other students to comment on them. The teacher persisted in discussing the solution although, at times, students only focused on surface-level issues. Furthermore, the teacher pushed students to engage more deeply with others' ideas by highlighting two issues in the discussed solution. First, the teacher placed the sticks (turn 1) so that students started to doubt whether a stick is long enough for the proposed construction. Second, the teacher focused the discussion on the exact value of the area. These aspects affected the argumentation to go more into detail. In addition, the teacher gave plenty of room for student dialogue. This was also visible in that the teacher walked to the corner of the room (turn 84) when a student presented a novel idea that started to create discussion. However, although the teacher gave students much room, the teacher reminded students of discussion rules and prevented them from talking too much simultaneously. In addition, this encouraged students to go more into detail in their argumentation.

Concerning organising dialogic teaching at a more general level, the lesson included a group work phase and a gallery walk, in which students examined the work of other groups, before the whole-class discussion. This gave the students plenty of possibilities to discuss and to prepare for the whole-class

discussion. The task was open, so that many different constructions were possible, which created curiosity about others' ideas and the need for dialogue. Additionally, dialogicity was fostered by the teacher's decision not to extend the discussion of a solution that was simple and did not create much discussion. This saved time and energy in discussing the solution, as presented above. In addition, the teacher reminded students of discussion rules several times.

Discussion

The analysis of the whole-class discussions in the three lessons provides several insights into dialogic argumentation and the three dimensions of dialogicity: dialogic teacher talk, students' dialogic moves and organising for dialogic teaching. In addition to dialogicity, an essential part of dialogic argumentation in mathematics and science is justifying. While all the three lessons included dialogic teacher talk, there were differences in students' dialogic and justifying moves as well as in organising for dialogic teaching. Lessons A and C were rich in student dialogicity, whereas lessons B and C were rich concerning justifying. Furthermore, lesson B was organised differently than the other lessons. Thus, it is important to consider all three dialogicity dimensions. A lesson may be organised for dialogic teaching, but it may well be that the dialogicity is only enacted on a structural level as a form of discussion (Mortimer & Scott, 2003; O'Connor & Michaels, 2007). Besides organising spaces for dialogicity, teacher talk must be dialogic in the sense of being open to various student ideas without judging them (Mortimer & Scott, 2003). Yet, dialogic teacher talk may enable students only to share several viewpoints separately, or it may include an interanimation of the ideas, as Scott et al. (2006) note. Thus, it is also important to consider the third dimension: dialogicity in the sense that students engage with each other's ideas through dialogic moves (Asterhan & Schwarz, 2009; Webb et al., 2014) and that students are heeded by other students (Segal & Lefstein, 2016). Yet, when considering argumentation, dialogicity along the three dimensions is not sufficient. The dialogicity must be related to justification to meet the requirement that, in argumentation, claims are supported with evidence (Conner et al., 2014; Krummheuer, 1995; Nielsen, 2013).

The results give insights into the interplay of the three dialogicity dimensions and justifying. Figure 3 depicts the overview of the interplay that was realised differently in lessons A–C, as we elaborate below.

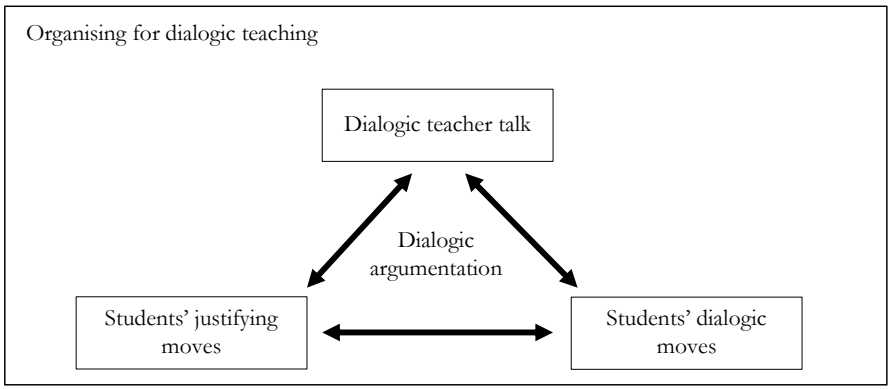


Figure 3
Interplay of the three dialogicity dimensions and justifying in dialogic argumentation.

Dialogic teacher talk supported students' engagement with other students' ideas in all the three lessons, although lesson B contained fewer students' dialogic moves. At the same time, dialogic teacher talk supported students' justifying moves in lessons B and C but not in lesson A. In lesson B, dialogic teacher talk supported students to present another articulated reasoning, although one was already presented. In lessons A and C, teachers highlighted issues in the solution under discussion to promote an exchange of ideas. The difference is that, in lesson A, the teacher let the students talk very freely, whereas in lesson C, the teacher prevented students from talking over each other and steered the discussion to consider the details of the underlying mathematics. Thus, in both lessons, dialogic teacher talk supported students' dialogic moves, but only in lesson C did the teacher press students to go more into detail in their argumentation. Correspondingly, the dialogic teacher talk supported students' justifying moves in lesson C but not in lesson A. We conclude that, eliciting students' ideas and being non-evaluative, the aspects emphasised in dialogic teacher talk (Mortimer & Scott, 2003; Lehesvuori et al., 2018), are important aspects of dialogicity but do not alone guarantee that students engage deeply enough with the elicited views. Besides dialogic teacher talk, in which students' ideas are received neutrally, the teacher needs to support students' argumentation using, for example the means presented in the framework of Conner et al. (2014). However, if the support is to be provided through dialogic teacher talk as in lesson C, direct teacher contributions from the framework of Conner et al. (2014) are excluded. The dilemma of avoiding judging students' ideas and still supporting argumentation is like the dilemma of avoiding telling students and still guiding them, as discussed by Hähkiöniemi and Francisco (2019).

Students' dialogic and justifying moves affected each other in many ways. In lesson A, students made several dialogic moves, and the discussion proceeded quickly. The articulated reasoning was not present, and even the described supports were very general. Thus, in lesson A, students' dialogic moves may have partly affected the argumentation to remain on the surface. On the contrary, in lesson C, students' dialogic moves together with dialogic teacher talk promoted the argumentation to go deeper, as the students' dialogic moves supported the presence of articulated reasoning. Conversely, lesson B included only some dialogic moves but two different articulated reasonings. It may well be that articulated reasoning that is presented right at the beginning of the discussion closes down the discussion, as reasons are already well explained. Thus, students' justifying moves may have harmed students' dialogic moves in lesson B. The tension between students' dialogic and justifying moves, which we noticed in lessons A and B, brings us to thinking about the balance between opening up and closing down classroom discussions (Scott & Ametller, 2007). According to Scott and Ametller (2007), while the discussion should be opened to explore several views, at some point, the discussion needs to be closed down to focus on the scientific perspective. Similarly, in dialogic argumentation, the discussion should be opened for students' dialogic moves, but at some point, the discussion should focus on some of the ideas more closely. However, the dialogue should not be closed down but, rather, investigate some ideas in greater depth. We saw that lesson C contained this kind of 'zooming in' on students' ideas, whereas lesson A did not. Opening up the discussion for students' dialogic moves and zooming in on students' justifying moves are actively orchestrated by the teacher in the same way as a teacher chains communicative approaches in Scott and Ametller's (2007) analysis. In lessons A and C, the teachers managed to create a space for students' dialogic moves, and in lesson C, the teacher patiently steered the discussion to zoom in on justifying moves. Zooming in on justifying moves bears some resemblance to the focusing questioning pattern of Wood (1998). In focusing questioning, the teacher elicits students' ideas and orients the discussion to the relevant aspects of the students' ideas. The difference to authoritative closing down is that, when zooming in or using focusing questions, the interaction is still dialogic. According to Webb et al. (2014), both engaging with others' ideas as well as presenting detailed explanations were positively related to achievement scores. Thus, dialogic and justifying moves are both important and, in the best scenario, they support each other and even co-occur, as in the case of lesson C.

Organising the lesson and more general teaching decisions affected the other dialogicity dimensions and justifying. In all the three lessons, the lesson structure allowed multiple opportunities for students to discuss in smaller groups before the whole-class discussion, which may prepare students for

engaging in the whole-class discussion. The tasks in lessons A and C were open, so that there were multiple correct answers. This openness probably encouraged the students to voice disagreements on which option is the correct one in lesson A and being interested in the other students' unique constructions in lesson C. This is in line with previous research that has suggested that open tasks support dialogue (Asterhan & Schwarz, 2016). Each of the small tasks in lesson B had a correct answer that could be reached through multiple ways of reasoning, which seemed to support students' justifying moves but decrease dialogic moves. In lessons A and C, the teacher's decision to focus the discussion on a solution that has aspects that could be improved, seemed to foster dialogicity. In doing this, the teachers actually used two of Stein et al.'s (2008) five practices for orchestrating productive whole-class discussion: selecting student works for discussion and sequencing the discussed works appropriately.

We have shown that the three dimensions of dialogicity, dialogic teacher talk, students' dialogic moves and organising for dialogic teaching, are important when considering dialogic argumentation. In addition, students' justifying moves are needed for the dialogue to include argumentation. We noticed that the three dimensions of dialogicity and students' justifying moves affected each other in several ways by supporting some aspects of dialogic argumentation while hindering others. Further research on the interplay of the three dimensions of dialogicity in supporting dialogic argumentation is still needed. Particularly the tension between students' dialogic and justifying moves as well as teachers' ways of coping with it could be studied to understand dialogic argumentation and teachers' ways of orchestrating it more thoroughly.

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Corresponding author
Markus Hähkiöniemi
The Department od Teacher Education, University of Jyväskylä, Finland
E-mail: markus.hahkioniemi@jyu.fi

Sami Lehesvuori
The Department od Teacher Education , University of Jyväskylä, Finland
E-mail: sami.lehesvuori@jyu.fi

Pasi Nieminen
The Department od Teacher Education, University of Jyväskylä, Finland
E-mail: pasi.k.nieminen@jyu.fi

Jenna Hiltunen
Finnish Institute for Educational Research, University of Jyväskylä, Finland
E-mail: jenna.hiltunen@jyu.fi

Kaisa Jokiranta
The Department od Teacher Education, University of Jyväskylä, Finland
E-mail: kaisa.jokiranta@jyu.fi