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ENHANCING DIALOGIC ARGUMENTATION IN MATHEMATICS AND SCIENCE

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Abstract

This paper reports on a teacher professional development (PD) programme addressing dialogic argumentation in mathematics and science classrooms. While argumentation skills are becoming more and more important in an increasingly polarised society, the social aspect of argumentation is often neglected in secondary education. Moreover, it is agreed that genuine argumentation requires time and space in classroom dialogue. There have been calls for research delving into how teachers could be familiarised with dialogic argumentation so that they could foster such dialogue in students. The described PD programme features versatile and continuous cooperation between scholars and participating teachers. The scholars are offering educational science's latest knowledge to schools while the teachers are ensuring that it is implemented in a successful and sensible manner. Monthly recorded lessons related to the programme take place in three phases: pre-active (planning), interactive (teaching), and post-active (evaluating and reflecting). Six teachers, teaching both mathematics and physics at lower-secondary schools, are involved in the two-year programme. In addition to discussing our PD programme, we present preliminary results on the initial status of all six teachers and the development of two case teachers. Analysis of lesson videos and teacher reflections has revealed varying starting points for teachers' PD and dialogic argumentation, especially when it comes to teacher awareness. The implications for pre- and in-service teacher education are also discussed.

Keywords

dialogic argumentation, professional development, mathematics and science education

Introduction

This paper presents a professional development (PD) programme addressing dialogic argumentation. The term dialogic argumentation refers to a language-mediated process in which teachers and students collaborate in examining and presenting claims and evidence in a critical manner. Studies conducted in the field of scientific argumentation have reported several challenges when it comes to teachers adopting scientific argumentation in their beliefs and practices (McNeill, Pimentel, & Strauss, 2013; Simon, Erduran, & Osborne, 2006). In response to these challenges, the purpose of the PD programme introduced in this study is to integrate science content and argumentation structure into the dialogic elements of interactions.

Dialogic argumentation requires that all participants have the opportunity to question, evaluate, and challenge ideas (Berland & McNeill, 2010, p. 781). This means that there should be space, both temporal and dialogical, in classroom discussions for students to bring forward their thoughts, ideas, and prior knowledge (Michaels, O'Connor, & Resnick, 2008). In addition, the classroom's dialogical culture should allow students to make mistakes without fear of being ridiculed or disregarded. As we determined in a previous study (Lehesvuori, Viiri, Rasku-Puttonen, Moate, & Helaakoski, 2013), these features are not self-evident for Finnish science teachers and so calls have been made for programmes addressing these issues. The presented programme aims to improve students' ability to form sound arguments and evaluate the validity of presented arguments. To make room for dialogic argumentation in the classroom's discussion culture, however, teachers should first become aware of dialogicity in teaching mathematics and science (Mercer, 2009). Dialogicity refers to the principles behind dialogic teaching, which are presented in the next section. Fundamentally, dialogicity enables different and even diverging ideas to be welcomed into classroom discussions (Bakhtin, 1986).

In this paper, we draw on a sociocultural perspective that underscores the importance of learning within a social context and the potential of verbal communication to enable the co-construction of knowledge (Vygotsky, 1978). The use of language is seen as fundamentally linked to the development of thinking (e.g., Lemke, 1990; Mercer, 2000; Mortimer & Scott, 2003; Wells, 1999) and is an area of ongoing interest within educational research (Roth, 2014; Sedova, Sedlacek, & Svaricek, 2016). A particular aim of our project is to develop students' argumentation and communication skills to address the challenges of future learning: in the modern world, the problem is not how to acquire information but rather how learners can be better

prepared as critical consumers of knowledge and as creative thinkers (Carneiro, 2007). Therefore, there have been calls for strategy-level pedagogical approaches, such as dialogic argumentation, where critiques of presented knowledge and diligence in making statements are central.

Previous studies on classroom argumentation have either been interventions with short PD programmes (e.g., van Driel, Meirink, van Veen, & Zwart, 2012; Zohar & Nemet, 2002) or longer studies that have concentrated on presenting and categorising distinct features of classroom discourse (e.g., Osborne, Erduran, & Simon, 2004). Prior to the PD program introduced in this paper, the dynamics between the teacher's orchestration of the discussion and students' argumentation and the effects of the teaching materials used have not been systematically examined in a longitudinal study. The present study introduces a longitudinal research project wherein the interplay between student argumentation and teacher pedagogical actions is examined systematically in both physics and mathematics education. The project takes into consideration challenges brought up in previous research (McNeill et al., 2013; Simon et al., 2006). For example, the argumentation tasks are designed to address curricular goals, thus integrating dialogic argumentation into the content more seamlessly. As discussed by Simon et al. (2006), teachers' initial statuses should be taken into account and developed over time, foregrounding the need for more longitudinal intervention.

Research questions

After the designed PD programme is presented, the following questions will be addressed:

1. How is teachers' awareness of dialogic features present in teacher reflections on their classroom talk?
2. What dialogic features are the teachers aware of when discussing their teaching?

During the PD programme, we expect teachers will adopt features of dialogicity and argumentation into their pedagogical views as well as their practices. Before change can be expected to take place, however, the first step is to increase awareness. The findings of this study will provide information on the different ways teachers indicate their awareness of dialogicity. Furthermore, the findings will help researchers to adjust the PD programme to better suit individual teachers for the second year of the programme (Simon et al., 2006). Argumentation strategies and structures are given increasingly more weight along with dialogicity.

Theoretical background on dialogicity and argumentation

Previous studies have examined argumentation from different perspectives. The structure of argumentation is often studied using the Toulmin model of argumentation (Toulmin, 1958) to recognise such argument components as claims, data, and warrants. When the argumentation involves several students and a teacher, research has looked at who produces the elements and how the elements build on one another (Conner, Singletary, Smith, Wagner, & Francisco, 2014). Argument content has been studied, for example, by analysing types of student justification in the inductive–deductive continuum (Marrades & Gutiérrez, 2001). Teacher moves to support student argumentation have also been studied (Conner et al., 2014; Simon et al., 2006). Some teacher moves invite students to share their ideas, and some focus student attention on a particular issue. Thus, some teacher moves are more dialogic than others. In this study, we will not examine teacher moves but rather more general principles of dialogicity in argumentation and how these are present in teacher actions and teacher reflections.

Fundamentally, dialogicity involves the mutual acknowledgement of different voices, which is at the heart of Bakhtin's (1986) descriptions of dialogicity. Furthermore, dialogic argumentation can be understood as a part of a dialogic pedagogy in which different ideas and perspectives are acknowledged. Dialogic argumentation then can be considered a specific strategy-level approach indicated by emerging dialogic features (Alexander, 2006). Alexander's dialogic teaching includes the following five principles:

- *Collective*: Teachers and children address learning tasks together, either as a group or as a class.
- *Reciprocal*: Teachers and children listen to each other, share ideas, and consider alternative viewpoints.
- *Supportive*: Children articulate their ideas freely without fear of embarrassment over 'wrong' answers; children help each other reach common understandings.
- *Cumulative*: Teachers and children build on their own and each other's knowledge and experiences.
- *Purposeful*: Teachers plan and facilitate dialogic teaching with particular educational goals. (Alexander, 2006, p. 28)

Whereas Alexander's principles can be considered a good fit in regard to conceptualising the fundamentals of dialogicity, Mortimer and Scott's (2003) characterisation of authoritative and dialogic discourse provides a way to approach the specifics of science and mathematics teaching (Essien, 2017). Overall, dialogic aspects are being increasingly brought into mathematics education (Bakker, Smit, & Wegerif, 2015). The differentiation between an authoritative approach and a dialogic one is briefly described as follows:

- *Interactive authoritative approach*: Student responses are often evaluated as right or wrong and the teacher neglects diverging ideas. The authoritative approach focuses on the scientific point of view.
- *Interactive dialogic approach*: Student ideas (e.g., everyday views) are explored and exploited without an evaluative aspect. In a dialogic approach, the teacher tries to elicit the students' points of view and works with these contrasting views instead of trying to reach a specific point of view.

Although the different theoretical grounds between Alexander's (2006) and Mortimer and Scott's (2003) descriptions of dialogicity have been pointed out (Lehesvuori, 2013), the focus here is not on their differences but rather on identifying how these two perspectives have been adopted and adapted in real dialogic classroom interaction examples. For this purpose, both perspectives have their own strengths for understanding the various forms and levels of dialogicity in classrooms. In this paper, for instance, while Alexander's (2006) framework offers accessible principles for teachers and researchers to lay the ground for more dialogic interactions, Mortimer and Scott's (2003) framework covers the dualistic nature of classroom discussion in science and mathematics. In other words, meaningful learning includes both authoritative and dialogic communicative approaches (Scott & Ametller, 2007).

Method

Context

PD programmes are often based upon lectures and the transmission of knowledge and so lack integration into instruction (Abell, 2000) and fail to access teachers' needs for PD (Chval, Abell, Pareja, Musikul, & Ritzka, 2008). The cornerstone of the designed PD programme is the creation for teachers of regular opportunities to plan and implement lessons with dialogicity and argumentation and reflect upon this during the two-year programme. In the programme, researchers insert theoretical knowledge into argumentation tasks and teachers are expected and are given opportunities to share their practical experiences and expertise. Thus, the PD programme includes continuous discussion and cooperation between scholars and teachers aimed at increasingly dialogical and student-centred classroom discourse practices (Kiemer, Gröschner, Pehmer, & Seidel, 2015). In addition, involvement in the process of developing learning activities for research purposes gives the participating teachers a sense of ownership over the materials, resulting in feelings of comfort and empowerment (Simon et al., 2006).

To lay the ground for dialogic argumentation, it is first necessary to address dialogic interaction explicitly before moving towards the content and structure of argumentation (see Figure 1). During the PD programme, we

expect teachers to adopt features of dialogicity and argumentation into their pedagogical views and practices. However, argumentation does not follow by simply introducing dialogicity into the classroom and giving students argumentation tasks but needs to be explicitly taught (Osborne et al., 2004). The second year of the PD programme will address the basics of argumentation along with how to teach argumentation. The first year will prepare the students for the second year as the students will become familiar with the norms of argumentative discussion: voicing one's thoughts, listening, commenting, and giving feedback.

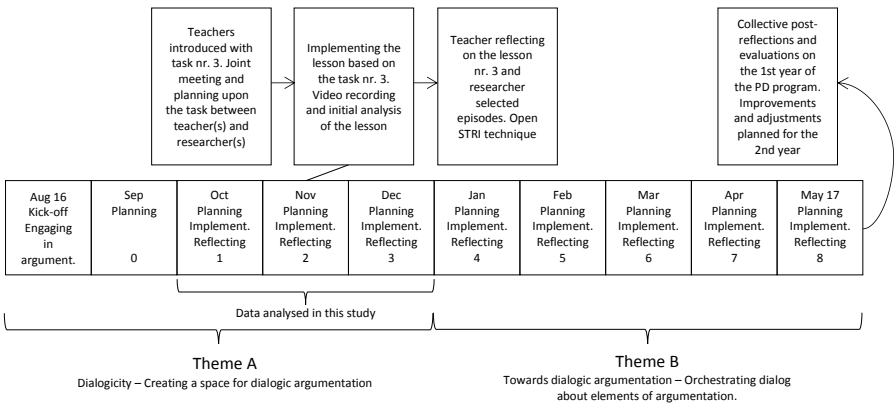

Figure 1. Overview of the first year of the PD programme.
Note: The second year will be adjusted based on the results from the first year.

Each unit (1–8) included three phases as follows:

a) *Pre-active*: A preliminary planning session in which a draft of the argumentation task is introduced by the researchers and modified based on teachers' remarks.
b) *Interactive*: A video-recorded implementation of the argumentation task (one lesson).
c) *Post-active*: A reflective PD discussion on excerpts from the video-recorded lesson (chosen by the researchers).

The three-phase structure of the PD training originates from previous research in the field (Westerman, 1991). Instead of beginning by delivering the theoretical load to teachers, the approach is more based in practice (Smith, 2001). In the PD training presented here, explicit examples are provided through videos for reflection. Conceptualisations are then addressed and developed jointly in subsequent planning and reflective sessions, which again is something that conforms to still-trending approaches to teacher PD

(Loughran, Mulhall, & Berry, 2004; Smith, 2001). Videos have been successfully used to create environments in which teachers engage in productive discussions on teaching and learning to foster PD (Borko, Jacobs, Eiteljorg, & Pittman, 2008). Whether this will lead to changes in practice and knowledge will be examined as the study proceeds. In addition to planning and reflective sessions, researchers and teachers interact via email regarding any changes and ideas related to forthcoming lessons. For example, teachers may suggest a topic for the next argumentation task. In the event that teachers want to use argumentation tasks more often, they have access to the tasks and other materials through the project website.

We believe that continuous interdisciplinary interaction between researchers and teachers throughout the programme facilitates bridging the gap between theory and practice as teacher PD comes about through continuous reflection on one's own and others' educational beliefs and practices (Helleve, 2009). As noted by McNeill et al. (2013), it is also effective for PD that teachers can discuss their experiences together. For this, joint meetings are organised at the end of each semester.

Mathematics was taught during both semesters and physics during either the autumn (one teacher) or spring semester (five teachers). In Finland, instructors often teach both physics and mathematics, thus providing an internationally unique opportunity to study the differences between the subjects. During the semester in which physics was taught, two argumentation tasks were designed and executed each month. In the pre-active phase, two tasks were discussed in one session. In the post-active phase, the researchers chose an excerpt approximately every other month from mathematics and physics.

Data collection

For each teacher ($N = 6$), data related to PD is collected in three phases monthly over two years:

- Pre-active: Audio-recorded planning of lesson sessions together with researchers.
- Interactive: Video-recorded teacher lessons.
- Post-active: Audio-recorded reflections together with researchers (Westerman, 1991).

As teachers are very busy, the pre- and post-active phases are conducted during one meeting. At two schools two teachers joined meetings together, and at two schools there is only one teacher participating the research. Two researchers join the meetings at the same time. The teachers are involved throughout the process from planning to reflection. First, researchers provide teachers with argumentation tasks, which teachers can comment on and suggest improvements to. When the task is ready, the teachers conduct the lesson. Typically, a lesson involves student argumentation in small groups and

a teacher-orchestrated whole-class argumentation discussion at the end. Next, the researchers watch the video-recorded lesson(s) and note down interesting aspects. From this, a topic for the PD discussion is chosen. One or two excerpts are also selected to be shown at the PD meeting to enable teacher reflection. Finally, together with the researchers, the teachers reflect on their lessons in video-stimulated recall interviews (O'Brien, 1993). As implied above, at two schools teachers can also see and comment on a colleague's lessons.

The total data analysed for teacher PD will eventually consist of more than 100 video-recorded lessons and reflections. The data for this paper consist of the autumn 2016 PD discussions (N = 12) complemented with an analysis of two classroom interaction examples. While both classroom interaction examples included dialogic indicators, the ways the two teachers reflected upon and acknowledged these features were quite opposite, thus leading the authors to select these as case examples. While one teacher acknowledged the features of dialogicity in his reflections, the other did not bring up these features, even though the researcher initiated a discussion on the topic.

Data analysis

Analysis of classroom interactions: The data analysed for this paper involves the first three modules with a three-phase structure (planning–implementing–reflecting). In other words, we will focus on "Theme A: Dialogicity – Creating a space for dialogic argumentation" (see Figure 1). The video analysis included consideration of dialogic/authoritative indicators (Lehesvuori, Ramnarain, & Viiri, 2017). Dialogic indicators address interactional moves in dialogue, including open questions (Chin, 2007), commenting on ideas that emerge in lessons, stating and explaining points of view, and being given ample time for thinking (Lehesvuori, Ramnarain, & Viiri, 2017). Students need the support of the teacher, who in turn must be sensitive to student initiatives (Aguiar, Mortimer, & Scott, 2010) and able to use talk to provide continuity and ensure reciprocity. The analysis of whole-class discussions was used as the basis for designing the PD meetings and selecting video clips for the meetings.

Mapping teachers' awareness of dialogicity: Thematic analysis (Braun & Clarke, 2006) of teacher reflections was used to map teacher and researcher initiatives on dialogicity. By presenting both teacher and researcher initiatives, we are able to shed light on the nature of reflective discussions – if only the researcher was bringing up features of dialogicity, it could be hypothesised that teacher awareness in regard to dialogicity was still underdeveloped, and when a teacher took up the dialogic features presented in the videos, it could be assumed that the teacher was aware of the features of dialogicity.

The main themes for mapping teacher awareness originated in descriptions of dialogicity (Alexander, 2006; Mortimer & Scott, 2003):

- Collectivity: To enhance collective and shared instructional and pedagogical activities, such as teacher-orchestrated whole-group discussions (Alexander, 2006). Students should listen to one another respectfully. Different ideas are welcomed and encouraged by others without debate (Mercer, 2000).
- Supportivity: To support and prompt students further in their thinking. Students should not fear being wrong; instead, all ideas are welcomed (e.g., Lehesvuori, Ramnarain, & Viiri, 2017; Mortimer & Scott, 2003).
- Purposefulness: To plan and guide discursive activities while paying attention to scientific processes and strategies with the explicit presence of educational goals (e.g., Alexander, 2006). Students should engage meaningfully with problems and phenomena and pay attention to argumentative strategies, cf. Mercer's (2000) exploratory talk.

Alexander's (2006) five principles were reduced to three: collectivity, supportivity, and purposefulness. The reason why cumulativeness was not included originates in the conceptual overlap with Mercer's (2000) cumulativity, within which ideas are merely collected without critical consideration. We are planning to include cumulativeness in our analytical framework when we analyse student–student interactions within peer discussions, which differ from exploratory talk in their lack of criticality and reasoning. To avoid conceptual misunderstandings with teachers (and the research community), cumulativity was therefore not dealt with in this paper. Reciprocity is something that we feel is built into interactive pedagogy, which this study also emphasises. For clarity, we have therefore selected the three main features to be highlighted in this part of the study.

The development of sub-themes for researcher and teacher initiatives in the feedback discussions was more grounded than data-based (Braun & Clarke, 2006; Voogt & Roblin, 2012), and so these themes can be considered as preliminary results that will eventually lead to the development of coding schemes in follow-up studies.

The unit of analysis consists of a sentence or several sentences addressing a specific theme. More specifically, the analytical unit is defined as an initiative, meaning a sentence or several sentences raising discussion on a dialogic theme. Often an initiative entails either a teacher or researcher taking up a dialogic feature stimulated by a video example or ongoing discussion. The unit is considered a new initiative (coding unit) when a new feature or a different point of view on the same feature is brought up. Examples of how the raw data are sequenced into units of analysis (initiatives) are provided in the

findings section as part of the analysis of case teacher reflections. The coding was conducted using Atlas.ti data analysis software.

Reliability was weighted through researcher triangulation by the authors (Cohen, Manion, & Morrison, 2007). The first author coded possible initiatives, which were then coded by the second author. After the first round, there was agreement on 73% of codes. After discussions and adjustments to the themes, the coding was repeated by the second author, after which inter-rater agreement was 85%. The remaining disagreements were discussed until a satisfactory consensus was reached. In addition, a "member check" (Lincoln & Guba, 1985) can be somewhat considered to have taken place with regards to the dialogicity of the interactions, as the teachers were introduced to lesson episodes selected by the researcher for the reflective sessions. All participants were asked for research permission before the study and could withdraw at any point. All data will be securely stored and used only for the stated research purposes, and the findings are presented so as to ensure complete anonymity.

Findings

Teacher implementation and awareness of dialogic features – Teacher example cases
Teacher example cases: Mark and David (pseudonyms) are male teachers who are around the same age and who have approximately the same amount of experience teaching physics and mathematics. These teachers were selected as exemplary cases as a result of the initial data analysis during the first quarter of the programme, which included whole-class discussions and PD discussions. We begin with Mark, who demonstrated awareness of dialogicity and implemented the dialogic approach during teacher-orchestrated whole-class discussions.

Teacher Mark: Bringing forth features of dialogicity

Classroom interaction example: The video extract is from Mark's first video-recorded lesson. This episode is from a whole-class discussion at the end of a lesson in which Mark was collecting student ideas on a mathematical problem. In the problem, students were asked to examine three rules (A–C) on how, when folding a paper, the number of folds relates to the number of parts into which the paper is divided (see Appendix A).

The teacher began the whole-class discussion by acknowledging student efforts.

> *Thank you for your discussions in groups. You have been very talkative, and in this lesson, that's a very good thing. But hey! Raise your hand if you chose option A at the beginning. There's one, there's another…*

After this initiation, Mark started collecting student ideas. The following video clip was presented to Mark in the reflective feedback and PD session:

1: Mark: *How could we make this work?*

2: Student 1: *Well, like, the number of folds or ... or* [Mark: *Folds*] … *or these parts, well those multiplied by two. Something like that.*

3: Mark: *Yeah* (rising intonation) … *multiplied by two, yeah* (rising intonation). *More ideas from other groups?*

4: Student 2: *Well, the same theory that we discovered here.*

5: Mark: *Remind us, I can't recall right now.*

6: Student 2: *Well, the theory of student 1 was the same as option A except the other way around.*

7: Mark: *OK* (rising intonation). *Well, could you figure out a theory that would fit for all folds?*

8: Student 2: *Well, at least I haven't found it.*

9: Mark: *OK, any more ideas?*

10: Student 3: *We tried it like if there is 16 parts, then in the next one there is 32 parts. It's like the number of parts is multiplied by two.*

11: Mark: *The number of folds?*

12: Student 3: *No, not the number of folds, I'm not talking about folds.*

13: Mark: *Yeah, so the number of parts is multiplied by* [Student 3: *Two*]*, yeah.*

14: Student: *16 Parts, and the next one has 32 parts* [Mark: *Yeah*]*, and the next one has 64 parts.*

15: Student 1: *So, the number of parts is multiplied by two.*

16: Mark: *So, the number of parts is doubling, but what happens to the number of folds in there?* (Discussion continues with teacher directing the discussion towards the number of folds).

This episode was considered to be dialogic since Mark was collecting student ideas without any evaluative aspect. This was indicated by the rising intonation in teacher feedback (turns 3 and 7). Rising intonation signals a teacher's supportiveness and interest in student responses and indicates that the teacher is willing to hear more (Lehesvuori, Ramnarain, & Viiri, 2017). Another feature supporting dialogicity is that several students took part in the discussion. The repetition (turn 3) in this case was considered to be neutral acknowledgement, which has the same function as rising intonation. Furthermore, the teacher deliberately and repeatedly directed the discussion towards the number of folds. In doing so, the teacher built on the students' ideas regarding the number of parts and created for them the possibility to make a connection to the number of folds. Due to the features introduced, this episode can be considered dialogic.

Reflections: The reflection session began with the researchers and Mark watching the video excerpt presented above. Mark began to comment on the clip spontaneously, without researcher initiation.

Mark: *It feels like I'm disturbing them all the time. At least I feel so.*
Researcher: *Well.*
Mark: *As I was watching, I noticed I didn't give them enough time to explain.*
Researcher: *Might be, but you had a quite open approach as you enquired for further ideas and didn't evaluate whether it was a good or bad idea.*
Mark: *Yeah, the main idea was to collect ideas from everyone. And if something special would emerge, then some more explanations would be discussed.*

Mark's comments reveal criticism in regard to inadequate wait time, but more importantly a clear and explicit reference to collectivity ("*Yeah, the main idea was to collect ideas from everyone*"). As noted after the example episode, the researcher acknowledged another dialogic feature – supportivity (no good or bad answers, prompting feedback). A bit later Mark brought up (again spontaneously) a feature that was highlighted within the programme.

Mark: *Two students were making contact there … two students were interacting with each other. If not directly, at least implicitly.*
Researcher: *Yes. That is one thing we try to emphasise in this programme.*

The emphasis the researcher referred to is on student–student interaction which occurs even during whole-class discussions, meaning that students become more confident in examining, challenging, and justifying the ideas emerging in the discussions. This can support collectivity but more importantly serves dialogic argumentation. Due to space limitations, we will present only one more reflection, this time initiated by the researcher as he referred to another episode in the whole-class discussion.

Researcher: *There was this boy who called out another's name, was it George or something, well, anyway, he said that he had a comment on George's idea. He turned towards George, and it was even audible when George said, 'Yeah, go ahead!' and nodded while listening to the other student. That evolved, like, spontaneously and suddenly.*
Mark: *Yeah, could students be, like, guided to talk to each other and could this be supported with guiding questions if needed?* [Researcher: *Yeah*] *The idea being to justify your ideas to each other. Just thinking about the future. Like, tell the opponent, or your own group members, how you defend your choice* [Researcher: *Yeah, that could be!*]*, and the opposing side listens and thinks about counter-arguments perhaps.*

Here, the researcher again highlighted the student–student interaction, but Mark took this further towards the rules for (dialogic) argumentation. This is considered an indication of the purposeful nature of dialogicity, which goes along with dialogic argumentation.

Overall, the examples here illustrate that Mark was aware of dialogicity and already had potential to go further in the training programme: towards dialogic argumentation. In total, during this reflective discussion (1.5 h) Mark had five dialogic initiatives and the researcher three (Table 2). Thus, the

teacher bringing dialogic features into the discussion through video stimulation complemented the above findings of the awareness of dialogicity.

Teacher David: Curtaining off dialogicity due to overly stressed correctness

Classroom interaction example: The topic and task were the same as those in Mark's lesson. Similarly as with Mark's lesson, the teacher, David, orchestrated a whole-class discussion at the end. The following extract was selected for the reflective PD discussion.

> 1: David: *And you had option C, 2 + 2 + 2 + 2. In your opinion, does this rule work?*
> 2: Group 1 simultaneously: *No!*
> 3: David: *Well, what was wrong, in your opinion?*
> 4: Student 1: *It doesn't increase by two.*
> 5: David: *Doesn't increase by two. So, rule C is that there will be two parts more if folded once. A good observation you had there. And, you had then option B. How about option B, did it work?*
> 6: Group 2 simultaneously: *Yes!*
> 7: David: Rule B works (neutrally). *So, option B was, 2 × 2 × number of folds* (writes on board). *Isn't it so! Well, let's have a look. If there were two folds, then 2 × 2 × 2.* (Another group's student raises a hand) *I'll ask them first and only after that will it be your turn. If there are two folds, then how many parts would option B give us?*
> 8: Student 2: *Eight.*
> 9: David: Eight! *So, with number two, if there are two folds, we would have eight. So, with this we just noticed that … Lizzy, Mike, and Jo* (students 1, 2, & 3)*, that if it is folded two times then with your choice it would give four parts. So, it then wouldn't work if it gives the wrong answer already with two folds. So, this rule then wouldn't work. Now, we have circled through the groups…*

This episode included some dialogic indicators. In turn 5, for example, the teacher gave supportive feedback: "*A good observation you had there*." Furthermore, the teacher collected different ideas without evaluating them as right or wrong. However, the discussion can be described as hasty as the teacher provided no space for spontaneous ideas and comments (turn 7: "*I'll ask them first and only after that will it be your turn*"). Furthermore, the repetition here signals the closure of an interaction chain, commonly known as IRF [I = initiation, R = response, F = feedback] (see Lemke, 1990), rather than an interaction being kept open. Due to these dominant features, this episode was not considered to be dialogic.

Reflections: After the video excerpt, the teacher began by focusing on the students and their behaviour – for example, their capability to take part in activities and follow instructions. After this, researcher 1 shifted the focus back to the video example.

> Researcher 1: *There, you just gave positive feedback, like saying 'A good observation you had there.'*
>
> David: *Yeah, and I repeated their answer.*
>
> Researcher 1: *It is indeed important that they get familiar with … or, like, receive that kind of positive feedback, like this is something that the teacher wishes from you.*
>
> Researcher 2: *And, in particular saying 'good observation' or 'good explanation' instead of just evaluating the content of the response. Since students are very worried about the correctness of their responses.*
>
> David: *I think it might change little by little due to the renewed curriculum, but this group here especially in mathematics is entirely accustomed to hearing whether the response is correct or not.*

During this exchange of thoughts, the researchers introduced supportive indicators found in the video example. The teacher mildly acknowledged this but shifted focus back to the students and their willingness to receive evaluative feedback. There were five further instances during this reflective PD discussion where the researchers tried to initiate thoughts on dialogicity but, as the following excerpt shows, the teacher did not respond to these initiatives in terms of reflecting on dialogicity. Here, as David acknowledges his repetition might leave students with uncertainty, researcher 1 shifted focus to dialogic indicators.

> Researcher 1: *In the video, there was this instance where you repeated students' response 'rule B works.' What were your intentions there?*
>
> David: *Well, when thinking about my own behaviour, I think this was partly purposeful. One reason is that I just repeat what they say so everyone will hear it, as some students speak very quietly. I repeat it so everyone will hear it. However, there might by misunderstandings that now the rule works although it doesn't … later on, I might shift this back to the students and ask them to think about whether it really works or not. So, I acknowledge this feature in my own talk.*
>
> Researcher 1: *Yeah, it is, from our point of view, a good thing to use this. That when you deal with something neutrally, like you said, 'rule A works,' you didn't indicate with your intonation that it was wrong* [David: *Oh so*]*, so the interest in the case will remain. So, you don't, so to speak, lock the answer…*
>
> David: *Yeah, I was still wondering whether students might sometimes just hear the part that "rule A works" and might stick with that idea although the rule doesn't work, and then they would have learned the thing, like, inaccurately…*

This example indicates that although the teacher acknowledged his repeating manoeuvre, he did not actually understand the dialogic aspect of it ("*Oh so*").

Moreover, it also implies that the teacher was very concerned about correctness in mathematics (learning things "*inaccurately*"). This was found to be a common fear among teachers and one that hinders, although it does not altogether prevent, the adaption of dialogic teaching practices (Osborne et al., 2004). Overall, instead of digging into the features of dialogicity, David shifted the focus to the content and its correctness despite the researchers' initiatives to open up this topic.

Dialogic features which were initiated by the researchers and teachers in the video-reflection meetings

Teachers' awareness of dialogic features was mapped based on the principles presented in Table 1. Each principle (main theme) surfaced in speech as initiatives (a sub-theme is an initiation of a discussion about a dialogic feature).

Table 1
Themes that emerged during PD discussions: dialogic principles (main themes) and initiatives (sub-themes)

Principle	Initiatives	
	Researcher initiatives	Teacher initiatives
Collectivity		
To enhance collective and shared instructional and pedagogical activities, e.g., teacher-orchestrated whole-group discussions (Alexander, 2006). Students should listen to one another respectfully. Different ideas are welcomed and encouraged by others without debate (Mercer, 2000).	The researcher emphasised the role of joint discussions and the ways to support this. The researcher specifically stressed the role of student–student interaction, even during whole-class discussions.	The teacher made sure to collect ideas from everyone. The teacher facilitated student–student interaction and supported students in challenging and contributing to one another's ideas. The teacher gave every group a chance to contribute to discussions. The teacher emphasised that groups and students should listen to each other (cf. reciprocity). The teacher redirected student questions and musings to the whole class. The teacher gave students turns in varying order to activate as many students as possible.

Supportivity		
To support and prompt students further in their thinking. Students should not fear being wrong; instead, all ideas are welcomed (e.g., Lehesvuori, Viiri, & Ramnarain, 2017; Mortimer & Scott, 2003).	The researcher brought up supportive features creating an open atmosphere where ideas are welcomed: no right or wrong. The researcher highlighted the value of student efforts at reasoning and justifying rather than just finding and guiding towards the right solution/answer. The researcher pointed out features of how the teacher could support dialogicity through opening up dialogic space; it could happen via open questions and supportive/neutral feedback. The researcher specifically stresses the importance of providing an extended wait time.	The teacher acknowledged that different ideas are welcomed and emphasised that there is no right or wrong. The teacher encouraged students to express their thoughts in their own words, i.e., different views are considered mutually and without evaluation (cf. Mortimer & Scott, 2003). The teacher gave students ample time to think and/or opened up space (and steps back) for peer discussions.
Purposefulness		
To plan and guide discursive activities while paying attention to scientific processes and strategies with the explicit presence of educational goals (e.g., Alexander, 2006). Students should engage meaningfully with problems and phenomena and pay attention to argumentative strategies, cf. Mercer's (2000) exploratory talk.	The researcher brought up features of dialogicity linked to argumentation, e.g., emphasising the role of long-term supportivity in further probing student participation, thinking, and reasoning. The researcher highlighted that students should be critical yet constructive and should be prepared to explain, justify, and challenge ideas.	The teacher collected ideas for further use and/or building on what had been said (this could be considered as purposeful cumulativity). The teacher guided students towards embracing the rules for argumentation: listening, challenging, and critiquing others' ideas in a sophisticated manner.

Whereas Table 1 presents different kinds of initiatives, Table 2 summarises the number of initiatives (main themes). Teachers A and B (B is David) attended the reflective sessions individually. Teachers C and D (D is Mark) and teachers E and F attended in pairs, as they work at the same schools.

Table 2
The number of teacher and researcher initiatives on collectivity (col), supportivity (sup), and purposefulness (pur) during three consecutive PD discussions

Teacher	PD session	Teacher initiatives	Researcher initiatives
A	1	2 (pur, col)	1 (col)
	2	4 (pur, col, col, col)	3 (pur, sup, col)
	3	0	3 (col, col, sup)
B (David)	1	0	1 (pur)
	2	0	6 (sup, sup, sup, sup, col, col)
	3	0	6 (sup, col, sup, sup, sup, col)
C & D (Mark)	1	2 (sup, col)	0
	2	5 (D: col, sup, col, pur, col)	3 (col, sup, sup)
	3	1 (col)	6 (sup, sup, sup, sup, sup, sup)
E & F	1	0	3 (sup, col, sup)
	2	0	5 (sup, col, sup, col, sup)
	3	5 (col, col, sup, sup, sup)	2 (col, col)
TOTAL		19 (5 sup, 11 col, 3 pur)	39 (22 sup, 15 col, 2 pur)

Comments: Analysis of classroom interactions and reflections indicated that teacher D (Mark) was already familiar with the concept of dialogic teaching. Mark's awareness of dialogicity was indicated in both lesson and reflections. These findings are supported especially by the second PD session Mark attended alone (five initiations of dialogic features). In David's (teacher B) case, it is clear that even though the researchers were increasingly trying to point out features of dialogicity (e.g., supportivity and collectivity in PD sessions 2 and 3), David did not take up these ideas during reflective discussions in terms of teacher initiatives. Indeed, the overview of dialogic initiatives (Table 2) conforms to the above notion that dialogicity was absent from David's view: there was no single initiative from David; instead, the researchers increasingly tried to bring up features of dialogicity, totalling 13 initiatives over three sessions.

Through the classroom and reflection examples, we illustrated one of the main reasons hindering the adoption of dialogicity in David's case: David was overly concerned about the correctness of the content. This is partly against the researcher/PD agenda which emphasises the importance of different and even wrong ideas when building on student contributions. With teachers E and F, we see some resemblance to David, but there were two references to dialogicity in the third PD discussion, thus giving an indication of some adoption of dialogicity.

Discussion

The findings of this study show what dialogic features teachers may raise in video reflection discussions in this kind of PD programme. We presented two different initial statuses as examples of dialogic interactions and teacher reflections on these through the teacher cases of Mark and David. While Mark demonstrated an awareness of dialogicity in his reflections and practised dialogicity in his classroom, David did not grasp the researchers' initiatives on dialogicity. Specifically, David did not respond to examples of dialogic indicators that were found in his lessons and presented to him through videos during the reflective discussions. David's lack of awareness of dialogicity was noticed in the other PD meetings, too. The overview of initiations from the first quarter of the PD programme supports these different starting points for teachers when it comes to welcoming dialogic pedagogy into teaching.

Even though dialogicity is found in science classrooms infrequently (Lehesvuori, Viiri, Rasku-Puttonen, Moate, & Helaakoski, 2013; Mercer, Dawes, & Staarman, 2009), the dialogic example presented in this paper illustrates how the prevailing authoritativeness can be challenged through the explicit and intentional implementation of dialogic indicators (Lehesvuori, Ramnarain, & Viiri, 2017). As David's examples show, however, dialogic indicators in one's speech without awareness of dialogicity merely lead to fragmented moments of dialogicity, which is not enough to lay the ground for authentic dialogic argumentation. We believe that through the intentional and explicit use of dialogic indicators teachers can open up dialogic space to facilitate authentic student argumentation, even during teacher-orchestrated discussions. Dialogicity should be manifested in the classroom beyond fragmented dialogic moments to develop the ground for authentic and dialogic argumentation (Mercer, 2009; Michaels, O'Connor, & Resnick, 2008; Resnick, Michaels, & O'Connor, 2010).

Dialogicity is one of the factors in a classroom's atmosphere from which students can build up the confidence to challenge the ideas of others as well as their own (Kiemer et al., 2015; Watters, 2016). Although interaction in mathematics and physics lessons neither can nor should be solely dialogic (Scott & Ametller, 2007), we hope that every teacher will experience successful dialogic argumentation episodes during the programme. Indeed, in some cases so far dialogic examples have been found merely at an indicator level, such as in brief dialogic moments including open questions and/or supportive feedback (Lehesvuori, Ramnarain, & Viiri, 2017).

This paper provides insights into the teachers' initial statuses, while the findings of the entire PD programme will eventually provide more longitudinal knowledge on teacher (and student) development in dialogic argumentation. We think that awareness of dialogicity, already present in Mark's reflections, is a seed towards growth in regard to more sustainable reformation of teacher practices (Desimone, 2009), particularly when complemented by a concrete strategy and continuous practice, as in the PD programme for dialogic argumentation.

Dialogicity alone is not enough to achieve authentic argumentative dialogue in the classroom: it is merely a requirement for dialogic argumentation. During the first year of the project presented in this paper, the focus has been on training our teachers in dialogicity and thus also conditioning students to actively participate in conversations, listen to each other, and comment on one another's ideas. However, it is the teachers themselves who have to adopt dialogicity into their views before dialogic argumentation can be enshrined in the norms of student interactions (Berland, 2011). Consequently, we have not yet seen a significant improvement in students' argumentation skills. Next autumn, our project will continue with an emphasis in teacher PD on the basics of argumentation.

Limitations and future study

Challenges in the adoption of dialogicity are partially expected, but previous studies have found less resistance among student teachers during similar programmes with a focus on dialogicity (Lehesvuori, Viiri, & Rasku-Puttonen, 2011). To persevere, explicit examples of dialogic activities need to be continuously designed, implemented, and brought to PD meetings. Due to being limited to case studies, we are not able to make generalisations here; still, as the programme continues we can visualise the growth of teachers in dialogicity and dialogic argumentation. The reasons for the different stating points are likely multifaceted. However, we hope the existing gap illustrated through the teacher cases can be bridged during the second year of PD. Thus far, the reported results are based on a surface-level analysis of teachers' awareness, and it is necessary to go beyond surface-level analysis in further studies.

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References

Abell, S. K. (Ed.). (2000). *Science teacher education: An international perspective*. Dordrecht: Kluwer Academic Publishers.

Aguiar, O. G., Mortimer, E. F., & Scott, P. (2010). Learning from and responding to students' questions: The authoritative and dialogic tension. *Journal of Research in Science Teaching, 47*(2), 174–193.

Alexander, R. (2006). *Towards dialogic teaching* (3rd ed.). York: Dialogos.

Bakhtin, M. (1986). *Speech genres and other late essays*. Austin: University of Texas Press.

Bakker, A., Smit, J., & Wegerif, R. (2015). Scaffolding and dialogic teaching in mathematics education: Introduction and review. *ZDM, 47*(7), 1047–1065.

Berland, L. (2011). Explaining variations in how classroom communities adapt the practice of scientific argumentation. *Journal of the Learning Sciences, 20*(4), 625–664.

Berland, L. K., & McNeill, K. L. (2010). A learning progression for scientific argumentation: Understanding student work and designing supportive instructional contexts. *Science Education, 94*(5), 765–793.

Borko, H., Jacobs, J., Eiteljorg, E., & Pittman, M. E. (2008). Video as a tool for fostering productive discussions in mathematics professional development. *Teaching and Teacher Education, 24*(2), 417–436.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–81.

Carneiro, R. (2007). The big picture: Understanding learning and meta-learning challenges. *European Journal of Education, 42*(2), 151–172.

Chin, C. (2007). Teacher questioning in science classrooms: Approaches that stimulate productive thinking. *Journal of Research in Science Teaching, 44*(6), 815–843.

Chval, K., Abell, S., Pareja, E., Musikul, K., & Ritzka, G. (2008). Science and mathematics teachers' experiences, needs, and expectations regarding professional development. *Eurasia Journal of Mathematics, Science & Technology Education, 4*(1), 31–43.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed.). London: RoutledgeFalmer.

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

Desimone, L. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher, 38*(3), 181–199.

Essien, A. A. (2017). Dialogic and argumentation structures in one quadratic inequalities lesson. In J. Adler & A. Sfard (Eds.), *Research for educational change: Transforming researchers' insights into improvement in mathematics teaching and learning* (pp. 82–99). London: Routledge.

Helleve, I. (2009). Theoretical foundations of teachers' professional development. In J. O. Lindberg & A. Olofsson (Eds.), *Online learning communities and teacher professional development: Methods for improved education delivery* (pp. 1–19). Hershey: IGI Global Information Science Reference.

Kiemer, K., Gröshner, A., Pehmer, A.-K., & Seidel, T. (2015). Effects of a classroom discourse intervention on teachers' practice and students' motivation to learn mathematics and science. *Learning and Instruction, 35*, 94–103.

Lehesvuori, S. (2013). *Towards dialogic teaching in science: Challenging classroom realities through teacher education*. Jyväskylä: University of Jyväskylä.

Lehesvuori, S., Ramnarain, U., & Viiri, J. (2017). Challenging transmission modes of teaching in science classrooms: Enhancing learner-centredness through dialogicity. *Research in Science Education*. Advance online publication. https://doi.org/10.1007/s11165-016-9598-7

Lehesvuori, S., Viiri, J., & Rasku-Puttonen, H. (2011). Introducing dialogic teaching to science student teachers. *Journal of Science Teacher Education, 22*(8), 705–727.

Lehesvuori, S., Viiri, J., Rasku-Puttonen, H., Moate, J., & Helaakoski, J. (2013). Visualizing communication structures in science classrooms: Tracing cumulativity in teacher-led whole class discussions. *Journal of Research in Science Teaching, 50*(8), 912–939.

Lemke, J. L. (1990). *Talking science: Language, learning and values*. Norwood: Ablex Publishing Company.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Newbury Park: Sage Publications.

Loughran, J. J., Mulhall, P., & Berry, A. (2004). In search of pedagogical content knowledge in science: Developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching, 41*(4), 370–391.

Marrades, R., & Gutiérrez, A. (2001). Proofs produced by secondary school students learning geometry in a dynamic computer environment. *Educational Studies in Mathematics, 44*(1–3), 87–125.

McNeill, K. L., Pimentel, D. S., & Strauss, E. G. (2013). The impact of high school science teachers' beliefs, curricular enactments, and experience on student learning during an inquiry-based urban ecology curriculum. *International Journal of Science Education, 35*(15), 2608–2644.

Mercer, N. (2000). *Words and minds: How we use language to think together*. London: Routledge.

Mercer, N. (2009). Developing argumentation: Lessons learned in the primary school. In N. Muller Mirza & A.-N. Perret-Clermont (Eds.), *Argumentation and education: Theoretical foundations and practices* (pp. 177–194). Berlin: Springer.

Mercer, N., Dawes, L., & Staarman, J. K. (2009). Dialogic teaching in the primary science classroom. *Language and Education, 23*(4), 353–369.

Michaels, S., O'Connor, C., & Resnick, L. (2008). Deliberative discourse idealized and realized: Accountable talk in the classroom and in civic life. *Studies in Philosophy and Education, 27*(4), 283–297.

Mortimer, E. F., & Scott, P. (2003). *Meaning making in science classrooms*. Milton Keynes: Open University Press.

O'Brien, J. (1993). Action research through stimulated recall. *Research in Science Education, 23*(1), 214–221.

Osborne, J. F., Erduran, S., & Simon, S. (2004). Enhancing the quality of argument in school science. *Journal of Research in Science Teaching, 41*(10), 994–1020.

Resnick, L. B., Michaels, S., & O'Connor, C. (2010). How (well structured) talk builds the mind. In R. Sternberg & D. Preiss (Eds.), *From genes to context: New discoveries about learning from educational research and their applications* (pp. 163–194). New York: Springer.

Roth, W.-M. (2014). Science language Wanted Alive: Through the dialectical/dialogical lens of Vygotsky and the Bakhtin circle. *Journal of Research in Science Teaching, 51*(8), 1049–1083.

Scott, P., & Ametller, J. (2007). Teaching science in a meaningful way: Striking a balance between 'opening up' and 'closing down' classroom talk. *School Science Review, 88*(324), 77–83.

Sedova, K., Sedlacek, M., & Svaricek, R. (2016). Teacher professional development as a means of transforming student classroom talk. *Teaching and Teacher Education, 57*, 14–25.

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education, 28*(2–3), 235–260.

Smith, M. S. (2001). *Practice-based professional development for teachers of mathematics*. Reston: National Council of Teachers of Mathematics.

Toulmin, S. (1958). *The uses of argument*. Cambridge: Cambridge University Press.

van Driel, J. H., Meirink, J. A., van Veen, K., & Zwart, R. C. (2012). Current trends and missing links in studies on teacher professional development in science education: A review of design features and quality of research. *Studies in Science Education, 48*(2), 129–160.

Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *Journal of Curriculum Studies, 44*(3), 299–321.

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. M. Cole, V. John-Steiner, & E. Souberman (Eds.). Cambridge: Harvard University Press.

Watters, J. J. (2016). Engaging elementary students in learning science: An analysis of classroom dialogue. *Instructional Science, 44*(1), 25–44.

Wells, G. (1999). *Dialogic inquiry: Towards a sociocultural practice and theory of education*. Cambridge: Cambridge University Press.

Westerman, D. A. (1991). Expert and novice teacher decision making. *Journal of Teacher Education, 42*(4), 292–305.

Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching, 39*(1), 35–62.

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