Abstract

Recent research has argued that inquiry-based science learning should be guided by providing the learners with support. The research on guidance for inquiry-based learning has concentrated on how providing guidance affects learning through inquiry. How guidance for inquiry-based learning could promote learning about inquiry (e.g. epistemic practices) is in need of exploration. A dialogic approach to classroom communication and pedagogical link-making offers possibilities for learners to acquire these practices. The focus of this paper is to analyse the role of different forms of guidance for inquiry-based learning on building the communicative approach applied in classrooms. The data for the study comes from an inquiry-based physics lesson implemented by a group of five pre-service primary science teachers to a class of sixth-graders. The lesson was video recorded and the discussions were transcribed. The data was analysed by applying two existing frameworks – one for the forms of guidance provided and another for the communicative approaches applied. The findings illustrate that providing non-specific forms of guidance, such as prompts, caused the communicative approach to be dialogic. On the other hand, providing the learners with specific forms of guidance, such as explanations, shifted the communication to be more authoritative. These results imply that different forms of guidance provided by pre-service teachers can affect the communicative approach applied in inquiry-based science lessons, which affects the possibilities learners are given to connect their existing ideas to the scientific view. Future research should focus on validating these results by also analysing in-service teachers' lessons.

Introduction

This study presents and analyses the role of different forms of guidance (Lazonder & Harmsen, 2016) for inquiry-based learning (IBL) have on pedagogical link-making (Scott, Mortimer, & Ametller, 2011) by teachers and the communicative approaches (CAs) (Mortimer & Scott, 2003) they apply. Episodes from a science lesson implemented by a group of pre-service teachers (PSTs) are analysed to provide examples of these roles.

Inquiry-based learning and related practices have been highlighted as a beneficial way of learning science in policy papers (National Research Council, 1996; National Research Council, 2000; NGSS Lead States, 2013) and meta-analyses (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Minner, Levy, & Century, 2010). IBL commonly refers to three main areas: learning to do inquiry (e.g. learning to design and carry out investigations), learning about inquiry (e.g. how scientific knowledge is developed) and learning through inquiry (e.g. conceptual knowledge) (Bybee, 2000; Gyllenpalm, Wickman, & Holmgren, 2010). Recent research has shown that IBL should be supported by providing guidance for the learners to reach optimal content learning outcomes through inquiry (Alfieri et al., 2011; Furtak, Seidel, Iverson, & Briggs, 2012; Lazonder & Harmsen, 2016). The role of guidance for IBL in supporting learning about inquiry, such as epistemic practices, dialogue and argumentation (Bereiter & Scardamalia, 2006; Driver, Asoko, Leach, Scott, & Mortimer, 1994; Osborne, 2010), has not been studied to the same extent even though this has been called for (Hmelo-Silver, Duncan, & Chinn, 2007).

The traditional and still dominant (Mercer, Dawes, & Staarman, 2009; Muhonen, Rasku-Puttonen, Pakarinen, Poikkeus, & Lerkkanen, 2017; Wells & Arauz, 2006) authoritative approach to classroom interaction sees the teacher as an authoritative figure who holds the scientific knowledge, which limits the learners' ability to engage in authentic inquiry where ideas are shared and alternative views are considered (Lemke, 1990). Through a dialogic approach to classroom interaction, more space is given for learners' own ideas and conceptions, which can then be investigated and either refuted or confirmed through evidence and thus connected with the scientific view (Mortimer & Scott, 2003). This connection of existing knowledge and new ideas is central to the constructivist perspective to learning (Larochelle, Bednarz, & Garrison, 1998). Teachers should address these connections in their teaching through the process of pedagogical link-making (Scott et al., 2011).

Previous research (Lehesvuori et al. 2011a) provides a holistic model that links different phases of IBL to different communicative approaches but just vaguely describes the role of guidance in enacting these approaches. In this study we examine a case example about the role of providing different forms of guidance for IBL have on shaping the CAs applied in the classroom. The novelty of this paper lies in combining the multitude of research on supporting inquiry-based learning and processes central to it by providing guidance (de Jong & Lazonder, 2014; Lazonder & Harmsen, 2016) with the existing research on pedagogical link-making and different CAs (Mortimer & Scott, 2003; Scott et al., 2011). The results will provide a new angle to the theory base of both strands of literature.

The goal of the theoretical background presented next is to highlight the theoretical connections between different forms of guidance, different CAs and pedagogical link-making. After this, we draw upon a case example in order to analyse empirically how the forms of guidance provided are connected with pedagogical link-making and different CAs.

Theoretical background

Inquiry-based learning and guidance

Different definitions for IBL are used in the literature, but they usually include certain phases or features of inquiry (Bell, Urhahne, Schanze, & Ploetzner, 2010; National Research Council, 1996; National Research Council, 2000). We conceptualize the different phases of IBL using the inquiry cycle formulated by Pedaste et al. (2015) through a systematic review of the existing literature on IBL. The cycle consists of five phases: stimulating interest (Orientation), stating theory-based questions and/or hypotheses (Conceptualization), planning and carrying out investigations (Investigation), drawing conclusions based on the data (Conclusion), and communicating the findings of a particular inquiry phase or the whole cycle to others and reflecting on one’s own actions (Discussion). The Discussion phase can be a separate part of the cycle, or it can follow a particular phase of the cycle.

Even though IBL has been advocated as a beneficial method of learning science, as discussed in the introduction, there have also been voices critical of the method. Especially, the cognitive load placed upon the learners by engaging in the processes essential to IBL has been called too heavy, which would render the method ineffective (Kirschner, Sweller, & Clark, 2006; Mayer, 2004). The answer to this critique has been to emphasize the potential of supporting IBL by, for example, the teacher, learning material or simulation (de Jong & Lazonder, 2014; Furtak et al., 2012). Meta-analyses have shown that providing support improves the learning outcomes attained (Alfieri et al., 2011; Furtak et al., 2012; Lazonder & Harmsen, 2016). This support for learning is often called *guidance* or *scaffolding*. Guidance can be defined as "any form of assistance offered before and/or during the inquiry learning process that aims to simplify, provide a view on, elicit, supplant, or prescribe the scientific reasoning skills involved" (Lazonder & Harmsen, 2016, p. 687). Scaffolding, on the other hand, is classically defined as ''the process that enables a child or novice to solve a problem, carry out a task, or achieve a goal which would be beyond his unassisted efforts" (Wood, Bruner, & Ross, 1976, p. 90). Both terms are related to instructional support aimed at promoting learning by moving some of the intellectual burden from the learner to a more knowledgeable other (e.g. teacher). While similar features can be found in the literature both about scaffolding (van de Pol, Volman, & Beishuizen, 2010) and guidance (de Jong & Lazonder, 2014), scaffolding relates more to a process that emphasizes the constant diagnosis of learners' understanding (Puntambekar & Kolodner, 2005; van de Pol, Volman, & Beishuizen, 2012), whereas guidance relates more to individual guiding actions by teachers (Lehtinen & Viiri 2017) or types of guidance (e.g. tools) that are provided for IBL (de Jong & Lazonder, 2014; Lazonder & Harmsen, 2016; Zacharia et al., 2015). We use the term guidance in this paper to describe the support for learning provided by the PSTs given its previous use in the literature regarding the inquiry-based teaching of science in general (Lazonder & Harmsen, 2016), but we still acknowledge the important contribution to the topic made by the literature on scaffolding.

Different categorizations have been developed to organize guidance for IBL provided to learners (de Jong & Njoo, 1992; Quintana et al., 2004; Reid, Zhang, & Chen, 2003). A recently developed typology by de Jong and Lazonder (2014) and then slightly modified by Lazonder and Harmsen (2016) classifies different forms of guidance according to the specificity of the learning support they offer to the learning processes. The typology is presented in Table 1. This specific typology is used to classify the different forms of guidance provided by the PSTs in this paper, because it has been used in multiple studies regarding guidance for IBL (e.g. (Lazonder & Harmsen, 2016; Zacharia et al., 2015)) and especially guidance provided by PSTs for IBL (Lehtinen & Viiri 2017).

Table 1. Typology for forms of guidance and their descriptions by Lazonder and Harmsen (2016) (slightly modified from de Jong and Lazonder (2014)).

Form of guidance	Description
Process constraints	Reduce the complexity of the learning process by limiting the number of options the learners need to consider.
Status overviews	A real-time progress report of the learning process or evolving knowledge which makes the progress apparent.
Prompts	Reminders to carry out certain actions or learning processes.
Heuristics	Suggestions on how perform a certain action or learning process, such as hints or reminders.
Scaffolds	Taking over more demanding parts of a learning process often by structuring the activity.
Explanations	Giving out target information or specifying how to perform an action.

The research on guidance for IBL has concentrated on the effects that providing guidance overall (Alfieri et al., 2011; Furtak et al., 2012) or certain forms guidance in particular (Lazonder & Harmsen, 2016) have on the content learning outcomes. Lazonder and Harmsen argue that the specificity of the provided guidance can also influence the understanding and appreciation of different epistemic practices related to inquiry. Hmelo-Silver, Duncan and Chinn (2007) also point out that learning “softer skills” such as epistemic practices related to science or learning how to collaborate (Bereiter & Scardamalia, 2006) need to be considered in addition to science content learning outcomes when designing guidance for IBL.

Communicative approaches applied in the classroom and pedagogical link-making

Mortimer and Scott (2003) have developed a framework that describes classroom discourse with two dimensions: interactive/non-interactive talk (I/NI) and the authoritative/dialogic (A/D) approach. Interactive talk allows the learners to participate, whereas non-interactive talk is a lecture in which the learners are not expected to participate. The dialogic approach takes into account learners’ different and possibly diverging ideas, whereas the authoritative approach focuses on one particular idea or view – usually the prevailing scientific view – controlled by the teacher.

These two dimensions can be combined to form four different communicative approaches (CAs) that teachers can apply. The four CAs and their descriptions are listed in Table 2.

Table 2. The communicative approaches and their descriptions by Mortimer and Scott (2003).

Communicative approach	Description
A/I	A question-answer routine where learners' responses are evaluated by the teacher and ideas diverging from the scientific point of view are rejected. The focus is on the scientific view.
D/I	Learners' ideas are elicited and then explored without evaluation. The teacher is not trying to achieve a specific point of view but instead works with the learners' views.
A/NI	The teacher lectures and presents the scientific content. The focus is on a specific point of view.
D/NI	The teacher takes into account contrasting points of view, such as learners' own ideas. Even though the teacher is lecturing, different points of view are being taken into account.

Even though CAs consist of multiple teacher-learner exchanges, some features regarding a single turn of conversation have been identified as indicators of a certain CA (Lehesvuori et al. 2017). Indicators of a dialogic approach include teachers' open questions (Alexander, 2006, p. 41; Chin, 2007) that elicit explanations or predictions from the learners without the teacher knowing the answer beforehand. On the other hand, closed questions rarely lead to dialogic interaction, because they aim for pre-defined answers (Chin, 2007). Teacher feedback is another indicator of different CAs. Evaluative feedback can be an indicator of an authoritative approach, because it presents the teacher as the more knowledgeable one in the discussion. Reacting to learners' responses with another question or initiation (thus forming an IRFRF pattern (Mortimer & Scott, 2003)) supports the learners in elaborating and making their ideas explicit (Scott, Mortimer, & Aguiar, 2006). This pattern indicates a more dialogic approach to classroom communication.

Dialogic and authoritative CAs have different possibilities for promoting practices related to IBL. Conducting investigations based on learners' preconceptions about the phenomenon under study and then argued for or against them using evidence from the investigations is central for IBL (Rönnebeck, Bernholt, & Ropohl, 2016). Thus, engaging in argumentation and working with conflicting views can be seen as part of the epistemic practices related to IBL (Driver et al., 1994; Furtak et al., 2012; Osborne, 2010; Rönnebeck et al., 2016). Science classrooms' typical communication pattern, the so-called "IRF triadic dialogue" (Lemke, 1990), which consists of the teacher's *Initiation* of talk (e.g. a question), the learner's *Response* and the teacher's *Feedback* (Sinclair & Coulthard, 1975), does not promote learning these practices. Seeing the teacher as the authoritative figure who gives feedback on the learners' responses based on the prevailing scientific view limits the learners' ability to engage in authentic inquiry, where ideas are shared and alternative views are considered (Lemke, 1990; Sadeh & Zion, 2009). Eliciting learners' own ideas and conceptions and contrasting them could help the learners form an authentic view of scientific inquiry, where preference is given to claims which are backed up by evidence and that are shared with peers (Driver, Newton, & Osborne, 2000; Sadler, 2006). Scott, Mortimer and Ametller (2011) use the term "pedagogical link-making" to describe the practices of teachers and learners in making connections between ideas through interactions in the classroom. They identify three different forms of pedagogical link-making:

1) Supporting knowledge building,
2) Promoting continuity, and
3) Encouraging emotional engagement.

Each of these forms can contain different types of approaches; for example, knowledge building can be supported by making links between every day (i.e. learners' existing ideas) and scientific ways of explaining or by making links between different scientific concepts. These links can take place during a time scale of years (making links to learning or teaching in different parts of curricula) to minutes (making links referring to different parts of the same lesson). An example of link-making taking place within a lesson is the "opening up" and "closing down" of discussions (Scott & Ametller, 2007). Discussions (that can last from a few minutes to the whole lesson) can be "opened up" with a dialogic approach, which enables the learners' existing views to be collected and worked with. Even though applying dialogic approaches to communication in the classroom enables the learners to practise skills related to authentic inquiry, there is also a place for authoritative approaches. These can be necessary when the gap between the learners' existing ideas and the prevailing scientific view is too large to be addressed through the dialogic aspect alone (Lehesvuori et al. 2011a). Thus, discussions that were "opened up" through dialogic approach, should be "closed down" when necessary using an authoritative approach to classroom communication. By eliciting the learners' existing ideas and views in the "opening up" stage, the learners are able to make links between them and the scientific view presented in the "closing down" phase. This sort of cumulative structure (Lehesvuori et al. 2013) of discussion enables meaningful links to be made between learners' existing understanding and the prevailing scientific view, and thus information is built on top of learners' previous experiences and knowledge (Alexander, 2006, p. 28; Mercer, 2008; Scott & Ametller, 2007; Scott et al., 2011). In general, meaningful science teaching should contain both authoritative and dialogic approaches (Scott & Ametller, 2007), but we do not argue for always following dialogic discussions with authoritative talk. The need for authoritative approach for classroom communication is dependent on the situation and the judgement of the teacher.

Theoretical connection between forms of guidance and communicative approaches

Based on existing conceptualizations of CAs and forms of guidance for IBL, we argue that the authoritative–dialogic dimension of classroom communication by Mortimer and Scott (2003) bears a resemblance to the continuum of specific–non-specific guidance by de Jong and Lazonder (2014) and Lazonder and Harmsen (2016). Providing more non-specific forms of guidance, such as process constraints or prompts, gives more space to the learners' own ideas, which can then be explored through a dialogic approach. This can happen when the whole class discussion is "opened up" (Scott & Ametller, 2007) and the learners' ideas are explored. On the other hand, when an authoritative approach is applied to classroom communication, the teacher can be seen as taking the side of the prevailing scientific view. The learners can be led toward this view by providing more specific forms of guidance, such as scaffolds or explanations. This can happen in the "closing down" phase of discussion (Scott & Ametller, 2007) where the teacher links the ideas that were previously elicited from the learners with the prevailing scientific view. This would be an example of two forms of pedagogical link-making, both supporting knowledge building and promoting continuity (Scott et al., 2011). Scott and Ametller describe the structure of "opening up" and "closing down" discussion as one that supports meaningful science learning.

Aim of the case study

As the theoretical basis for studying the role of different forms of guidance in building different CAs has been outlined in the previous sections, we will move on to analysing two excerpts from an example lesson. Through analysing the guidance provided in these two excerpts, we investigate analytically the previously theoretically argued connection. The analysed excerpts showcase the "opening up" and "closing down" of classroom discussions (Scott & Ametller, 2007) and the pedagogical link-making (Scott et al., 2011) that occurs between these two episodes. The role of different forms of guidance provided by teachers and the effect they may have on the CAs applied by in the classroom has not been studied, even though there is a call for research on the effect providing different forms of guidance on science teaching processes (Hmelo-Silver et al., 2007; Lazonder & Harmsen, 2016). This paper complements the existing literature on guidance for IBL by also analysing the role different forms of guidance have on the CAs applied in the classroom discourse through a case example.

Our research question is

"What is the role of providing different forms of guidance for inquiry-based learning on building the communicative approach applied by the pre-service teachers in the lesson under study?"

Context of the study

The context of the case example is primary PSTs' teaching of physics at the primary level. PSTs' inquiry-based teaching might differ from that of in-service teachers due to, for example, their limited content knowledge (Childs & McNicholl, 2007) or their limited understanding of inquiry-based teaching (Demir & Abell, 2010; Seung, Park, & Jung, 2014; Yoon, Joung, & Kim, 2012). PSTs' perceptions of teaching are based mainly on their own experiences in school as learners (Abell, 2000). These experiences are based on classroom interaction mostly based on lecturing and closed questions with evaluative feedback (IRF pattern) (Mercer et al., 2009). Through pre-service teacher training, secondary PSTs have been able to implement science lessons that contain both dialogic and authoritative approaches (Lehesvuori et al. 2011b) ,and primary PSTs have improved their conceptions toward more dialogic inquiry-based teaching (Lehesvuori et al. 2011a). Regarding guidance by PSTs for IBL, Yoon, Joung and Kim (2012) report that Korean PSTs describe having difficulties with balancing between guiding the learners in their IBL activities and giving them space to work on their own. Lehtinen et al (2016a) report the same issue in a Finnish context regarding IBL where simulations are used to conduct the investigations.

The data for the case example were collected as a part of an intervention for primary PSTs (n = 40) (see Lehtinen et al. 2016b for extensive details on the whole study cohort) aimed at promoting the use of simulations for IBL. Simulations mimic the behaviour of a real system and allow learners to observe the effect of interacting with this system (de Jong & Lazonder, 2014). They are very well suited to be used to as a part of IBL because they allow the learners to freely investigate different hypotheses or research questions and thus come to conclusions. They also allow for the visualization of otherwise unobservable features, such as electric charges moving from one object to the other. Literature reviews have concluded that investigations performed using simulations enhance students' conceptual understanding and motivation when compared with lecturing or laboratory activities (Rutten, van der Veen, & van Joolingen, 2015; Smetana & Bell, 2012).

Participation in the intervention and the study was voluntary for the PSTs, and written consent for the study was collected. The intervention was integrated into the PSTs' science methods course and was conducted in a period of two months, with weekly 90-minute meetings and independent homework. The main part of the intervention was the planning and implementing of an inquiry-based science lesson where simulations had to be used to conduct at least part of the investigations. This planning and implementation as done in groups of five PSTs each. The first third of the intervention was used to introduce the PSTs to the basic structure of IBL in science and to the PhET (Physics Education Technology) simulation database (University of Colorado Boulder, 2017). The last two thirds were spent on the planning and implementation of the lesson. To ensure that the PSTs obtain experience in teaching inquiry-based science with simulations, each of the groups were instructed to use a certain PhET simulation as a part of their lessons. The planning process was supported by feedback from the two teacher educators in charge of the intervention and by using peer feedback. This was done to surpass the most common difficulties in IBL, such as how to get the learners to generate hypotheses or draw conclusions (de Jong & van Joolingen, 1998; García-Carmona, Criado, & Cruz-Guzmán, 2016). The lessons were implemented in primary school science lessons from third to sixth grade.

The case example is one of the eight lessons implemented as part of the intervention. This lesson was chosen for this case study because the five PSTs implementing that particular lesson applied the dialogic approach more than PSTs from any other lesson. The lesson also featured all the five phases of IBL as defined by Pedaste et al. (2015). The five PSTs who planned and implemented this lesson were five females ($M_{age} = 26$, $SD_{age} = 4$) of which four had under six months of teaching experience and one had between one and a half and two years of teaching experience. None of them had used simulations in teaching or learning science before the intervention. The topic of their lesson was "Static Electricity", and the simulation used to conduct part of the investigations was the "Balloons and Static

Electricity” simulation from the PhET database (University of Colorado Boulder, 2017). Figure 1 shows the simulation. The lesson topic and the simulation used was decided in cooperation with the participating class’s teacher to fit their curriculum at the time of the data collection. The topic of static electricity is familiar to most primary aged learners from their everyday life, which enables them to possibly have their own everyday ideas about the phenomenon. In addition to the simulation the learners also used different hands-on equipment such as balloons, transparencies, combs and scraps of paper to conduct part of the investigations. Previous research has indicated that combining the use of simulations and hands-on material benefits primary-aged learners more than using just a simulation to conduct the investigations (Jaakkola, Nurmi, & Veermans, 2011).

The whole class phases (other than the Investigation phase) were orchestrated by one or two PSTs with the others observing. During the Investigation phase each PST guided one small group of learners in their experiments. The learners first investigated static electricity using the “Balloons and Static Electricity” –simulation where they could interact with a balloon and sweater and experiment with them. The simulation visualized how to the negative charges from the sweater are transferred to the surface of the balloon, causing the sweater to become positively and the balloon negatively charged. After using the simulation, each group of learners could investigate same phenomena using different hands-on material such as combs or transparencies. Through these hands-on investigations, the learners could connect the observations made from using the simulation to the real world scenario. The simulation was available for use also during the hands-on investigations.

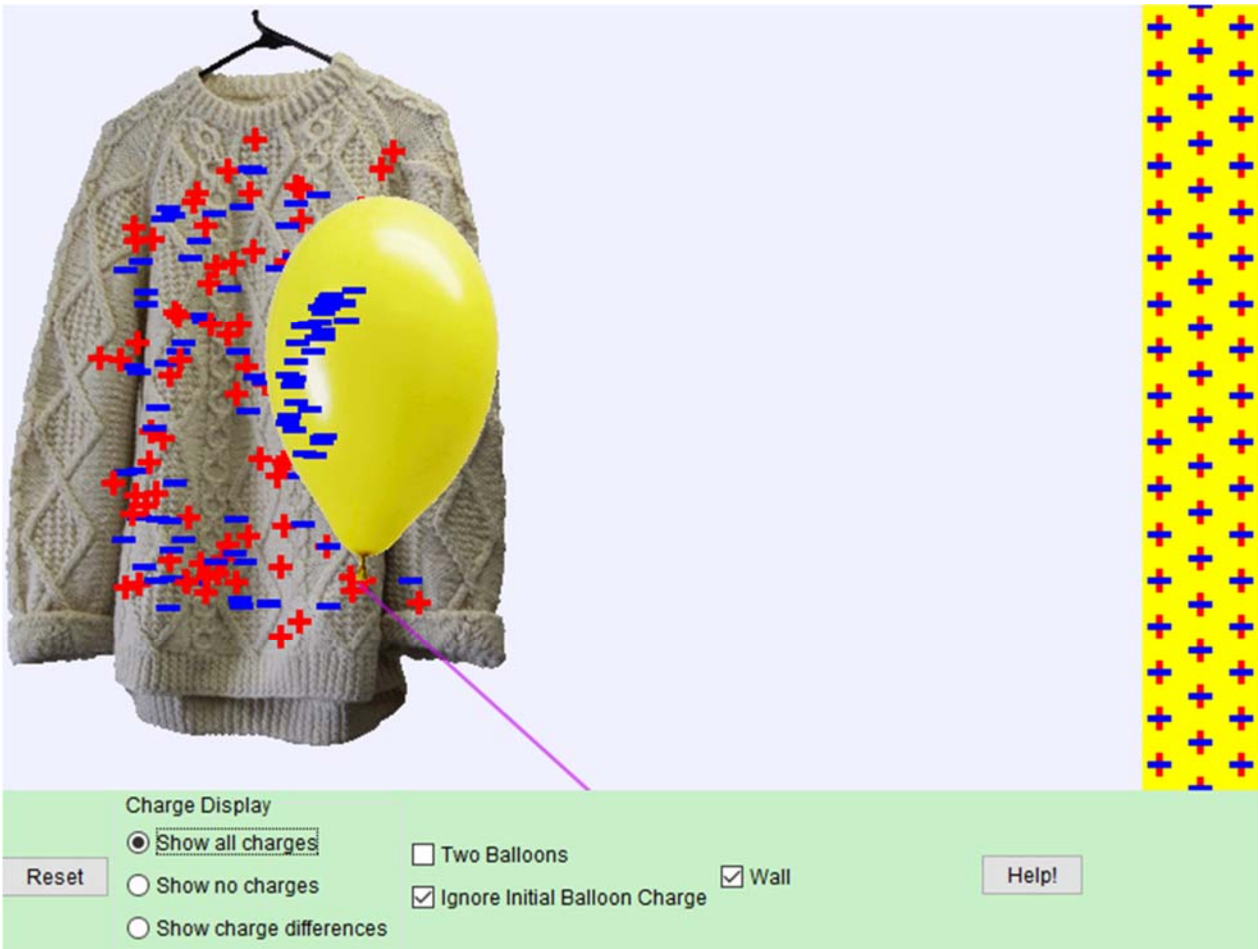

Fig. 1 The “Balloons and Static Electricity” –simulation used in the lesson under study.

The lesson under study was implemented in a class of 15 sixth-graders aged 11 to 12 as part of their science curriculum. The course of the lesson divided into episodes and the phases of inquiry by Pedaste et al. (2015) is described in Table 3.

Methods

The data used for this study was collected primarily by two video cameras, which recorded the lesson from the front and the back of the classroom. These two cameras recorded both the audio and the video of the whole class teaching episodes in front of the classroom and smaller groups’ investigations that were conducted around five different table groups in the classroom. The investigations with the simulations and the hands-on material were both conducted around the same desks. Even though the focus of this case study is on the whole class teaching episodes, additional audio data was collected using screen capture programs running on the laptops that ran the simulations. This audio was used to analyse the learners' and teachers' actions during the Investigation phase of IBL. All the video and audio data was transcribed, and both the transcriptions and the video and audio data were used in the analysis. Overall, the data used in the analysis amounted to 140 minutes of video and audio.

The analysis of the video data began with defining the phases of IBL present in the lesson. This was done using the descriptions for the phases of IBL from Pedaste et al. (2015) and comparing the teaching-learning processes in the lesson to those descriptions. The lesson was divided into five phases of IBL based on this analysis. After this, the analysis was conducted as two parallel and separate processes: one dealing with the analysis of the guidance provided by the PSTs for IBL in the lesson and the other dealing with the analysis of the CAs applied by the PSTs in different episodes during the lesson.

The basis for the analysis of the forms of guidance were the descriptions of the forms of guidance by de Jong and Lazonder (2014) and Lazonder and Harmsen (2016), examples from previous research on different forms of guidance provided by software by Zacharia et al. (2015) and previous research on how these forms manifest themselves as *guiding actions* that the teachers verbally provide (Lehtinen & Viiri 2017). A guiding action was defined as a teacher's verbal action that fit one of the descriptions for forms of guidance by Lazonder and Harmsen. These guiding actions were single teacher utterances (e.g. Prompt: "*Why do you want to reject the hypothesis?*") apart from the guiding actions that were provided as scaffolds. According to the definition of de Jong and Lazonder, scaffolds support the dynamics of the activity, often by providing learners with the components of the process, which provides structure. Teachers provide similar support by, for example, asking multiple closed questions in a row when the learners are presenting the results of their investigations (Lehtinen & Viiri 2017). The questions provide structure for the complex problem of reporting one's results. Thus scaffolds are often longer than single utterances and consist of few teacher Initiation–learner Response turns. The coding for different forms of guidance could have been continued by forming data-based categories for guiding actions e.g. prompts (Lehtinen & Viiri 2017). This was not done in this paper, because the used coding only served as a basis for the further analysis of the roles of the different forms of guidance have on building the CA. Instead, during the further analysis detailed in the Findings section the role of each guiding action was analysed individually.

The analysis for the CAs applied by the PSTs started with defining the units of analysis – episodes. We define an episode change as happening whenever there was a change in topic, a contrast in behaviour or a transition to the next type of conversation or activity (Jordan & Henderson, 1995). Multiple episodes can be contained within the same phase of inquiry. For example, moving from a teacher-led demonstration to a demonstration where a volunteer learner is called in front of the class to demonstrate the same phenomenon is seen as a transition from one episode to another even though they both are a part of the Orientation phase of inquiry. The episodes and their topics are presented in Table 3.

Table 3. The episodes and their topics divided into the phases of inquiry by Pedaste et al. (2015).

Phase of inquiry	Episode/min	Topic
	E1 / 0–2	Teacher-led demonstration of static electricity
	E2 / 2–3	Learner demonstrates the phenomenon in front of the class
	E3 / 3–5	Probing learners' ideas regarding the phenomenon, which are then written on the blackboard
	E4 / 5–6	Learners' come up with ideas in small groups
	E5 / 6–8	More probing for learners' ideas regarding the phenomenon, which are also written on the blackboard
	E6 / 8–9	Instructions for investigations
Investigation	E7 / 9–27	Conducting the investigations
	E8 / 27–28	Instructions to end the investigation
	E9 / 28–30	Collecting the first group's findings from their investigations
	E10 / 30–31	Collecting the second group's findings from their investigations
	E11 / 31–32	Collecting the third group's findings from their investigations
	E12 / 32–33	Collecting the fourth group's findings from their investigations
	E13 / 33–34	Collecting the fifth group's findings from their investigations
	E14 / 34–36	Coming back to the first idea on the blackboard
	E15 / 36–37	Coming back to the second idea on the blackboard
	E16 / 37–38	Coming back to the third idea on the blackboard
	E17 / 38–39	Coming back to the fourth idea on the blackboard

After this, the dominant CA was defined for each episode. When defining the dominant CA, attention was paid to the fact that authoritative episodes could contain dialogic passages or attempts that still do not transform the sequence into a dialogic one or vice versa. Definitions by Mortimer and Scott (2003) were used in defining the dominant CAs. To illustrate the overall communicative structure of the lesson during the whole-class teaching sequences, a communication graph was constructed (Figure 2). Our analysis focuses only on the whole class teaching sessions (so not on the Investigation phase). Similar communication graphs have been used previously to visualize different CAs applied in science lessons (Lehesvuori et al. 2013). The graph showcases the dominant CAs for each episode and their temporal position in the lesson. There were no guiding actions in the episodes that were categorized as authoritative and non-interactive. We define the dominant form of guidance by analysing the role each guiding action (which each have a certain form) in forming the CA of each particular episode. The dominant form of guidance plays the largest role in forming the CA. This analysis is gone through in more detail in the Findings section of this paper through the excerpts from the data.

Trustworthiness

By providing a thick description (Lincoln & Guba, 1985) of the data and analysis procedure we aim to provide an account on the transferability of the findings. We also mostly "stay close to the particulars" (Simons, 2015) within the presented case lesson. The crucial temporal aspect of teaching (Lemke, 1990; Scott et al., 2011) is highlighted by concentrating on the analysis of one case lesson. Reliability scores were not calculated for the codings due to a) the small amount of data, b) the case nature of this study, c) the fact that researcher triangulation was conducted throughout the research process (Miles & Hubermann, 1994) – the first author carried out the primary video analysis, and the findings were evaluated and discussed between the authors until consensus was achieved – and d) the preliminary interpretations were presented and discussed with experts of classroom communication analysis. In previous studies with similar data, good reliability scores have been achieved for the analysis of PSTs' guiding actions (Lehtinen & Viiri 2017) and for the analysis of PSTs' CAs (Lehesvuori et al. 2011b).

Findings

Figure 2 illustrates the phases of inquiry, the communicative approaches applied and the dominant forms of guidance in these episodes.

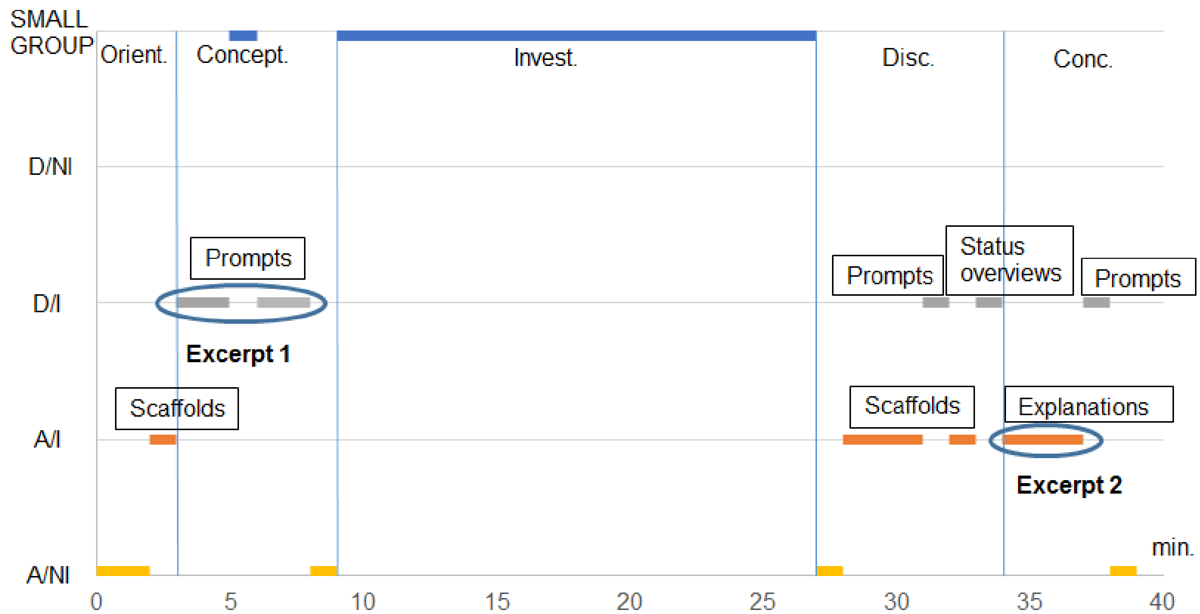

Fig. 2 The phases of inquiry, communicative approaches applied in the different episodes, dominant forms of guidance in the episodes and the analysed excerpts.

As shown in Figure 2, non-specific types of guidance (prompts and status overviews) were the dominant forms of guidance in the episodes, where the communication was dialogic and interactive. On the other hand, in the episodes where the communication was classified as authoritative and interactive, more specific forms of guidance (scaffolds and explanations) were dominant.

The two analysed excerpts come from the "opening up" and "closing down" parts of the lessons. The first excerpt is from the Conceptualization phase and the second from the Conclusion phase of inquiry. PSTs' Initiations, learners' Responses and PSTs' Feedback are marked on to the excerpts with numbers in subscript to represent which learner is responding. The guiding actions provided by the PSTs are also listed and marked by bold type.

Excerpt 1 – Opening up the lesson through providing prompts

The following excerpt comes from the Conceptualization phase of the lesson. In consists of two whole-class teaching episodes (E3 and E5 in Table 3) separated by a small group discussion. Before the excerpt, the PSTs have demonstrated static electricity in the Orientation phase by rubbing a balloon with a woollen sweater and watching it stick to a wall and push other balloons. In the excerpt, PSTs A, B, C and D orchestrate a whole group discussion about the learners' ideas regarding the demonstration.

1	*PST A:*	*My hair stood up – didn't it – and then the balloon got stuck to the wall – the one a bit better and the other one not so well – and then there was some small movement when Victoria moved the balloon – **what really happened there**? Oliver tell us.*	I	Prompt
2	*Oliver:*	*Static electricity.*	R_1	
3	*PST A:*	*Good – we will now collect together your ideas and observations about this phenomenon – static electricity – **can you, Oliver, tell a bit more accurately what is static electricity** – **have you ever done that with a balloon?***	F/I	2 X Prompt
4	*Oliver:*	*Well yeah… Static electricity is that thing when something becomes electric when you rub it if I remember correctly.*	R_1	
5	*PST B:*	*OK so we'll write that something becomes electric when you rub it… **Does anyone else have some ideas**?*	F/I	Prompt
		(PST D writes "A thing turns electric when it's being rubbed" on the blackboard)		
6	*PST C:*	*Some sort of explanations of why this happens.*		
7	*PST A:*	*Yes we are not even looking yet for the final answer, because there are a lot of ways to look at these physical phenomena.*		
8	*PST B:*	*So you don't have to think if this is right or wrong but just, well, what you think – **why did the balloons do what they just did**?*	I	Prompt
9	*PST A:*	*Do you have any ideas Mary or Jane or Julia… **have you tried that sometimes**?*	I	Prompt
		(Mary, Jane and Julia nod.)	R_2	
10	*PST A:*	*OK, so you know the phenomena.*	F	
11	*PST B:*	*What if we'll give you a minute to discuss in your own groups, and then*		

		we'll collect your thoughts if you have something new – so think in your own group for a while about ***why do these balloons stick to the wall when they were rubbed to the scarf and why did it move on the desk*** *– you can talk for about a minute and we can walk around.*	I	Prompt
12	*PST A:*	*And those answers can elaborate on what Oliver said or they can be completely different thoughts.*	I	

The episode begins with PST A prompting the learners about their ideas regarding the demonstration with the balloons (turn 1). Oliver brings up the term static electricity in his answer (turn 2), and PST A affirms the term (turn 3). PST A continues to prompt Oliver about static electricity (turn 3), and his answer is written on the blackboard. The discussion turns again to the whole class with PST A's prompt (turn 5). As no one answers, PSTs A and B explicitly state that there is no one correct answer (turn 7) and that all ideas are welcome in the discussion (turn 8). When the learners still do not offer their ideas for discussion even when prompted (turn 9), PST B instructs the learners to discuss their ideas with their peers (turn 11). During the small group work, two ideas are written on the blackboard based on the learners' ideas: "Electricity is magnetic -> electromagnetism" and "The balloons repel one another". After this, PST B continues with the whole class teaching.

13	*PST B:*	*OK so now you have had a minute to discuss and part of your ideas have already been written on the blackboard, but now* ***could you tell what your group came up with?*** (gestures to one of the groups)	I	Prompt
14	*Larry:*	*Yes, at least that electricity is sort of a magnet.*	R_3	
15	*PST B:*	*Electricity is sort of a magnet, OK…* ***So is it a bit like this one we have already* "Electricity is magnetic"*?***	F/I	Heuristic
		(Larry nods)	R_3	
16	*PST B:*	*OK* ***did you girls have something, Julia or Jane or Mary?***	F/I	Prompt
17	*Julia:*	*If you rub the balloons they start to repel one another and they can also pull, for example, hair to it.*	R_2	
18	*PST A:*	*Yeah, yeah.*	F	
		(PST C adds "Pull things toward them" to the blackboard to complement		

		the statement "The balloons repel one another".)		
19	*PST B:*	***You came up with really good ideas in your groups.***	F	Status overview

The second episode begins with PST B prompting two of the groups for their ideas (turns 13 and 16) and pointing out a similarity between Larry's idea and a statement already on the blackboard (turn 15). The episode ends with PST B giving positive feedback to the learners on their actions (turn 19).

When analysing the roles different forms of guidance play in building the CA throughout these two episodes, we must investigate what forms of guidance are provided and which are not. Looking first at what forms of guidance are provided, multiple prompts are used to elicit learners' conceptions and existing ideas regarding static electricity. The prompts are open questions that are used to collect the learners' ideas about the demonstration from the Orientation phase, which served as a primer for the prompts. After the first initial prompts in the first episode, the learners are reluctant to share their ideas with the whole class. After the prompts in turns 5 and 8 attempt to invite more learners to share their ideas, the prompt in turn 11 instructs the learners to discuss the ideas in groups with their peers. The talk between peers when compared with the teacher-learner talk can promote engagement in discussions and argumentation and increase the ownership of information (Barnes & Todd, 1977). Through peer discussions, more ideas are brought forward by listing them on the blackboard. This ensures that they remain a part of the discussion for the duration of the whole lesson. In turn 15, PST B recognizes that Larry's idea resembles an idea that is already on the blackboard. Through a heuristic, she guides Larry to see the connection. At the end of the episode, PST B provides the learners with a status overview, which gives the learners a real-time report on their work thus far.

When analysing what forms of guidance are missing from these episodes, the main attention can be given to the lack of explanations by the PSTs. Even though the learners' ideas are not in unison with the scientific view (e.g. Larry in turn 14), the PSTs do not give out this information. Instead, they just acknowledge the learners' ideas (e.g. in turns 5 and 16) without evaluation. This reduces the teachers' level of authority and gives more space to the learners' own conceptions (Osborne, 2010).

In these two episodes the PSTs succeed in opening up (Scott & Ametller, 2007) the discussion by giving the learners opportunities to express their ideas, which enables them to be worked with throughout the lesson. This is achieved through providing the learners with multiple prompts as a form of guidance. Overall, the dominant CA in the episodes is interactive and dialogic. Arguments for this interpretation can be expressed through the following points:

- The PSTs use multiple prompts to elicit learners' ideas, which also allows the learners to participate.
- PSTs' responses to these ideas are not evaluative, and explanations are not provided to close the gap between the ideas and the scientific view. Instead, in turns 3 and 15, the response serves as a new question, probing the learners for more elaboration and forming an IRFRF pattern (Mortimer & Scott, 2003).
- The ideas are written on a blackboard, enabling the PSTs to work with these ideas throughout the lesson and bringing them forth as valuable contributions.
- Peer discussions are encouraged. Prompting the learners to talk with one another increases the reciprocity of teaching and encourages the sharing of ideas and consideration of alternative viewpoints (Alexander, 2006, p. 28).

Excerpt 2 – Closing down the lesson through providing explanations and making links

The second excerpt comes from the Conclusion phase of the lesson. It consists of two whole-class teaching episodes (E14 and E15 in Table 3). After investigating with the simulation and the hands-on materials in small groups in the Investigation phase and going through each group's observations in the Discussion phase, the PSTs turn the learners' attention back to the ideas listed on the blackboard in the Conceptualization phase (previous excerpt). PSTs A, B, C and E orchestrate a whole-class discussion.

20	*PST A:*	*At the bottom of the blackboard we had:* "The balloons repel one another and pull things toward them".		
21	*PST B:*	*What do you say –* ***can we dismiss or accept this claim?***	I	Prompt
22	*Paul:*	*Dismiss.*	R_1	
23	*PST B:*	***Why do you want to dismiss it?***	I	Prompt
24	*Paul:*	*Well because they repel one another but it has to do with the electric*	R_1	

		charge –		
25	*Oliver:*	*And besides –*	R_2	
26	*Paul:*	*It's not the balloons that repel one another – it's the electric charge that the balloons and the other object had that repel each other.*	R_1	
27	*Oliver:*	*And they don't attract.*	R_2	
28	*PST B:*	*Yes that was –*	F	
29	*PST C:*	***Very well said.***	F	Status overview
30	*PST B:*	*Yes.*	F	
31	*PST A:*	***So the balloon in itself – any kind of balloon – it doesn't pull everything to itself – it's not like the Earth's gravity, isn't that so****? Good point – or, in a way –* ***you found the heart of the matter*** *in your observations, yeah…*	F	Explanation Status overview

The first episode begins with PSTs A and B prompting the learners about the first of the learner-generated ideas on the blackboard (turns 20 and 21). After a PST B's prompt for reasoning (turn 23) for Paul's answer for rejecting the idea (turn 22), Oliver and Paul give their reasoning based on their investigations with the simulation, which visualized the electric charges on the balloons (turns 24–27). PST C provides a status overview (turn 29), which provides information to the learners about the good quality of Paul's and Oliver's answers. PST A closes the discussion by providing an explanation between the differences between the pull caused by Earth's gravity and the pull that the learners observed in the Orientation phase of the lesson between the rubbed balloon and the wall. After this, the next episode starts with the next learner-generated idea on the blackboard.

32	*PST A:*	*… how is it with magnetism –* ***in the beginning there was a lot of talk about electromagnetism and magnetism – what do you think about that?***	I	Prompt
33	*PST B:*	*Oliver.*	I	
34	*Oliver:*	*Well, the so-called magnetism is caused by the electric charge – it is not really magnetic, the charge causes it*	R_2	
35	*PST A:*	***You used the words "so-called", so magnetism is maybe something else.***	F	Heuristic

36	*PST B:*	*Yes.*	F	
37	*PST A:*	***Magnetism is what, for example, birds use to orient themselves – they use magnetic fields*** – *isn't that so?* – ***there were some observations that there was something similar as with magnets – they repel each other. I played with train tracks when I was younger, and you know that the train cars stick to each other one way and the other way they don't, and that's a magnetic phenomenon, but now, like Oliver said, this phenomenon was about electricity.***	F	Explanation
38	*PST B:*	*Yes, so we could put parentheses around it or do we dismiss it all together?… Let's dismiss it.*	F	
39	*PST A:*	*What do you say, Oliver – I already drew one line* ***– do we dismiss it?***	I	Prompt
40	*Oliver:*	*In principle, we dismiss it, because it is not magnetic.*	R_2	
41	*PST E:*	***It's a completely different phenomenon.***	F	Explanation
42	*PST A:*	***So a similar thing but still different.***	F	Explanation

The second episode also begins with PST A prompting the learners about an idea on the blackboard (turn 32). Oliver's answer (turn 34) distinguishes between magnetism and electric charge. PST A seizes upon Oliver's words and provides a heuristic through a hint (turn 35) that, in fact, magnetism is something different from the phenomenon under study. After this, PST A gives examples about phenomena relating to magnetism – birds' orienting themselves with Earth's magnetic fields and toy trains sticking together – and thus gives an explanation (turn 37) about the differences between magnetism and electric charges. After PST A's prompt (turn 39) to possibly dismiss the idea, PSTs E and A provide final explanations (turns 41 and 42) to differentiate between magnetism and electric charges.

In these two episodes, the explanations that PSTs A and E provide play a dominant role in building the dominant CAs. The explanations give additional content information relating to the leaner-generated idea under discussion in both episodes. By providing the explanations after prompting the learners for their ideas, the PSTs can be seen as holding the scientific view and presenting it to the learners through the explanations. Even though Paul's and Oliver's answers are not in conflict with the scientific view, by giving the explanations the PSTs ensure that all learners are able to make the connection between the ideas collected in the Conceptualization phase and the scientific view (Scott & Ametller, 2007). In addition, the heuristic guiding action in turn 35 where PST A takes an affirmative position to Oliver's preceding answer has an effect on the CA. By reasserting Oliver's response to the prompt and hinting at the difference between magnetism and electric charges, PST A evaluates Oliver's answer and takes an authoritative position.

Two types of pedagogical link-making can be discerned from these episodes. The first type is evident in both episodes when PSTs A and B form a micro-scale link to the events of the first excerpt by referring to the learners' pre-existing ideas written onto the blackboard (turns 20 - 21 and 32). This link promotes continuity throughout the lesson by referring explicitly to the learners' ideas elicited during the Conceptualization phase of inquiry and develops the scientific story (Scott et al., 2011). The guidance in the form of prompts (turns 21 and 32) serve to close this pedagogical link. This sort of cumulative structure where new knowledge is built on top of previous knowledge reflects the epistemic practices of inquiry (Furtak et al., 2012; Osborne, 2010) and learning about inquiry (Bybee, 2000; Gyllenpalm et al., 2010). The second type is evident when the PST A links the scientific way of explaining with the everyday way of explaining and real world phenomena (turns 31 and 37) by differentiating between them. This happens through her providing guidance in the form of explanations on those turns. These explanations promotes knowledge construction and are aimed at ensuring that the learners are able to differentiate between the pull of Earth's gravity and the pull of an electrically charged balloon (turn 32) or magnetic and electric phenomena (turn 37).

Similar to the first excerpt, multiple prompts (e.g. turns 21 and 32) are used to elicit learners' conceptions on the ideas collected in the Conceptualization phase. These prompts form a pedagogical link that promotes continuity throughout the lesson and enables the learners to connect their pre-existing view with the information gained from the Investigation phase of inquiry. The difference here compared to the first excerpt is that in these two episodes the learners' responses to these prompts are systematically followed by heuristics and explanations that serve as authoritative teacher turns. These specific forms of guidance form a pedagogical link that promotes knowledge construction.

In these two episodes, the PSTs close down the discussion that was opened up by collecting the learners' ideas in the Conceptualization phase that were then investigated in the Investigation phase. Even though Oliver and Paul were able to move from their peers' initial ideas of magnetism and electric charge being connected with each other to the scientific view, all learners might not have succeeded in the same. By closing down the discussion with an authoritative approach and a pedagogical link, the PSTs ensure that the scientific view relating to electric charge is clarified for all learners. Overall, the dominant CA applied in these two episodes is authoritative and interactive. Arguments for this interpretation can be expressed through the following points:

- The PSTs' prompts promote interaction between the learners and PSTs.
- Learner responses to these prompts are followed by specific forms of guidance (heuristics and explanations). This guidance does not build on the learners' responses but instead showcases the scientific view in regard to the ideas collected at the beginning of the lesson.
- There are some cases of the IRF pattern (e.g. turns 39–42) (Sinclair & Coulthard, 1975) in the discourse, which is one possible signal of an authoritative CA (Scott et al., 2006).

Discussion

The findings of this case example showcase how providing guidance for IBL with differing specificity had an effect on the CAs that the PSTs applied in their teaching. Providing series of prompts (low level of specificity) in the Conceptualization phase of the lesson enabled the PSTs to collect learners' ideas regarding the demonstration from the Orientation phase. Learners' ideas were not evaluated with explanations or heuristics (high level of specificity), but instead the PSTs worked with these different points of view stemming from the learners' ideas (Scott et al., 2006). Prompting for ideas opened up the lesson dialogically and interactively. While in both the "opening up" phase of the lesson and the "closing down" phase multiple prompts were used to elicit learners' ideas, the dominant CA was different in these phases. In the "opening up" phase, these prompts were followed by further prompts, forming longer question chains in an IRFRF pattern (Mortimer & Scott, 2003). In addition, the learners' answers were not evaluated or followed by explanations. These factors played a role in the dialogic CA applied in the "opening up" phase. This is in contrast with the "closing down" phase, where the prompts were followed by heuristics and explanations. Through these specific forms of guidance, the PSTs focused on the scientific view and aimed to consolidate it. This had an effect on the applied CA which was authoritative and interactive. The PSTs linked the dialogic "opening up" and authoritative "closing down" phases of the lesson together through pedagogical link-making which connected the learners pre-existing ideas to be connected with the findings from their investigations. The lesson had thus cumulative and meaningful structure where the learners were given a chance to investigate their own ideas in the Investigation phase and to understand that new information is built on top of pre-existing knowledge (Alexander, 2006, p. 28; Mercer, 2008; Scott & Ametller, 2007). These are features of learning about inquiry – that is, how scientific knowledge is constructed (Bybee, 2000).

The analysis of the excerpts from this study make it clear that in-depth analysis of the provided guidance, which also takes into account the temporal properties (Lehesvuori et al. 2013) and pedagogical link-making (Scott et al., 2011), is needed to study the complex connection between the forms of guidance and the applied CA. The findings of this study have twofold implications regarding both research of guidance for IBL and teachers' practice. Regarding research, while the need for guiding or supporting IBL has been well documented in the literature, research has concentrated on the effect that providing different forms of guidance for IBL has on content learning outcomes (Alfieri et al., 2011; Lazonder & Harmsen, 2016). The findings from the example lesson showcase the role that the presence or absence of different forms of guidance can have on planning and implementing meaningful science lessons where learners are given chances to share and make explicit their existing knowledge with others, conduct investigations to possibly challenge existing knowledge and make connections between their knowledge with the scientific view and understand the possible omissions in previous thinking (Scott & Ametller, 2007). Research on how guidance for IBL can influence the use of epistemic practices of science through inquiry has been called for (Hmelo-Silver et al., 2007), and this paper sheds more light on this matter. Zacharia et al. (2015) gave some recommendations based on their literature review on how different phases of IBL should be guided to promote learning. The focus of their literature review was on guidance provided by software for IBL on lessons where simulations or online laboratories are used to conduct the investigations, such as in the case example lesson. Their recommendations include providing scaffolds and prompts in the Conceptualization phase and did not include providing direct information (i.e. explanations) in the Conclusion phase. The findings from this case example lesson complicate these recommendations: providing specific forms of guidance in the "opening up" phase (Conceptualization) and not providing them in the "closing down" phase (Conclusion) could have detrimental effects on the learners' ability to meaningfully connect their existing knowledge with the scientific view (Scott & Ametller, 2007). This implication should be studied with more data from multiple contexts and also from in-service teachers' lessons.

Regarding teachers' practice, previous research has conceptualized a holistic model (Lehesvuori et al. 2011a) regarding implementing meaningful inquiry-based science lessons that include both a dialogic "opening up" phase and a more authoritative "closing down" phase. This model offers only limited tools for detailed lesson planning, which is essential for implementing inquiry in practice (Zubrowski, 2007). The case lesson analysed in this paper provides an example on how different forms of guidance can have a role on implementing meaningful inquiry-based science lessons. By consciously providing prompts throughout the lessons and by providing specific forms of guidance only after the Investigation phase, the PSTs elicited learners' ideas throughout the lesson but provided the scientific view only after the learners have had a chance to investigate their existing ideas. Potentially, the results from this case example that connect the somewhat concrete typology of the forms of guidance by Lazonder, and Harmsen (2016) with the more abstract typology of different CAs (Mortimer & Scott, 2003) could give teachers new ways to plan lessons with differing CAs.

Limitations

The limited amount of data makes drawing broader conclusions challenging. The aim of this article was to study the role of guidance in building the CA applied in science lessons through both a theoretical overview and a fine-grained analysis of case example lesson by pre-service teachers. More research is needed to validate the findings from different grades and also from in-service teachers' lessons. Pre-service teachers' limited content knowledge could have an effect on their teaching, including the guidance they provided (Childs & McNicholl, 2007). We also acknowledge that many other features, such as wait time, intonation or the use of personal pronouns, have an impact on the CA applied by teachers (Lehesvuori et al. 2017).

Compliance with Ethical Standards

Conflict of Interest: The authors declare that they have no conflict of interest.

Informed consent: Informed consent was obtained from all individual participants included in the study.

Research involving Human Participants: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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