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Scaffolding primary teachers in designing and enacting language-oriented science lessons: Is handing over to independence a fata morgana?

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ABSTRACT

The purpose of the design-based research reported here is to show – as a proof of principle – how the idea of scaffolding can be used to support primary teachers in a professional development programme (PDP) to design and enact language-oriented science lessons. The PDP consisted of six sessions of 2.5 h each in which twelve primary school teachers took part over a period of six months. It centralised the language support that pupils need to reason during science lessons. In line with the idea of scaffolding, the structure of the PDP targeted teachers' gradual independence in designing lessons. The first research question is how scaffolding was enacted during the PDP. The analysis of video recordings, field notes, researcher and teacher logs, and teacher design assignments focused on the enactment of three scaffolding characteristics: diagnosis, responsiveness and handover to independence. The second research question concerns what teachers learned from the participation in the PDP that followed a scaffolding approach. The data analysis illustrates that these teachers had learned much in terms of designing and enacting language-oriented science lessons. In terms of diagnosis and responsiveness, our PDP approach was successful, but we problematise the ideal of scaffolding approaches focused on handover to independence.

1. Introduction

Anyone with the ambition to design, on the basis of research, a professional development programme (PDP) for new learning goals faces several challenges (cf. Borko, 2004). The literature provides many pieces of advice on what to focus on in PDPs, but the advice is often of a very general nature. For example, it is important to stimulate reflection and provide opportunities to link what is learned during a PDP with classroom instruction (Borko et al., 2010, p. 549; Van Veen, Zwart, & Meirink, 2012). At the same time, it is acknowledged that teacher learning is situated and that a PDP has to be adaptive to local needs (NSTA, 2006; Putnam & Borko, 2000). Applying such research to improve PDP is, as Paul Cobb says, a matter of “fighting our way up to the level of concrete practice” (Qvortrup, Wiberg, Christensen, & Hansbøl, 2016, p. 276) — a saying that aligns with the sociocultural adage of ascending from the abstract to the concrete (Ilyenkov, 1960/2008).

In a design research project we drew on several bodies of literature (language-oriented science education, scaffolding, genre

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pedagogy — summarised in the next section) to help teachers design and enact language-oriented science lessons for primary education, a relatively new learning goal for a PDP. Scaffolding, in short, can be characterised as temporary adaptive support with learners' independence as the ultimate aim (Van de Pol, Volman, & Beishuizen, 2010; Wood, Bruner, & Ross, 1976). It is considered a form of excellent teaching (Maybin, Mercer, & Stierer, 1992; Van de Pol, 2012) and is here applied to teachers rather than pupils. Our approach to language-oriented subject education is informed by content-based language instruction (e.g., Brinton, Snow, & Wesche, 2003; Gibbons, 2002), in which teachers scaffold pupils in the genres relevant to the specific topic that is being taught (e.g., reasoning about floating and sinking). Scaffolding thus operates at two levels in this study – to promote teachers' learning during a PDP and to promote pupils' learning of scientific genres – but our focus is on the adaptive support to teachers, provided by researchers-educators.

The purpose of the study reported here is to contribute to knowledge about how teachers can be scaffolded within a PDP with the aforementioned learning goal. As the first question we ask:

RQ1: How was the idea of scaffolding enacted in the professional development programme with the aim to design and enact language-oriented science lessons for primary education?

An answer to this question is necessary to give the reader a sense of the scaffolding approach as an intervention and to check how well the idea of scaffolding was implemented. Next we ask what teachers learned from this approach:

RQ2: What have teachers learned from their participation in the professional development programme in which a scaffolding approach was taken?

2. Theoretical background

Given the intention of our research to support teachers in primary education to integrate language in their science lessons, this section first elaborates on this goal. Next we formulate the overall idea of scaffolding to shape the PDP as well as the learning activities used to facilitate teacher learning. We also highlight the theoretical ideas from the genre literature that we had to transform (simplify or concretise) so as to make them productive in the PDP which had to be adaptive.

2.1. Goal of the PDP: supporting teachers to integrate language in science education

Teaching science in primary classrooms is a challenge for teachers worldwide. This can be explained by many primary teachers lacking background knowledge in science and technology, their limited pedagogical content knowledge, inadequate understanding of problem-solving skills, and low self-efficacy (Traianou, 2006; Van Aalderen-Smeets, Walma van der Molen, & Asma, 2012).

It has been argued that centralizing language while teaching science may be a potential solution to challenges primary teachers face (Howes, Campos, & Lim, 2004) and beneficial for learning both science and language (Romance & Vitale, 1992; Vars, 1996). Firstly, primary teachers are generalists, teaching all subjects, often with a particular strength in language arts (Appleton, 2007). For them, science appears to be more attractive when it integrates other aspects of the curriculum (Appleton, 2002). Integration with language also increases (preservice) teachers' comfort in teaching science (Akerson & Flanigan, 2000). Secondly, many scholars have advocated integration from a conceptual point of view by pointing to the close relationship between language and science (cf. Vygotsky, 1962; Zwiep, Straits, Stone, Beltran, & Furtado, 2011). Language learning is a vital component of learning science (Haug & Ødegaard, 2014). In particular, pupils' participation in the science classroom is dependent on teacher-pupil discourse, in which language functions as a mediating tool (cf. Vygotsky, 1962, 1978). Access to specialised science language is crucial for reasoning about scientific phenomena (Mercer, Dawes, Wegerif, & Sams, 2004). Some even go so far as to state that learning science implies learning the language of science (Braund, 2009; Lemke, 1990).

The primary science teacher's role is thus hybrid by nature: It requires understanding scientific phenomena related to pupils' explanations and argumentation, as well as the ability to provide pupils access to the specialised language needed to do so. To realise the latter, approaches of content-based language instruction (e.g., Brinton et al., 2003; Gibbons, 2002) have advocated ample opportunities for pupils to produce language themselves. This allows so-called bridging discourses to occur (Gibbons, 2002): interactional patterns in which teachers can support pupils' language development from everyday, spoken-like language to subject-specific, written-like registers. During such teacher-student interaction teachers are to pose higher-order questions and employ interactional skills that invite pupils to contribute to classroom discourse (e.g., Mercer et al., 2004; Mercer, Dawes, & Kleine Staarman, 2009; Scott, 1998). Furthermore, teachers need to explicitly attend to how specialised language is organised in a particular science domain, as each topic within the discipline of science requires its own language usage (Halliday, 1978; Stoddart, Pinal, Latzke, & Canaday, 2002). To do so, the formulation of language learning goals, in addition to content-specific learning goals, has been advocated in lesson planning (Smit, 2013). Furthermore, several researchers (e.g., Gibbons, 2002; Smit, Van Eerde, & Bakker, 2013) have advocated the deliberate enactment of scaffolding strategies in teacher-pupil interaction (e.g., reformulating, repeating correct utterances, or asking for more precise language) so as to promote pupils' development of the required language.

One of the pitfalls we knew to watch out for is the tendency of teachers using language-oriented approaches to focus on vocabulary (e.g., Haug & Ødegaard, 2014; Henrichs & Leseman, 2014). To promote pupil reasoning, attention also needs to be paid to formulations, or even genres (recurring text types in school and society, such as reports and recounts; Gibbons, 2002). However, in a previous PDP inspired by genre pedagogy (Hyland, 2004) teachers strongly advised us to no longer mention genres in PDP as these were considered too abstract, but instead speak of "reasoning steps" which were spelled out in targeted language. This is an example of a local term that functioned better than the official concepts from research: on the one hand scientific reasoning and on the other the abstract notion of genre. As researchers we came to appreciate the term reasoning steps as a bridge between a focus on language and on science. It helped teachers learn to specify learning goals in intermediate reasoning goals that included targeted language (more than just vocabulary). As such, the notion of reasoning steps forms an example of ascending to the concrete.

In our experience with language-oriented science and mathematics education it is not sufficient for teachers to be aware of the language required for learning the subjects, or to spell out language goals accompanying science or mathematics learning goals. Additional design of innovative language-oriented teaching materials is usually required. So far such materials are scarce, and what is available is often developed by researchers specialised in the topic (e.g., Smit, 2013, for mathematics). Very few teachers have developed the design capacity needed to realise such materials, yet teachers need to have a significant role in curriculum design, because they are the actors in the school system who are primarily responsible for pupils' learning (Huizinga, 2014; Keys & Bryan, 2001; Parke & Coble, 1997). Promoting teachers' design capacity has also been argued to enhance teachers' sense of ownership (Vos, 2010), and to contribute to sustainable educational innovations (Brown, 2009; Peercy, Martin-Beltrán, Silverman, & Daniel, 2015). It is for these reasons that we decided to focus our PDP on the design and enactment of language-oriented science teaching.

We employed the idea of scaffolding to shape and enact the PDP. In line with the scaffolding idea, we intended to provide tailored help and exemplary materials (Beyer & Davis, 2009; Penuel & Gallagher, 2009) with the aim to help teachers become independent in designing and enacting innovative practices.

2.2. Scaffolding within a professional development programme

The key idea we intended to realise in this project was that of scaffolding as an integrative concept (Bakker, Smit, & Wegerif, 2015): It captures many aspects of good teaching, for example working within learners' zone of proximal development, adaptively supporting them with what they need, and aiming for independence (Maybin et al., 1992). In the original examples of scaffolding, the target skill was mostly a well-defined ability such as solving a puzzle (Wood et al., 1976). Although typically related to teacher-pupil interaction with the aim to help pupils move forward, scaffolding in this study is employed to shape and trace *teachers'* learning in a PDP. There is in our view nothing in the idea of scaffolding learners to restrict the application of the scaffolding concept to pupils.

In our definition of scaffolding, key characteristics are diagnosis, responsiveness and handover to independence (Smit et al., 2013). Diagnosis refers to identifying teachers' levels of competencies, their local needs and potential. Responsiveness refers to adaptive action, in this case by educators to offer the support that teachers need. Thus scaffolding has the potential to address the situated nature of teacher learning. The ultimate aim of scaffolding is to help teachers become more independent in whatever skills or competencies are to be developed. Handing over to independence can be seen as a combination of two parallel processes: fading of support and transfer of responsibility (Van de Pol et al., 2010). In terms of the scaffolding metaphor, once learners have done the work that they needed the scaffolds for, these can be removed. Or, in another reading of the metaphor: Once the building does not need the support of the scaffold anymore to stay upright, the scaffold can be removed.

Despite the potential of scaffolding approaches and the body of literature with regard to teaching pupils (Belland, Walker, Olsen, & Leary, 2015; Van de Pol et al., 2010), the approach has hardly been used with teachers. Exceptions in the context of science and mathematics education tend to focus on preservice teachers rather than in-service teachers, and either adopt the metaphor to only refer to built-in scaffolding in instructional materials (e.g., Nason, Chalmers, & Yeh, 2012; Sleep & Boerst, 2012; Toh et al., 2014), or do not explicitly refer to key characteristics of scaffolding (e.g., Van der Valk & De Jong, 2009). If the latter is the case, there is the pitfall that the concept of scaffolding loses its meaning and becomes overgeneralised. Thus, little is known about how teachers can be scaffolded and what they learn from it.

The conceptualisation of scaffolding used in this study includes the long-term dimension of most learning processes, such as learning to realise language-oriented science education. This long-term dimension is captured in three features of scaffolding. Firstly, the scaffolding characteristics are *layered* in nature as they can be enacted both in and outside live interaction (that is, during as well as outside PD sessions — referred to as *online* vs *offline* enactment). For example, a researcher-educator can diagnose a teacher's level during a session, but also on the basis of a homework assignment. Secondly, the enactment of scaffolding characteristics is *distributed* over time. A response to a teacher's diagnosed level may take place in a next PDP session. Finally, long-term scaffolding is *cumulative*, with teachers' independence emerging as the cumulative effect of diagnoses and responsive actions throughout time.

One of the points of debate in the literature on scaffolding is whether handing over to independence or transfer of responsibility is a convincing and realistic aim of scaffolding. As Fernandez, Wegerif, Mercer, and Rojas-Drummond (2001, p. 53) write: "The metaphor of a 'scaffold' implies a temporary support that is removed once the construction work has been completed." From the literature on dialogic teaching however (Wegerif, 2007), it could be argued that support is often not removed, but only changes in nature. Dialogic teaching pleads for opening up spaces for learning without pre-specifying the exact tasks in which learners have become independent. Another point of criticism is that the idea of scaffolding only works for well-defined skills that can be taught (Stone, 1998, p. 350). In the discussion we come back to this more general and theoretical point about scaffolding, which also has methodological implications.

2.3. What promotes teacher learning?

We have so far underpinned the goal of our PDP (language-oriented science teaching) and the main approach to be enacted (scaffolding). In this section we zoom in on mediating processes relevant to teacher learning. We capitalise on four learning activities mentioned by Bakkenes, Vermunt, and Wubbels (2010) as returning key elements in the literature on developing teacher expertise in the context of educational renewal: 1) learning by experimenting, such as trying out a new teaching method or making new materials; 2) learning in interaction with others, such as teachers or researchers); 3) using external sources, for example reading publications or viewing exemplary video materials; and 4) consciously reflecting on one's own teaching practices, for instance by filling in logs.

More specifically we needed to think through how to support teachers' design capacity. As design researchers we are inclined to use hypothetical learning trajectories (HLTs, Simon, 1995). Originally, the notion of HLT was introduced to formulate theory- and practice-informed conjectures about pupils' learning during particular instructional activities. It typically consists of 1) learning goals, 2) pupils' starting points concerning relevant prior knowledge, 3) characterisation of learning activities and 4) conjectures about pupils' learning processes during these activities. In design research, HTLs can be adjusted along the way based on intermediate reflection, so as to be adaptive to local circumstances (Bakker & Van Eerde, 2015). Conjectures about pupil (or teacher) learning always remain hypothetical. It has been suggested that teachers may benefit from working with HTLs (Gravemeijer, 2004). However, in a previous PDP we found that HLTs were too difficult for teachers to work with, let alone formulate themselves. One challenge in the current project was thus to find a way to capture the essence of such trajectories (adaptivity by means of quick turns in prediction and reflection) in a workable format.

3. Methods

3.1. General approach

We used design-based research (cf. Barab & Squire, 2004) to design the PDP, and subsequently evaluated data collected in this project to answer the two aforementioned research questions. We continue this section with the initial design of the PDP, which was adapted based on intermediate diagnoses of teachers' progress.

3.2. Initial design of the PDP

The focus of the PDP was on teachers learning to design and to enact language-oriented science education. Three themes were leading in the formulation of learning goals: 1) reasoning steps needed for pupils to understand and explain scientific phenomena, 2) language needed for these reasoning steps, to be specified as language goals in lesson preparation, and 3) language promoting strategies as the ways how teachers can promote and support the required language in teacher-pupil interaction. These themes were also leading in the construction of the lesson preparation format (see Fig. 1) as well as in the scaffolding analysis conducted for research question 1 (see Section 3.5.1).

Long-term scaffolding was designed through an emphasis on diagnosis (identifying teachers' starting point, but also close monitoring during and in between sessions), the flexibility to change initial plans and a gradual change of support. In the beginning we provided a full, "exemplary" lesson plan, and we gradually moved to independent lesson design at the end of the programme.

In the initial design we included schooling on science topics such as sinking and floating in the first PDP sessions. We also planned to involve the participating teachers in experimental inquiry during the sessions themselves, so as to experience and better understand the scientific phenomena (cf. Keys & Bryan, 2001; Minner, Levy, & Century, 2010). Furthermore we included schooling on the integration of language in the initial design. We planned to promote participants' understanding and use of interactional skills (e.g., using longer silence) so as to promote extended discourses during science lessons (cf. Gibbons, 2002). Furthermore, participants were introduced to types of higher-order questions to be employed in science teaching (e.g., What do you think? What explanation do you have for…?, What evidence have you got for that?), as well as to a repertoire of the aforementioned scaffolding strategies (e.g., reformulating). Along with teachers' increasing language-oriented design and teaching practices over time, we aimed for reflective discussions and activities about these practices.

Teachers were encouraged to systematically predict and reflect on pupils' learning, the reasoning steps involved in such learning, and pupils' required language development (based on Smit, 2013, for mathematics education). Central to the preparation of lessons was the emphasis on predictions and reflections (inspired by the idea of HLTs), by means of which the teachers tried to envision pupils' scientific reasoning steps during a particular instructional activity, plan activities and think of the language pupils need. For the participants, used to drawing on textbooks and a more procedural preparation of science lessons, this was a new way of preparing science lessons. The lesson preparation format for teachers that was developed and used over the course of the PDP, a simplification of the original idea of an HLT, is represented in Fig. 1. The format included all key aspects of the envisioned language-oriented approach to science teaching and promoted teachers' prediction and reflection.

Between the PDP sessions we planned periods of three to four weeks in which participants were asked to design and enact lessons (experimentation). In the results section on RQ1 we describe how the initial design of the PDP was further shaped and adapted to the teachers' needs, based on diagnoses made by the researchers-educators.

3.3. Setting and participants

The PDP consisted of six sessions of 2.5 h for which course materials were developed and adjusted along the way. The total number of hours spent by the participants, including preparing the sessions and doing homework, was about 50 h. The sessions were led by two researchers (first and second authors of this article), who drew on their experience in language-oriented design-based research (e.g., Smit, Bakker, van Eerde, & Kuijpers, 2016). The two researchers took turns during the sessions in leading the session or taking notes (i.e., diagnosing teachers' learning). The participants were twelve in-service primary teachers, from six primary schools in the eastern part of the Netherlands. All teachers entered the programme voluntarily and were dedicated to become more knowledgeable in designing and realising language-oriented science education. Participants received a certificate for the Teacher Register if they attended at least 80% of the meetings.

Science learning goals:
Reasoning steps:
Language goals:
Starting point (starting level of pupils):
Instructional activities <u>Description of instructional activity 1</u> - Linked to reasoning step ...... - Higher-order questions so as to promote reasoning steps - Time required: - Materials needed: - Working method: - Progression: <u>Description of instructional activity 2</u> …. etc.
Intentions to apply interactional skills and scaffolding strategies - Interactional skills that I will apply: ○ Creating space for more and longer contributions of pupils ○ Show interest in the pupils' contribution ○ Pass questions and reactions on to other pupils - Scaffolding strategies that I will apply: ○ Reformulate pupils' utterances ○ Refer to particular reasoning steps ○ Refer to specific words or formulations ○ Ask pupils to improve spoken or written language ○ Repeat correct pupil utterances ○ Making explicit the quality of pupil contributions ○ Ask pupils to independently formulate reasoning steps
Conjectures about pupils' thinking during instructional activities:
Evaluation (attainment of learning goals):

Fig. 1. Lesson preparation format.

For answering the second research question, we used the data of two case-study teachers, Fiona and Sannie (pseudonyms, both female), from one rural school (< 100 children) in the eastern part of the Netherlands. Their pupils were of middle socio-economic status and had, according to the teachers, poor language skills. There was no science textbook and less than one hour per week was spent on science education. Fiona, teacher in Grades 3 and 4, had 20 years of teaching experience. Sannie, teacher in Grades 5 and 6, had 11 years of teaching experience.

3.4. Data collection

Data collection included video recordings of all PDP sessions (all interaction between teachers and researchers-educators was transcribed verbatim), questionnaires at the start and the end of the programme, field notes made during all professional development sessions by one of the researchers, teachers' written assignments (e.g., design of lessons based on the lesson format), scaffolding logs filled out by two researchers (first and second author), teachers' written logs, as well as audio recordings of mid- and post-interviews held with Sannie and Fiona (transcribed verbatim). The field notes and written assignments were not analysed separately. However, they did feed into the development of HLTs, the scaffolding logs, and instructional course materials.

3.5. Instruments and data analysis

3.5.1. Research question 1: enactment of the scaffolding approach

For shaping and tracing the scaffolding process along the way, we used two instruments. Firstly, we used hypothetical learning trajectories (Simon, 1995). In line with a study by Mackay, Bakker, Smit, and Keijzer (2018), we employed them for shaping and tracing *teachers'* learning during the PDP. The HLTs thus assisted in realising and monitoring offline responsiveness.

Secondly, the researchers-educators filled out scaffolding logs (five in total). These contained diagnoses made both during sessions (*online*) and in between sessions (*offline* by reading teacher logs and written assignments), related to the aforementioned three themes in the PDP. Furthermore, the scaffolding logs contained (literal) teacher quotes from PDP sessions, and additional sources upon which the diagnoses were based (e.g., field notes, assignments). Last, the scaffolding logs included intentions for the next PDP session. Both the diagnoses and the intentions fed into the HLT for the subsequent session.

For answering the first research question on the realisation of long-term scaffolding during the PDP, a coding matrix for retrospective analysis was developed to check if the approach could justifiably be characterised as scaffolding. This format contained the following components:

- all *diagnoses*, chronologically ordered into the three aforementioned themes (reasoning steps, language goals, language promotion);
- the accompanying teacher quotes (highlighted in the transcripts in yellow) and other sources upon which diagnoses were based;
- quotes from the researchers-educators that included *online responsive reactions* to teachers' utterances or needs (highlighted in the transcripts in green);
- adaptations and decisions concerning the design of PD sessions (derived from course planning documents and HLTs), which embodied *offline responsiveness*; underlying learning activities (cf. Bakkenes et al., 2010) were highlighted in blue.

All steps in the analysis were conducted by one researcher (first author) and verified by another (second author). Subsequently, the findings from the analysis were triangulated with the teacher logs by the second author: The second author read through all teacher logs and added diagnoses and responsive reactions that could not be identified based on the video recordings and interaction transcripts. In this way, she also verified whether the diagnoses made were consistent with the utterances in the teacher logs. She added a few nuances to the scaffolding analysis. The resulting scaffolding analysis formed the basis for the story thread in which key moments in teachers' learning were described against the background of diagnoses and responsive actions over time. The story thread, written up by the first author, was read and judged accurate by the second author.

3.5.2. Research question 2: learning outcomes

To investigate what teachers have learned from their participation in the PDP, we used two instruments: interviews (mid- and post-interview) and questionnaires (pre and post).

3.5.2.1. Interviews. We developed interview formats for the mid-interview (after the third PD session), and the post-interview (after the sixth and last PDP session). The interview formats consisted of eight main questions, each containing two to five sub questions, and were informed by the aforementioned four learning activities that were mentioned by Bakkenes et al. (2010). All questions were intended to elaborate on the answers in teachers' written logs. The written log formats consisted of eight open-ended questions. Examples of questions are: (How) did the literature you have read affect your science lessons? What was your own contribution to the lesson plan/design? What are your intentions for the next science lessons? Each interview lasted about 45 min. During the semi-structured mid- and post-interviews, the case study teachers Fiona and Sannie were asked individually to reflect on their learning experiences, as written up in their logs. The interviews were audio-taped and transcribed verbatim.

3.5.2.2. Questionnaires. The pre-questionnaire consisted of nine questions concerning teachers' background and school setting, 33 statements concerning teachers' content knowledge (n = 6), pedagogical content knowledge (n = 3), design capacity (n = 3), interaction in science lessons (n = 3), language promoting strategies (n = 9) and participants' ambitions in the PDP (n = 12), and four open-ended questions concerning participants' ambitions. Each statement had to be responded to on a 5-point scale, ranging from 1 (totally disagree) to 5 (totally agree). Examples are: 'In my science lessons, I pay attention to difficult words (e.g. gravity)' (language promoting strategies) and 'My content knowledge about scientific phenomena is sufficient' (content knowledge). Filling out the questionnaire took about 30 min. The post-questionnaire took about 20 min. We maintained the statements of the pre-questionnaire as much as possible. The following adaptions were made: we removed general background questions and added eight statements concerning interaction and language promoting strategies; we changed all statements concerning participants' PDP ambitions into future ambitions and, finally, we added five open-ended questions concerning participants' experiences with the PDP.

3.6. Data analyses

To analyse Fiona's and Sannie's self-reported learning outcomes as expressed during the individual mid- and post-interviews, we employed an analytic framework for teachers' reported learning outcomes inspired by Bakkenes et al. (2010), consisting of four categories: (1) changes in knowledge and beliefs, (2) intentions for practice, (3) changes in practice, and (4) changes in emotions. However, because changes in emotions hardly appeared in our data and were hard to code reliably, we decided to leave them out of further analysis. The three main categories are summarised and illustrated in Table 1.

In the transcripts of the mid- and post-interview with Fiona and Sannie, first all utterances in which Fiona or Sannie reported a learning outcome in the pre- and post-interview were identified and coded by one researcher. For Fiona the numbers of such utterances were 23 and 28 respectively, for Sannie respectively 30 and 61. Afterwards, a second researcher coded these utterances. After this initial round of coding, a few adaptions were made. As mentioned before, we excluded the utterances about emotions. Then one utterance was removed because it was not related to any of the learning goals. Finally, the coding scheme was improved. These changes resulted in 128 utterances that were judged by both coders. Cohen's kappa was .66, implying that the categories could be

Table 1
Coding scheme for reported learning outcomes.

Code	Description	Examples (Dutch)	Examples (translated into English)
Ckb	*Changes in knowledge/beliefs*: the teacher reports on (growing) awareness, acquired knowledge, new ideas; or the teacher reports on confirmation of already existing beliefs	Oh ja, oh, ik kan niet zomaar hapsnap een les gaan geven. Dat kwam mij meer tot inzicht van…Het is meer zo van als ik zomaar pats boem die proefjes ga doen, dan is het weer zo, oh, dat leggen we even daar neer. En dan blijft het erbij. En dan vervliegt het weer (mid-Sannie)	Oh yes, I cannot just give a lesson off the top of my head. I came to that insight… It is that just doing an experiment is just only an experiment, and then that's it. It is put down. And it stays like that. It is immediately forgotten about (mid-Sannie)
Cp	*Changes in practice*: the teacher states that things have changed in his/her way of teaching	Ja, dat probeer ik wel te stimuleren bij kinderen, dat ze toch met een zin antwoord geven. (mid-Fiona)	Yes, I try to stimulate that with the children, that they answer using a full sentence. (mid Fiona).
Ip	*Intentions for practice*: the teacher reports that he/she wants to do things differently in the future, or reports that he/she wants to hold on to certain old practices	Dus ik wil meer naar de – langzamerhand toch meer naar de coachende leerkracht toe. En met techniek wil dat heel mooi. En dat kan je met veel meer vakken doen. (post-Sannie)	So I would like to gradually move towards a more coaching way of teaching. With a technical topic that can be done nicely. And it can be done also in other subjects. (post-Sannie).

distinguished sufficiently reliably. Secondly, for each utterance that was identified as a learning outcome, both researchers coded independently which overarching PDP goal it concerned (learning goals and reasoning steps, language goals or language promotion).

To investigate the learning outcomes of all participants, we analysed scores of the statements in the pre- and post-questionnaires, except for the statements concerning participants' ambitions. We applied a Wilcoxon signed rank test, to test whether scores on the post-questionnaire differed significantly from those on the pre-questionnaire.

4. Results

4.1. Results RQ1: enactment of long-term scaffolding in the PDP

In this section, we describe how we designed and enacted the PDP, drawing on the initial overall design as described in the methods section, and how we adaptively responded to participants' needs and increasing independence as observed along the way — both during live interaction (*online*) and outside live interaction in between sessions (*offline*), on the three themes of (1) reasoning steps, (2) language goals, and (3) language promotion.

We consider diagnosis based on the questionnaire as the starting point for planning and realising long-term scaffolding in the PDP. The questionnaire showed that most participants, although having acquired some experience in teaching primary science, indicated to suffer from insufficient knowledge and skills for teaching primary science. A few participants mentioned they wanted to learn to formulate more specific learning goals, to realise science lessons that centralise pupils' thinking, and to consider their own role in supporting thinking during science lessons (e.g., by posing thought-provoking questions). Most participants, however, only demonstrated experience in so-called hands-on science education, in which “doing experiments,” rather than explaining and reasoning, was central. Concerning the focus on language, only one participant mentioned explicitly he wanted to learn how to formulate language goals for his science lessons. Several participants expressed the ambition to realise language promotion during their science lessons, for example by effective questioning and by teaching children to describe their observations and their learning experiences.

In response, during the first PDP session, we gave an overview of what constitutes teaching science at primary level (based on research literature in Dutch professional journals), and introduced the programme's focus as:

- Designing and enacting science lessons in which scientific phenomena are investigated *and* explained.
- Centralising pupils' reasoning (steps) in lesson (re)design and enactment.
- Focusing on the language required for these reasoning steps, both in lesson design and enactment.

We further emphasised the role of talk for learning, the language-oriented nature of science (explaining, reasoning etc.), and the importance of providing pupils access to specialised classroom discourse. We introduced different types of language to be used (daily language, general academic language, and subject-specific language as well as formulations). As in all PDP sessions from the first onwards, we dedicated time to investigate a science phenomenon collaboratively, so as to expand participants' knowledge and discuss misconceptions. In exploring the topic of sinking and floating, we gave the participants an overview of reasoning steps for sinking and floating, to be put in a logical (teaching) order by themselves. The assignment on reasoning steps triggered participants' thinking about learning goals in relation to smaller steps in pupils' thinking to be promoted. This was an unfamiliar way of approaching science education for the participants, as the following utterance during session one illustrates:

> You have given us, for sinking and floating, reasoning steps to be followed during the lesson. Does this imply that we can transfer those reasoning steps to another science theme? Can we make up such reasoning steps ourselves in some logical way?

During a diagnostic assignment, we further observed that many participants seemed to view their science lessons as fairly language-oriented already. As an offline response, we decided to include an interactive activity that would help participants reflect on their own practices more rigorously. Furthermore, we planned to allow ample time in the following session for introducing and discussing the language-oriented lesson preparation format in which learning goals, reasoning steps and language goals were related (see Fig. 1, an expanded teacher version of an HLT). In the first PDP session, we also diagnosed that participants needed to elaborate their scientific knowledge of sinking and floating. Therefore, more than initially planned, we provided them with literature on this topic and planned an extra experiment on sinking and floating and a reflective group discussion for session two. All in all, the very first session already pointed towards the need for slowing down the initially planned pace in the programme. As part of our offline responsive reaction, we decided to leave the topic of language promotion for later in the programme.

Sessions two and three centralised the relation between learning goals, envisioned reasoning steps during science activities and the required language to do so, with a particular focus on the preparation of lessons. The aforementioned lesson preparation format was introduced and discussed repeatedly. Sessions two and three – in line with the idea of long-term scaffolding – further offered some examples of good practice derived from other (research) settings (e.g., a video fragment in which a teacher poses a variety of thought-provoking questions that elicit reasoning during a primary science lesson). Concerning language goals, several participants stated to have started to include these in lesson preparation and to think about which words to centralise. However, we diagnosed that most teachers still tended to isolate word knowledge from science reasoning which led to a vocabulary-oriented way of teaching. Concerning reasoning steps, participants indicated to struggle with determining what particular reasoning should be central to their lessons. Partly, this could be explained by their lack of knowledge concerning the science content. In response, when introducing a new science topic in session three (acoustics), we first provided the participants with new scientific insights and the opportunity to experiment with acoustic phenomena themselves. Then, together with the participants (and as such moving towards more participant independence), we formulated reasoning steps derived from the learning goals given during the PDP session.

At first, the participants seemed hesitant, but thereafter, they started to become engaged in formulating reasoning steps and also started to include the notion of reasoning steps in their own contributions. In online response to the diagnosed isolation of word knowledge, we then related these reasoning steps to the language required for such reasoning, hereby specifying the difference between daily language, general academic language, subject-specific language and formulations. In this way we intended to encourage participants to interweave targeted reasoning and language use in their lesson planning. We discussed with them that by using several small experiments and asking questions to promote reasoning, they could at the same time enlarge pupils' word knowledge and use of proper language formulations, strengthen their reasoning skills and thereby enlarge their understanding of the phenomenon of sound. In their lesson preparation format, the participants started to couple science content specific learning goals, language goals (word knowledge but also use of proper formulations), to experiments and reasoning promoting questions they could ask to bring about the correct concept of sound (see Table 2).

Later on, one of the participants stated: “Yes, it was only after that that I started thinking about what language is being used during each particular instructional activity. In fact, another kind of language is needed. That was sort of the eye-opener for me.” This statement and similar other utterances led to the diagnosis that the relation between learning goals, pupils' reasoning and language (goals) had started to sink in. This was confirmed in session four, when several participants demonstrated more advanced thinking about reasoning steps in relation to language goals when preparing a lesson with the aforementioned lesson format. We further diagnosed that participants were more directed towards diagnosing pupils' starting points and adapting to these. For instance: “We [teachers] think we know that they [pupils] already know what high and low are, but that isn't necessarily the case.”

Up to and including session three, participants rarely exhibited attention for the theme of language promotion. Only one

Table 2
Example of aspects to take into account when preparing a language-oriented science lesson (the topic of sound and acoustics).

Science learning goals	Language goals
• Pupils know the properties of sound • Pupils construct their own stringed instrument	• Word knowledge: – Daily language: loud, high, low, instrument – General academic language: to hear, sound, to produce – Subject-specific language: vibration, pitch, medium, eardrum • Formulations such as: a tighter string produces a higher tone
Reasoning steps 1. Sound consists of vibrations 2. Sound needs a medium to move 3. The magnitude of the vibration determines the volume of sound 4. The speed of the vibration (the amount of vibrations per second) determines the pitch of the sound	
Activities • Pupils hold a ruler over the edge of the table, and then pull and hear the vibration • Pupils make a small stringed instrument with a beaker and an elastic and investigate the sound	
Questions to promote reasoning How is it possible that you can hear sound? What happens when you use a tighter elastic? How can you produce a higher tone? Or a lower tone? How can you produce a louder sound? Or a softer sound?	
Example of scaffolding strategy to use When pupils state “sound just moves somehow”, I reformulate it by using the sentence “sound needs a medium to move”	

participant mentioned to more often centralise a key concept during her lessons, and to write up key concepts to be used "for herself." Another participant stated to more deliberately promote pupils' talk by posing thought-provoking questions. However, we felt participants were not ready for an additional focus in their lesson preparation and enactment (that is, using language promoting strategies) until after session three.

In session four, participants were introduced to interactional skills (e.g., allowing time to think; showing interest in pupil contributions; passing on questions and reactions) so as to promote pupils' language production in science lessons. Besides, participants were introduced to higher-order questions (e.g., "what happens if" questions and "what is the relation between … and …" questions). Last, participants were introduced to the idea of scaffolding, here related to the adaptive responses to be provided by the teacher in teacher-pupil interaction by means of scaffolding strategies (e.g., reformulating utterances, asking for more precise language, and making explicit the quality of pupil utterances).

All in all, due to continuous online and offline diagnosing and responsive PDP design along the way, it was only after session four (out of six) that participants had been introduced to all essential ideas on the aforementioned three themes central to the PDP. The main challenge for sessions five and six was therefore to help the participants move towards independence in design and enactment of language-oriented science education so as to complete the scaffolding process.

For session five, we therefore decided to only briefly introduce a new science topic (balance) to the participants. After a short explanation of some key concepts, participants were asked to come up with an experiment on this topic themselves. In retrospect we diagnosed that this was – at least for some participants – a bridge too far. In an attempt to be as conscientious and detailed as possible in this final stage, we also provided the participants with an extensive list of feedback on their written homework assignments (lesson preparation formats) during session five, after which none of the participants spoke for a while. During this session, the teachers started to demonstrate – more than in earlier sessions – insecurity and more awareness of their imperfection regarding the targeted way of teaching: "Sometimes I perform quite well, however, sometimes I am completely wrong. Sometimes I have prepared my lesson so thoroughly, using what I've learned, but in practice I am teaching the old-fashioned way." Furthermore, the first explicit critical remark was made by one of the participants:

> Maybe you can keep the examples with which you provide us smaller; how do you prepare and enact *this one* activity. We now get all sorts of ideas and we aim to enact these in only one lesson, which is impossible.

In response, we explained that we were indeed trying to realise the learning goals formulated at the start of the PDP, and that this caused the field of tension at stake. A positive note included the progress shown by teachers in realising language promotion during classroom interaction. For instance, they reported on both adequate use of scaffolding strategies and their awareness of using these.

For session six all participants were asked to do a presentation on a new, unfamiliar science topic from a language-oriented perspective. Although we realised beforehand that all participants still experienced a lack in competence to do this, we felt that we had to "complete" the PDP in this way: Without the fading of support, the PDP could not be characterised as scaffolding. Participants' evaluation of session six included positive remarks on the progress made (regarding all three themes) and their own efforts to prepare a presentation for the other participants. However, they also stated not to be ready for dissemination of what they had learned in their own schools. As researchers-educators, we also diagnosed – for example on the basis of their presentations – that both in design and enactment teachers did not demonstrate the independence for which we had aimed. In the discussion section we return to this point, because we think using the scaffolding metaphor may lead to withdrawal of support where it is still needed. What if the metaphor of finishing the construction work leads astray? Or if there is no clear end goal of the PDP at all?

4.2. Results RQ2: learning outcomes

In this section, we describe what teachers have learned from their participation in the professional development programme in which a scaffolding approach was enacted. Firstly, we illustrate the findings on reported learning outcomes with quotes from both interviews. Table 3 shows the distribution of utterances containing self-reported learning outcomes among the aforementioned three

Table 3
Distribution of reported learning outcomes among four categories (as coded by researcher 1).

	Fiona		Sannie		Total
	n	%	n	%	
Mid-term interviews					
Changes in knowledge and beliefs (CKB)	13	59%	13	50%	26
Changes in practice (CP)	5	23%	12	46%	17
Intentions for practice (IP)	4	18%	1	4%	5
Total	22		26		48
Post-term interviews					
Changes in knowledge and beliefs (CKB)	10	37%	28	53%	38
Changes in practice (CP)	16	59%	19	36%	35
Intentions for practice (IP)	1	4%	6	11%	7
Total	27		53		80
Overall total	49		79		128

categories (changes in knowledge and beliefs, changes in practice, and intentions for practice.

The analysis of self-reported learning outcomes (128 in total) suggests that several types of changes have taken place in the PDP. The majority of reported learning outcomes were coded as changes in knowledge and beliefs. Both Fiona and Sannie reported more changes in practice during the post-interview (respectively 16 and 19) than during the mid-interviews (respectively 5 and 12). Appendix A relates the changes to the three overarching goals of the PDP: pupil learning goals and reasoning steps, language goals and language promotion. The appendix shows that most learning outcomes were related to language promotion. The post-interview of Fiona shows a significant amount of utterances related to language promotion both in CKB and CP (resp. 7 and 13). Data from the post-interview of Sannie are in line with this result: in CKB as well as CP, most utterances were related to learning goals (resp. 15 and 6) and language promotion (resp. 11 and 13). They also mentioned more language promotion strategies in the post-interview, which was to be expected because this topic was only addressed in the second half of the PDP. For each category of self-reported learning, we now present quotes that illuminate and characterise Fiona's and Sannie's learning in design and enactment of language-oriented science lessons over time.

4.2.1. Change in knowledge and beliefs

In sum, during both interviews both Fiona and Sannie reported on growing awareness concerning all three kinds of PDP goals. Most changes in knowledge and beliefs concerned the formulation of learning goals and reasoning steps and language promotion.

Concerning the formulation of learning goals and reasoning steps in science, the teachers reported in the mid-interviews on the urgency of narrowing the scope of science lessons and the importance of teacher's domain-specific knowledge about science. During the post-interviews, there was an increased attention to pupils' thinking processes. Especially Sannie reported on changes in knowledge and beliefs concerning learning goals and reasoning steps. She demonstrated an increasing insight into the importance of centralizing pupils' thinking processes during science. When the interviewer asked Sannie what she thought was missing in their regular science programme, Sannie answered: “Children's thinking processes.” Later on, she stated “Uh, yes, at a certain moment, the connection of what they are doing is lacking. Parents are busier with the experiment itself than with children's reasoning processes.”

Concerning language promotion, both teachers showed an increased number of utterances during the post-interview in comparison with the mid-interview. During the post-interview, Sannie not only reported on a growing awareness of the importance of interaction and scaffolding, she also showed some awareness of the consequences of questioning and discussing for pupils language development: “Due to asking these kinds of questions, pupils are required to formulate their answers in a complete sentence instead of a single word.” Sometimes, Sannie explicitly mentioned the discrepancy with former science practices:

> Yes, before I primarily listened: “Is the answer right?” Yes or no and that was most important. Whether the answer was right or not, and then you would improve pupils' mistakes or ask another child to do so. Now I think, it is nice that the answer is correct, but actually that is not the most important thing. I would like you to answer by using a correct sentence.

4.2.2. Changes in practice

In all four interviews, most changes in practice were reported for the category “language promotion”. A closer look at their utterances revealed that the teachers mainly reported on the implementation of scaffolding techniques. In the mid-interview, Fiona stated: “Yes, I try to stimulate pupils to answer in complete sentences.” Sannie's answers in the mid-interview are in line with this result. She stated: “I try to indicate with what word a sentence has to start and when the word ‘because/as’ has to be used, the pupils need help with this.” Results from the post-interview resemble those of the mid-interview. Most learning outcomes were related to reformulating children's responses, e.g.: “So you tell the children; try to say it differently. Or you repeat a well formulated sentence again: ‘Hey, you said that correctly’. Before, I didn't do this.” (Sannie, post-interview). In the post-interview, Fiona stated:

> During the science lessons, I tried to master the language promoting strategies. Yes, and also asking pupils the right kind of questions, how do I get them to think and how do I stimulate them to give the correct answers using a full sentence.

In addition, other scaffolding strategies were used, for example referring to specific words. “Then I know, ah, I have to use the word “current” more often, then the pupils will also use it”.

4.2.3. Intentions for practice

A relatively low number of utterances concerned intentions for practice. Most reported learning outcomes in this category were found in Fiona's mid-interview (4) and Sannie's post-interview (6). For example, in the post-interview Sannie reported: “I need to deepen my knowledge with respect to questioning and language promoting strategies, I need to further deepen my knowledge, I believe.”

Secondly, to investigate the learning outcomes of all participants, we analysed the results of the questionnaires. Table 4 presents the mean scores before the PDP started (pre) and at the end of the PDP (post).

For all categories, the mean scores were higher on the post- than on the pre-questionnaire. A Wilcoxon Signed Rank Test for the nine teachers who filled in both pre- and postquestionnaire was close to significance, $z = 1.96$, $p = .051$ (two-tailed), effect size $r = .46$, which we consider substantial.

Table 4
Analysis of questionnaires, prior to and after the PDP (min = 1, max = 5) (n = 9).

	Number of questions	Pre	Post
		M (SD)	M (SD)
Science education			
Content knowledge	6	3.3 (1.3)	4.1 (0.6)
Pedagogical Content Knowledge science (PCK)	3	3.3 (1.3)	4.2 (0.6)
Design capacity	3	2.8 (1.5)	4.0 (0.9)
Language-oriented science education			
Interaction in science lessons	3	3.7 (1.4)	4.2 (0.7)
Language promoting strategies	6	3.7 (1.3)	4.5 (0.6)

5. Discussion

5.1. Summary

The purpose of this research project is to shed light on how long-term scaffolding can be realised in a professional development programme (PDP) that aims to support adaptively teachers to design and enact language-oriented science lessons for primary education. We tried to take into account that insights from research had to be transformed so as to be useful in PDP. Examples of such ascending from the abstract to the concrete include:

1. Talking about reasoning steps rather than genres.
2. Working with a lesson preparation format rather than hypothetical learning trajectories.

In answer to the first research question, we can conclude that many instances of online and offline diagnosis and responsiveness could be realised as part of long-term scaffolding in the ways described in this article. For each session we formulated hypothetical learning trajectories of what we intended to accomplish with learning goals and means to support, yet we were prepared to deviate from our plan whenever necessary. During and after sessions we fathomed how well the teachers' learning processes proceeded. On the basis of such diagnosis we decided how to respond. The results of the analysis suggest that we took this approach in the first half of the PDP, but – under pressure of handing over to independence – became less responsive towards the end of the PDP. Teachers sometimes said we tried to do too much in too short a time, and said the same about themselves when trying out a science topic with their pupils. We discuss this point below. In answer to the second research question, we can conclude that teachers generally felt they had learned many things, they often reflected, and were able to relate learning in the PDP to their classroom instruction.

The concept of scaffolding has its origin in interaction between adults and children, but has been adopted in education to include teacher-pupil interaction as well as whole-class interaction and the design of longer-term teaching interventions. In this study we extended the concept's use to the context of teacher professional development. All in all, the key characteristics of scaffolding were enacted – in line with the conceptualisation employed – both during (online) and outside (offline) PDP sessions (*layered* nature), *distributed* over time, and *cumulatively* resulting in teachers' increased independence over time. As such, this study serves as a proof of principle concerning the enactment of long-term scaffolding in a PDP for in-service primary teachers. One theoretical contribution of our study therefore is that we have shown that the idea of scaffolding, typically applied to pupils, can also be used in the professional development of teachers – something that has hardly been done before.

5.2. Handing over to independence as a fata morgana?

Here we return to a more general point about enacting scaffolding. As mentioned before in the theoretical background section, there is a debate about the closed nature of what scaffolding aims for (Griffin & Cole, 1984; Stone, 1998). In the original studies on scaffolding (e.g., Wood et al., 1976), pupils had to solve small tasks that often had unique solutions. However, in broadening the range of settings in which scaffolding was studied and applied, the progress to pre-defined learning goals has remained. In hindsight we think that critics from cultural-historical activity theory (CHAT) and scholars in the area of dialogic teaching have a point when they argue that the metaphor of scaffolding comes with limitations. For example, Engeström (2015, p. 135) argued that scaffolding is "restricted to the acquisition of the given." In the field of dialogic teaching, the emphasis is put on opening up spaces for learning (Wegerif, 2007), which we feel we did not do enough towards the end of the PDP. We think that the scaffolding concept would benefit from a crossover with such ideas from the dialogic teaching literature and CHAT. Instead of a straitjacket (Myhill & Warren, 2005), it can then become a germ cell that generates new activity and concretisations (Engeström, 2011, on Davydov).

Apart from a theoretical implication, this tension of wanting to work towards predefined learning goals versus leaving space for negotiation and serendipity also has a methodological counterpart. Engeström (2011) criticised some versions of design research for their closed nature. As an alternative he suggests formative interventions — an interventionist methodology in which (learning) goals can shift in negotiation with the participants. Our work with teachers concurs with this view, in particular the tension we encountered when working towards predefined learning goals and aiming for independence and transfer of responsibility.

One rebuttal could be that we simply had too few sessions to help teachers become independent in designing and enacting language-oriented science education, or that our goals with the PDP were too ambitious. Visnovska, Cobb, and Dean (2011), for example, only detected improvement of teachers' ability to think through pupil reasoning after several years. However, even if we admit to these points, we think the core issue remains: In cases where learning is not acquisition of a given (as in some parts of the curriculum), the metaphor of scaffolding may lead us astray in assuming that support has to be withdrawn, whereas in our experience, it is only the nature of required support that changes. Why withdraw support if learners still need it and more knowledgeable others are still there? One would not take away a person's crutches if she has a broken leg or remove a child's side wheels when he cannot cycle yet on two wheels. In hindsight we feel we have been too eager to be able to characterise our PDP as an enactment of scaffolding. Although we think we have done rather well in diagnosing and responding to what teachers needed in the beginning, the wish to handover the responsibility of designing and enacting language-oriented science lessons to the teachers made us blind to two things. Firstly, they were not ready to do this without support; secondly, designing and enacting such lessons is not a well-defined competence that can be acquired as a given. After all, we as researchers-educators also still seek advice in design, despite our years-long experience with content-based language instruction in mathematics and science.

Although causal claims are hard to underpin in such adaptive programmes without control groups, we think that the progress made by the teachers was instigated through our interventions. For example, we saw an increase in language promotion strategies reported to be used after these had been introduced and discussed in the course. Given the content and quality of their steps forward, it seems very unlikely that they would have made these steps without our support. We have the impression that reflecting about lesson preparation in terms of science and language learning goals in combination with hands-on experimenting and watching videos of their lessons proved useful learning activities (Bakkenes et al., 2010). Designing their own lessons may contribute to ownership and hence be a condition for realising innovative practices (cf. Huizinga, 2014).

5.3. Limitations and recommendations

One obvious limitation of our study is the small number of participants reported here (twelve, of whom nine filled in both pre- and postquestionnaires). Responsive adaptations are admittedly easier with small rather than large numbers of participants in the PDP, yet we think that the theoretical idea of scaffolding as operationalised here points to mechanisms that could fruitfully be deployed in other PDPs, provided handover to independence is not pushed too hard. A recommendation that follows from our mistake to withdraw support too early is that PDP providers are advised to gauge carefully if teachers are really ready for what the PDP works towards; in other words whether they stay within the teachers' ZPDs. Otherwise handover to independence becomes a fata morgana. The quality of the dialogue (see Mercer, 2000, on intermental development zones) may be more important than that specific pre-set learning goals are met and that the PDP can be classified as scaffolding.

A natural recommendation is to see if the PDP can be scaled up, perhaps without stressing the handover to independence. Our teachers worked with pupils who did not have apparent language problems, but for teachers working with language-weak or bilingual pupils it is even more important to increase their awareness of the language required to reason scientifically (Gibbons, 2002; Smit, 2013) and enhance their (re)design capacity to adapt existing lessons to pupils' needs.

Another limitation was the small number of sessions. It is known that the pedagogical design capacity of teachers is typically low (Davis, Beyer, Forbes, & Stevens, 2007). In our case, our ambitions on scaffolding language and centralizing reasoning steps were high. Another recommendation is thus to try and realise longer PDPs, lesson studies or professional learning communities with similar learning goals. Alternatively, teachers may benefit from prolonged engagement with the researchers and educators beyond the time limits of the project. More attention can be paid to the specific content knowledge and PCK required to design and teach language-oriented science lessons.

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Appendix A. Distribution of leaning outcomes related to PDP goals: pupil learning goals and reasoning steps, language goals and language promotion

	Fiona					Sannie			
	n	Learning goals	Language goals	Language promotion	No classification[a]	n	Learning goals	Language goals	Language promotion
Mid-interview									
CKB	*13*	5	2	1	5	*13*	4	4	5
CP	*5*			5		*12*	2	1	9
IP	*4*	1	1	1	1	*1*			1

Post-interview									0
CKB	*10*	2	1	7		*28*	15	2	11
CP	*16*	2	1	13		*19*	6		13
IP	*1*			1		*6*	3		3
Total		10	5	28	6		30	7	42

[a] Utterances not explicitly related to one of the aforementioned PDP goals.

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