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A Primary Teacher Learning to Use Scaffolding Strategies to Support Pupils' Scientific Language Development

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ABSTRACT

Although learning scientific language is crucial for learning science, many primary school teachers lack the knowledge and skills to support this. The present case study reports on a primary school teacher who learned to use a repertoire of scaffolding strategies for stimulating pupils' scientific language development in inquiry-based science lessons (14 pupils; grade 4). Teacher support included an instructional sequence, participation in interviews and writing reflective reports. The aim of this study is to identify how the teacher used the scaffolding strategies in a classroom with native speakers and which challenges she experienced during the process. Analysis of lesson transcripts showed that the teacher applied all scaffolding strategies suggested to her. Analysis of interview transcripts gave insight into five categories of challenges the teacher experienced while using scaffolding strategies, including her expectations regarding pupils' scientific language level and dealing with differentiation in the classroom. The findings show that a teacher can learn to apply multiple scaffolding strategies for stimulating scientific language development. Patterns in the use of scaffolding strategies arose related to the aim of the strategy, the situation (i.e., phase of the empirical cycle and teaching approach) and the required pedagogical content knowledge (and skill) of the teacher.

Keywords: scientific language, science and technology education, inquiry-based learning, scaffolding strategies, primary education

INTRODUCTION

Many primary school teachers struggle with the question of how they can effectively support science learning (Appleton, 2003; Fitzgerald and Smith, 2016). By 2020, all primary schools in the Netherlands will be required to include science and technology education in their everyday school practice (National Technology Pact 2020, 2012). This challenge is reinforced by the national trend to take an inquiry-based approach in which pupils are stimulated to actively investigate a scientific problem or phenomenon while working according to the steps of the empirical cycle (e.g., exploring, experimenting, presenting) (Furtak, 2006; Minner et al., 2010; Van Graft and Kemmers, 2007). Hence, there is a need to explore how primary school teachers can be supported to teach these inquiry-based science lessons.

Although no agreement exists on how science learning and language are exactly related, most scholars agree that learning the language of science is crucial for science learning (Anstrom et al., 2010; Valdés, 2004). As most pupils have to learn this scientific language at school and many primary school teachers have limited knowledge and skills to facilitate this (Silva et al., 2012), we explore in this study how a teacher can learn to scaffold her students' scientific language.

The source of inspiration is the literature on promoting general academic and subject-specific academic language (e.g., Osborne, 2010; Schleppegrell, 2004, 2007, 2012; Snow and Uccelli, 2009). Much of this literature is based on work with bilingual students, but the approaches developed in this domain turn out to be beneficial for speakers of their first language too (Gibbons, 2002; Silva et al., 2012). Previous research reported on scaffolding strategies that teachers successfully used to support second language learners in inquiry-based science lessons (Silva et al., 2012) and mathematics lessons (Smit and Van Eerde, 2013). What is unknown, yet relevant to know, is to what extent the usage of these scaffolding strategies can be transported to other settings, such as, in our case, science learning with native Dutch speakers. The aim of the current case study is to identify how a primary school teacher uses a repertoire of scaffolding strategies for supporting scientific language development in a classroom with native speakers and which challenges she experienced during the process.

THEORETICAL BACKGROUND

There is widespread agreement among researchers that pupils have to learn the language of science in order to learn science (e.g., Lemke, 1990; Snow, 2010; Wellington and Osborne, 2001). This does not only apply to second language learners, but for all learners in science classrooms (Gibbons, 2002; Silva et al., 2012). However, discussions exist about what this language, often referred to as "academic language", exactly entails (Valdés, 2014). This discussion mainly refers to the wide variety of categorical distinctions that exist regarding the concept of academic language in literature, which are the result of the complexity of the concept itself and the multiple viewpoints from which it has been investigated and defined (Anstrom et al., 2010). The existence of these categorical distinctions has been criticized by multiple researchers (e.g., Forman, 1996). Instead, a continuum has been suggested on which daily language is positioned on one end and formal or academic language on the other (Gibbons, 2002; Snow 2010). In line with this, the goal of the present study was to learn a teacher to support pupils' toward the use of scientific language. Inspired on the literature on promoting general academic and subject-specific academic language (e.g., Osborne, 2010; Schleppegrell, 2007; Snow, 2010), the scientific language we refer to in this study includes scientific vocabulary (e.g., hypothesis, data, friction, gravity) and scientific formulations (e.g., formulating hypotheses and research questions). Although we acknowledge the relevance of the discussion about the complexity of academic language, it is of minor importance for this study because of our broad focus on the language of science and the language to learn about science.

Scaffolding, according to Gibbons (2002), can be used as a teaching method to stimulate language learning during content lessons. Scaffolding can be 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 et al., 1976, p. 90). During scaffolding, a more knowledgeable other, such as a teacher or parent, provides temporal support to help a pupil to establish a learning task that he or she cannot yet establish alone. Over the course of the learning task the support gradually decreases in line with the development of the pupil until the task can be carried out independently (Gibbons, 2002). The method draws on the principles of the sociocultural theory that stresses the importance of social interaction for learning. According to Vygotsky, children's construction of knowledge is the result of the internalisation of external dialogue that they use when performing a learning task that is guided by a more knowledgeable adult. This guidance is necessary to help a child to proceed in the zone of proximal development (ZPD), defined as the difference between the developmental level that a child can accomplish individually and with support of an adult (Vygotsky, 1978).

Because of the adaptive nature of the scaffolding process, it is suggested to come close to "good teaching" (Bakker et al., 2015), which is defined as "the active and sensitive involvement of a teacher in students' learning" (Mercerand Littleton, 2007, p. 18). Teachers originally used scaffolding as a method to support individual pupils in their development (Smit and Van Eerde, 2013; Van de Pol et al., 2011). However, due to its benefits, recent studies also explored the possibilities of using scaffolding in small-group and whole-class settings (e.g., Abdu et al., 2015; Makar et al., 2015; Smit and Van Eerde, 2013). In particular, Smit et al. (2013) investigated how scaffolding can be used to support language development in whole-class settings and proposed three characteristics of whole-class scaffolding: (1) diagnosis (2) responsiveness (3) handover to independence. A teacher can implement scaffolding in the classroom by using scaffolding strategies: after implicit diagnosis (i.e., judgement of what pupils need) the teacher chooses a strategy that seems to be appropriate at that moment, in this way responding contingently, with the overall goal to make pupils more independent.

The inquiry-based approach of Van Graft and Kemmers (2007) appears to serve the aforementioned criteria of scaffolding. The lessons include whole-class conversations and collaborative work in which discussing, experimenting, writing exercises and reasoning have a central role (Anderson, 2002; Quintana et al., 2004). These

Table 1. Scaffolding strategies that are suggested to the teacher

1.	Reformulate pupils' utterances (spoken or written) into more scientific wording
2.	Ask pupils to be more precise in their spoken language or to improve their language
3.	Use gestures or tools to support verbal reasoning
4.	Repeat correct pupil utterances (written or spoken)
5.	Remind pupils to use a designed scaffold as a supporting material
6.	Ask pupils how a written text can be produced or improved into more scientific wording
7.	Discuss with the pupils the definition of scientific concepts and their connection to everyday language
8.	Introduce concepts that are necessary for pupils' scientific understanding

Note. Scaffolding strategies 1-6 are adopted from the study of Smit and Van Eerde (2013) and strategies 7-8 are based on the study of Silva et al. (2012).

activities stimulate pupils to use scientific language in spoken or written form, providing opportunities for the teacher to diagnose their current level. Subsequently, the teacher can enrich pupils' scientific language use by implementing a scaffolding strategy that seems suitable for the pupil(s) in the specific context. By providing support adjusted to the needs of the pupil(s), the teacher can contingently support them in their scientific language development. An important goal of inquiry-based learning is that teachers help pupils to transition toward independence of the teacher (Linn, 2000). This is in line with the third criterion of scaffolding, handover to independence. In this context, the learning goal is that pupils will be able to use the scientific language without the support of the teacher.

In this case study we assisted a teacher in using scaffolding strategies to support scientific language development during inquiry-based science and technology lessons in a classroom with native Dutch speakers. We developed an instructional sequence in which science and scientific language learning were integrated and we stimulated the teacher to use a repertoire of scaffolding strategies by participating in interviews (e.g., stimulated recall) and by writing reflective reports (see Bakkenes et al., 2010). We adopted the scaffolding strategies from the studies of Smit and Van Eerde (2013) and Silva et al. (2012). These studies were, to our knowledge, the only ones that reported on strategies that have been empirically tested in similar contexts of primary classrooms. We based our repertoire on that of Smit and Van Eerde (2013) because their strategies were developed for Dutch education, complemented with strategies developed by Silva et al. (2012). This resulted in the eight scaffolding strategies presented in **Table 1**.

We address the following research questions: (a) To what extent does the teacher use scaffolding strategies for supporting pupils' scientific language development during inquiry-based science and technology lessons? (b) What challenges does the teacher experience when using scaffolding strategies during these lessons? The findings of this study will provide a sense of understanding of what can be expected of a teacher learning to use scaffolding strategies in inquiry-based science & technology lessons.

METHODS

Context of the Case Study

The case study teacher Emma (pseudonym) worked at an elementary school in a suburban area in the Netherlands. At the time of this project, she had seven years of experience in primary education. Emma was selected for participating in this study because of her specialization in science and technology education and lack of experience with supporting scientific language development by using scaffolding strategies. To identify how a teacher can learn to use scaffolding strategies in science lessons, we selected a teacher who was able to teach the content of the lessons without additional support, was motivated to teach science and technology education, and eager to learn the didactics of inquiry-based learning of Van Graft and Kemmers (2007). Moreover, Emma worked at a school with above average attention for science and technology education. She conducted the lessons in a separate science and technology classroom within the school that provided a suitable environment with the necessary space and attributes for conducting the inquiry-based lessons. Emma gave the lessons to a grade 4 class consisting of 14 pupils in the age of 9 to 11 (7 boys, 7 girls). All pupils had the Dutch nationality and spoke Dutch as their first language. According to Emma, language proficiency was considered weak for two pupils, average for four pupils and above average for eight pupils. Three of the 14 pupils were familiar with the aforementioned approach of inquiry-based learning, since they had participated in an honours class.

For the present study, the researchers developed – in collaboration with a team of didactical and theoretical experts in the field of education, language, and science – an instructional sequence of science and technology suitable for supporting scientific language development. It consisted of four one-hour lessons according to the inquiry-based approach of Van Graft and Kemmers (2007) (see **Table 2**), with *friction* as the overarching subject. By covering all phases of the empirical cycle (i.e., exploring, designing an experiment, experimenting, drawing conclusions, presenting), the pupils investigated what factors influence the sliding speed of objects, such as material

Table 2. Content of each lesson and pupil activities

	Lesson content	Pupil activity
Lesson 1	Introduction and exploring	Being introduced to the subject of sliding and exploration of the subject
Lesson 2	Preparing and conducting research	Composing of research question, hypothesis and research method, conducting research and writing results
Lesson 3	Drawing conclusions and presenting research	Drawing conclusions and preparing presentations, presenting, giving feedback on presentations
Lesson 4	Presenting research and discussing	Preparing presentations, presenting, giving feedback on presentations

Note. The content of the lessons is based on the phases of the empirical cycle from Van Graft and Kemmers (2007).

characteristics and the slope of the slide. Each lesson included both science and language goals to support Emma towards integrating language development in her science lessons.

An example of a science goal is "pupils understand that sliding can be influenced by the slope of the slide and material characteristics" and an example of a language goal is "pupils use the thematic words to write a research plan (e.g., flat and steep)". Lessons were characterized by both whole-class discussions and collaborative work. The focus on scientific language was further established by inclusion of language instructions, examples of scientific formulations and activities that created opportunities for Emma to include scientific language in the lessons (e.g., the use of an scientific word list). Additionally, examples of scientific vocabulary were provided for each lesson, such as *angle, steep*, *hypothesizing* and *concluding*. Emma was encouraged to include other scientific concepts herself and to pay attention to the vocabulary that the pupils used or needed during the lessons. The lessons took place on a weekly basis with the exception of a three week gap between the first and second lesson.

Teacher Support

In addition to the instructional sequence, other components of teacher support included an instructional meeting, pre- and post-lesson interviews and reflective reports.

Instructional meeting. The project started with a one-hour instructional meeting during which the researchers introduced the pedagogy of inquiry-based learning based on the method of Van Graft and Kemmers (2007); the role of scientific language during inquiry-based science lessons; the concept of scaffolding and the scaffolding strategies that were selected for the present study.

Pre-lesson interviews. From the second lesson onwards, we conducted stimulated recall interviews before each lesson in which selected video fragments of the previous lesson were discussed with Emma. The duration of the interviews was 20 minutes and aimed at stimulating her to reflect on her use of scaffolding strategies. To enhance Emma's confidence in supporting scientific language development, we watched video fragments in which she correctly used scaffolding strategies and we encouraged this by positive reinforcement (Margolis and McCabe, 2003). Additionally, we provided her with feedback and suggestions to make some changes in her teaching in the subsequent lessons. For instance, before the second lesson, we encouraged Emma to have pupils speak independently by using the strategies "ask pupils to be more precise in their spoken and written language or to improve their language" and "remind pupils to use a designed scaffold as a supporting material". During these interviews we also discussed Emma's planning for the upcoming lesson and questions that she had concerning the lesson content or structure.

Post-lesson interviews. A post-lesson interview of 15 minutes was conducted after each lesson. During these interviews we covered general topics including the experiences of Emma regarding the content and structure of the lesson, the scientific language that was of interest, the use of scaffolding strategies and encountered challenges.

Reflective reports. To stimulate Emma to reflect on her use of the scaffolding strategies, she sent a weekly reflective report by email including a table with the various scaffolding strategies. She was instructed to formulate for each strategy whether she had used it during the lesson and to give some examples of when it was used. Emma mentioned multiple times that she had to postpone the completion of the reports to the end of the day and therefore experienced difficulties in memorizing what and how she used the strategies during the lesson. For validity purposes we decided to exclude these reports from the data analyses.

Analysis

The audio recordings of the interviews and the video recordings that were made of each lesson, including Emma's gestures that were relevant for supporting scientific language, but excluding off-topic talk, were transcribed verbatim. To answer the first research question, we identified the scaffolding strategies that Emma used during each lesson. As we were interested in how Emma applied the repertoire of scaffolding strategies we had suggested to her, we used the strategies presented in **Table 1** as initial framework for coding the lesson transcripts, using the software ATLAS.ti (www.atlasti.com). During the analyses we were aware that Emma might have applied additional scaffolding strategies outside this repertoire. However, we did not find any in the lesson transcripts. Text fragments in which Emma used or responded to pupil utterances that included scientific

Table 3. Coding scheme of the scaffolding strategies

Code	Definition
RepCor	Repeat correct pupil utterances (written or spoken)
UseGes	Use gestures or tools to support verbal reasoning
AskSpo	Ask pupils to be more precise in their spoken and written language or to improve their language
DisDef	Discuss with the pupils the definition of scientific concepts and their connection to everyday language
RemSup	Remind pupils to use a designed scaffold as a supporting material
RefUtt	Reformulate pupils' utterances (spoken or written) into more scientific wording

Note. The scaffolding strategies RefUtt to RemSup were adopted from Smit and Van Eerde (2013), and the strategy DisDef is adapted from Silva et al. (2012).

vocabulary or formulations were used as unit of analysis. Based on the work of Smit and Van Eerde (2013), we developed a coding manual with coding instructions for each strategy. All attempts by Emma to use one of the scaffolding strategies for supporting scientific language development were coded, regardless the obtained effect. During the coding process, there were problems with assigning several codes to text fragments. Therefore, it was decided to combine two codes into one broader category and to exclude one code from the data analysis. The code "ask pupils how a written text can be produced or improved into more scientific wording" and the code "ask pupils to be more precise in their spoken language or to improve their language" were combined into the category "ask pupils to be more precise in their spoken and written language or to improve their language". Additionally, the code "introduce concepts that are necessary for pupils' scientific understanding" was excluded from the data analysis. We decided this because the introduction of scientific concepts was often accompanied with asking for their definition. These fragments were coded as "discuss with the pupils the definition of scientific concepts and their connection to everyday language". This resulted in the coding scheme as presented in **Table 3**.

The frequencies of the remaining six scaffolding strategies were determined for each lesson, as were the total numbers and percentages. To ensure the reliability of the coding process, text fragments were coded by two raters. To familiarize herself with the data and coding manual, the second rater first coded a subset of 25 text fragments and discussed these with the first coder. Then, a second set of text fragments was randomly selected and coded by the second rater to determine the interrater reliability with use of the rule of Cicchetti (1976). This rule states that the number of fragments that should be coded to have a reliable analysis can be defined by the formula $2n^2$, where n is the number of codes. In the analysis $n = 6$, which implied that 72 fragments had to be coded. This resulted in 67 agreements in coding (93.1%; Cohen's kappa = .90), implying that the six categories could be distinguished reliably.

To answer the second research question, the transcripts of the pre- and post-lesson interviews were qualitatively analysed according to Boeije's (2005) guidelines. The analysis focussed on text fragments that included utterances concerning challenges that Emma experienced referring to the use of scaffolding strategies or to the concept of scientific language. In addition, several text fragments were included that indirectly referred to experienced challenges. After collecting all relevant text fragments, five categories of challenges were identified: (1) dealing with differentiation regarding pupils' varying levels of scientific language; (2) patience to stimulate pupils' scientific language; (3) uncertainties towards expectations of pupils' scientific language use; (4) necessity of practice to internalize the use of scaffolding strategies; (5) pupils' motivation to focus on scientific language development. A description of each category can be found in the results section.

RESULTS

Extent of Scaffolding Strategies Being Used

Table 4 shows the frequencies and percentages of the scaffolding strategies Emma used during the lessons. In total 221 instances were defined in which scaffolding strategies were used: in each of the first three lessons about 60 instances and 35 instances in the fourth lesson. The low amount of scaffolding strategies in the fourth lesson can be explained by the fact that this lesson mainly included pupils' presentations. Consequently, Emma had fewer opportunities to implement the scaffolding strategies. The following section provides examples of each strategy and a discussion of how Emma used them to support pupils in their scientific language development. The original quotations have been translated from Dutch to English.

Repeating correct pupil utterances. Emma used this strategy by literally repeating written or spoken language of pupils including scientific vocabulary or correct scientific formulations, or by responding with positive reinforcement. Emma used this strategy about equally in the different lessons during both whole-class conversations (see Examples 1 and 3) and small-group support (see Example 2).

Example 1
Emma: What is important for sliding?

Figure 1. The figure shows an example of how Emma used gestures to support verbal reasoning. Here she makes a diagonal arm gesture when using the concept *slope.*

Pupil: That the slide is not too steep, but also not too flat.
Emma: Steep. Very good words, well said, Lisa. Steep and flat.

Example 2
Emma: I'm really curious, guys. Let me see what you have done already. Research question, hypothesis, (…) method. Well, that is really extensive.
Pupil: Findings uhm… When the slope is small…
Emma: You're using the concepts wonderful Tim.

Emma also used this strategy by including both positive affirmation and elaboration in response to pupil utterances that included scientific language. Here her elaboration was always accompanied with explicit positive reinforcement (see Example 3). When she elaborated pupil utterances with a scientific concept or improved a scientific formulation without positive affirmation, it was coded as "reformulate pupil utterances into more scientific wording" (see Example 12).

Example 3
Emma: What does presenting mean?
Pupil: Telling something in real life and stuff.
Emma: Very good. Actually, you tell the rest of the group what you did.

Use gestures or tools to support verbal reasoning. Emma performed this strategy mainly by using gestures or additional tools, such as the scientific word list, as visual support during the explanation or use of scientific vocabulary in whole-class setting (see Example 4 and 5).

Example 4
Emma makes a diagonal arm gesture when using the concept *slope* (see **Figure 1**).

Example 5
Emma writes the concept *friction* on the scientific word list (see **Figure 2**).

The majority of instances of this strategy was found in the first lesson and the number decreased in the subsequent lessons (see **Table 4**). Emma used this strategy mainly to provide visual support during the introduction and explanation of new scientific concepts such as slope or angle, in whole-class conversations. The decrease of instances is in line with the declining number of newly introduced concepts during the course of the lessons.

Ask pupils to be more precise in spoken and written language or to improve their language. Emma used this strategy by explicitly or implicitly asking or hinting at the pupils to improve or elaborate their written or spoken language into more precise formulations or into more scientific wording. She used this strategy both during whole-class conversations (see Example 6) and when providing small-group support (see Example 7).

Example 6
Emma: Slope. Who can tell me that [what that means]?
Emma: Sara, slope.
Pupil: That it goes like this [makes an arm gesture].

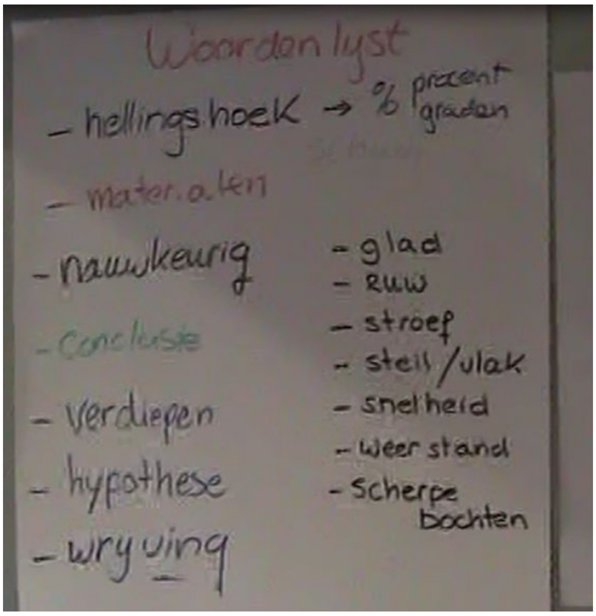

Figure 2. The figure shows the academic word list Emma used as a tool to support verbal reasoning. She frequently added scientific concepts (e.g., friction) to the word list.

Emma: No, now you tell it [by making an arm gesture].
Pupil: Well that it goes upwards.
Emma: A slope is… [implicitly]
Pupil: A slope is that something goes obliquely… that something slopes upwards or downwards [makes an arm gesture].

Example 7
Emma: The conclusion is… the shape of… [implicitly]
Pupil: Clay.
Emma: Makes… Well actually you have to… You have to give an answer on your research question now. That is the conclusion. How can you make a nice sentence to give an answer on [your research question] [explicitly]. We already started. The shape of... [implicitly]
Pupil: Clay makes a difference when you want to let it slide.

Compared to the first lesson (6 instances), the number of instances of this strategy was noticeably higher in the second (22 instances) and third lesson (12 instances). These increased numbers are in line with the intention we formulated in the interview preceding the second lesson and aimed at stimulating Emma to focus on this strategy. During the second and third lesson, she used this strategy mainly during small-group support to ask pupils for more precise scientific formulations such as research questions, hypotheses, research methods and conclusions (see Example 7).

Discuss with the pupils the definition of scientific concepts and their connection to everyday language. Emma used this strategy by asking pupils to give an explanation of the meaning of a scientific concept. In example 8 Emma used the strategy during a whole-class conversation.

Example 8
Emma: Who knows what a hypothesis is?
Pupil: Well, what you think is going to happen.

The numbers of instances of this strategy were highest during the first (7 instances) and the third lesson (9 instances). Emma used this strategy mainly when introducing and repeating the meaning of scientific vocabulary in whole-class conversations. The large amount of instances during the first lesson can be explained by the fact that a lot of new concepts were introduced and discussed compared to the other lessons. The high number of instances during the third lesson was due to pupils' confusion concerning the concept *data*. Here, the teacher used the strategy mainly to explain this concept while providing small-group support (see Example 9).

Example 9
Emma: Well what does your data tell you? What does data mean?
Pupil 1: A date.
Emma: No.

Table 4. Frequencies and percentages of used scaffolding strategies during the lessons

Scaffolding strategy	Lessons & main content 1 introduction, exploring	2 preparing and conducting research	3 concluding, presenting	4 presenting, discussing	Total	%
RepCor: repeat correct pupil utterances	20	20	29	15	84	38.0
UseGes: use of visual tools or gestures to support verbal reasoning	30	10	5	1	46	20.8
AskSpo: ask pupils to be more precise in their language or to improve their language	6	22	12	4	44	19.9
DisDef: discuss with the pupils the definition of concepts and their connection to everyday language	7	3	9	3	22	10.0
RemSup: remind pupils to use a designed scaffold as a supporting material	1	2	7	10	20	9.0
RefUtt: reformulate pupils' utterances into more scientific wording	2	1	0	2	5	2.3
Total	66	58	62	35	221	100.0

Pupil 1: That is also a data right?
Emma: What does data mean?
Pupil 2: Data means, well actually I think information.

Remind pupils to use a designed scaffold as a supporting material. Emma used this strategy by explicitly or implicitly reminding pupils to make use of the scientific word list. In example 10 Emma used this strategy explicitly during small-group support.

Example 10
Emma: Try to use the correct words in whatever you are doing [gestures towards the scientific word list]. With that, I am referring to the scientific language that is written over here. On the scientific word list. Slope, material, accurate, later on conclusion.

Emma used this strategy implicitly by gesturing towards the scientific word list when pupils were struggling in their use of scientific words or formulations. In example 11 Emma used this strategy during a whole-class conversation.

Example 11
Pupil: Well, when the… [held his arm diagonally] is steeper.
Emma: When the… [points to the word angle on the word list].
Pupil: Angle.

The number of instances of this strategy increased slightly during the course of the lessons. This is in line with the increasing number of scientific words that were added on the word list during each lesson, resulting in more opportunities for Emma to use the word list.

We coded the use of the word list as the strategy "using gestures or tools to support verbal reasoning", when Emma used it as visual support when explaining scientific concepts herself (e.g., pointing towards the word "angle" when explaining its definition in contrast with helping pupils who struggle with their formulations as in the example 11).

Reformulate pupils' utterances (spoken or written) into more scientific wording. Emma used this strategy by reformulating or elaborating pupils' written and spoken language into more scientific vocabulary or formulations when providing small-group support (see Example 12).

Example 12
Emma: Actually, you should write "I think that a wet towel slides better than a dry one". You only have "when it is dry".

Reformulating pupils utterances was performed least of all scaffolding strategies and seems to ask for a deeper understanding and knowledge of the desired level of scientific language that suits the abilities of the pupils.

Teacher Challenges Related to the Use of Scaffolding Strategies

During the interviews Emma reported challenges that she experienced while using scaffolding strategies to support scientific language development in her lessons. All five categories in which these challenges were divided are discussed below along with quotations derived from the interviews.

Dealing with differentiation regarding pupils' varying levels of scientific language. Emma mentioned several times that she found it challenging to adjust her support to the varying levels of scientific language that pupils have in one class. She stressed that she has different expectations concerning the abilities of individual children and that it is difficult to respond to this correctly. This was especially the case during whole-class conversations, rather than when providing support to small groups. The following quotation reflects her thoughts about this:

> "I think it is difficult to deal with the different levels. You can deal with it when they are working in smaller groups. Then you can decide, I think this [language] is good enough or you can repeat it slightly different, such as it is supposed to be. Well, it is something that I have to continue searching for. How do you preserve what you want to explain, without doing harm to the child?" [post 2]

Patience to stimulate pupils' scientific language. In the interview preceding the second lesson, Emma reported that she found it challenging to let pupils speak independently in whole-class conversations. She was tempted to use the direct instruction approach for explaining new scientific content, instead of stimulating pupils to think out loud. Since the latter provides opportunities to focus on pupils' scientific language development, we asked her why she did not take more time to let the pupils speak themselves. She explained herself as follows:

> "I do notice that the children think that focussing on language is difficult. The search towards… and that I am tempted to say it myself. Because otherwise it will take too much time and they get insecure, because they don't understand what I want." [pre 2]

Emma frequently expressed her concerns about the time investment and that pupils become insecure when she focusses on language in her lessons. She stressed that the focus on language is new for these pupils and that repetition might be necessary to increase their understanding of what she is aiming for. However, during the discussion of a video fragment of the third lesson, she showed a change in her thoughts concerning independent speech of pupils. The following quotation was in response to a video fragment in which three pupils were discussing different material characteristics:

> "Yes, nice to see that the children are coming up with that [scientific vocabulary] themselves. But I saw I had to restrain myself from interrupting. Nice to see that though." [pre 4]

This quotation shows a progression in Emma's insights concerning the abilities of the children to use scientific language to discuss the lesson content with each other, instead of requiring her continuous support.

Uncertainties towards expected level of pupils' scientific language use. During the interviews Emma expressed uncertainties concerning the expectations of the level of scientific language that the pupils should reach. These uncertainties were shown by asking us evaluative questions, such as:

> "How did you think that it went with these words, because I have to search for it, because when am I satisfied with the way that they are formulating a sentence? When is it good enough?" [pre 2]

Or

> "But [about the concepts] slope and material, briefly for you, did the children formulate their descriptions well in your opinion? Do you think they understand it?" [post 3]

These utterances show that Emma lacks the knowledge to determine what scientific language, including scientific formulations and vocabulary, she can value as appropriate for the current level of the pupils. This might explain why Emma implemented the strategy "ask pupils to be more precise in their scientific language or to improve their scientific language" quite often and the strategy "reformulate pupils' utterances into more scientific wording" least. By asking pupils to specify their language use Emma can diagnose pupils' current level and abilities. In contrast, reformulation of pupils' utterances requires more knowledge about their scientific language level to allow Emma to adapt her support to the needs of the pupil(s). The language goals included in the lesson descriptions appear to not sufficiently support Emma in determining the language level she should aim at during the lessons.

Necessity of practice to internalize the use of scaffolding strategies. Emma mentioned several times that she has to consciously think about focussing on pupils' scientific language, otherwise she is inclined to forget this:

> "You are tempted to say and show things yourself. And those formulations, that is something that you have to make your own, I notice. That you pay attention to it and that you ask the children to use the right formulation. I think that is something where I have to be consciously thinking about. And otherwise you forget it." [pre 2]

She attributed this challenge to either yet lacking internalization of scientific formulations and to the fact that she had to process different tasks at the same time during the lessons (e.g. scaffolding, method of inquiry-based learning and the content of the instructional sequence):

> "I have to make this my own. And you notice during the internalization of things that you have to carefully think about everything, like how do I present it (to the kids)." [pre 3]

Pupils' motivation to focus on scientific language development. In the interview that preceded the second lesson, Emma showed concerns about the importance that the focus on scientific language has for the pupils:

> "I think that it [focus on scientific language] can be important. But to also let the children see that it is important, that is difficult. I was reading lesson 2 yesterday and it made me worry that a lot of children will think 'why are we doing this?'" [pre 2]

From the second lesson onwards she explained more explicitly why it is important to focus on scientific language and what she expected from the pupils during the lessons. For example:

> "What I also want you to do this lesson, is that you learn how to say clearly what something means. And therefore you can use school language, or scientific language. So, try to explain everything clearly, that everyone can understand what you mean. So try to use the words *this* or *that* as little as possible." [Lesson 2]

DISCUSSION

The aim of this case study was twofold. First, we explored how our case study teacher Emma used the repertoire of scaffolding strategies we handed to her for supporting scientific language development during inquiry-based science and technology lessons in a classroom with native speakers. Second, we examined which challenges she experienced during these lessons. We designed an instructional sequence for science and scientific language learning and through the use of interviews and reflective reports, we stimulated Emma to use the scaffolding strategies. Below we discuss our most important findings and the limitations of the study, and we provide suggestions for future research.

The Extent to Which Scaffolding Strategies Were Used

In answer to the first research question we can conclude that Emma implemented all scaffolding strategies that we had suggested to her in her lessons. Patterns developed concerning the use of specific strategies related to the phase of the empirical cycle that was considered and the teaching approach (e.g., whole-class or small-group support). The distribution of scaffolding strategies was about equal during the first three lessons. When considering the third criterion of scaffolding, handover to independence, it might be expected that the number of strategies declines over time, contingently with the development of pupils (Smit and Van Eerde, 2013). However, as the majority of pupils was unfamiliar with the inquiry approach, each lesson included new activities accompanied with new scientific language in which pupils had to be supported. The amount of scaffolding strategies used did decrease noticeable in the fourth lesson. Although Emma had less opportunities to implement the strategies due to pupil presentations that dominated the lesson, the "presenting phase" of the inquiry-based approach (Van Graft and Kemmers, 2007) can also be seen as an end-goal of the scaffolding process in which the responsibility of the learning task, in this case scientific language learning, should be transferred to the pupils.

Although Emma managed to apply multiple scaffolding strategies during each lesson, the low amount in which she used the strategy "reformulating pupils' utterances" was noticeable. This strategy forced Emma to actively improve pupils' scientific utterances, while being responsive to their level(s) and aware of the lesson goals. Implementation of this strategy might therefore require more developed pedagogical content knowledge (PCK) compared to the other strategies. Drawing on the definition of Berry, Friedrichsen and Loughran, (2015, Chapter 3), PCK of teachers in this context includes knowledge on the scientific language related to the topic and the inquiry-based approach that is suitable for the level of the pupils, as well as knowledge on how to use the scaffolding strategies to reach the science and language goals as formulated in the lesson plan. To empower Emma in implementing strategies that appear more complex, additional support in enriching her PCK in this context might be desirable.

Moreover, the application of a repertoire of scaffolding strategies during teaching goes beyond the teachers' PCK and asks for skills to implement this knowledge and planned instructions during teaching and to adjust it to specific circumstances. In this context the teacher's pedagogical content knowledge and skill (PCK&S) are of major interest (Berry et al., 2015, pp. 36-38). Teachers need to be able to determine by reflection-in-action what strategy should be used in a specific situation with a specific student to support language development to best reach the goals formulated for the lesson. These skills appear especially important in this context, since the inquiry-approach is mainly student directed learning (Furtak, 2006), asking for responsiveness of the teacher on scientific language that children need and use themselves during the lessons.

Teacher Challenges Referring to the Use of Scaffolding Strategies

In answer to the second research question five challenges became visible regarding the use of scaffolding strategies of which we discuss the most important ones here. Emma expressed that she found it challenging to adapt support to individual needs of pupils when focussing on scientific language during whole-class conversations. The approach Emma used in whole-class setting seems in line with the original use of scaffolding where a teacher helps one learner to proceed in his or her ZPD, instead of adapting support to a whole class of children with multiple ZPDs (Van de Pol, Volman and Beishuizen, 2011). Since the latter is challenging, Smit and Van Eerde (2013) recommended orienting on a group ZPD during whole-class scaffolding, which they proposed "to exist alongside individual learners' ZPDs." In order for Emma to focus on language in a whole-class setting, she would have to learn to become aware of this group ZPD and learn how to be responsive to this ZPD during whole-class scaffolding.

Another challenge Emma expressed was to remain patient to support scientific language development during science learning, mainly due to a sense of uncertainty she felt among the pupils towards her expectations. Confusion of pupils often appears to be the case when teachers focus on language in science classrooms, because many teachers do not explicitly explain how language is used in science and what they expect of the pupils in this respect (Mercer, 1995; Mercer et al., 2004). This issue also applies to Emma, who was uncertain herself regarding the expectations of the level of scientific language she should aim for. During teaching she searched for appropriate vocabulary and formulations instead of planning this beforehand according to the language aims and instructions included in the instructional sequence. As a consequence, her attempts of focussing on language lacked explicit aims and were therefore often not clear for her pupils. This finding contributes to the aforementioned suggestions that development of Emma's PCK and PCK&S in this context is needed.

Emma also experienced motivational issues of pupils regarding the significance of focussing on scientific language during science learning, which she found challenging to deal with. Mercer et al. (2009) argue, although in the context of dialogical teaching, that an important task of the teacher is to increase the awareness of children regarding the role of speech in enhancing their scientific understanding. As dialogic teaching and scaffolding are assumed to be related (Bakker et al., 2015; Gibbons, 2006, p. 175), this notion seems to apply to the use of speech, and in particular the scientific language used during this speech, in the context of scaffolding as well. However, during the interviews Emma never expressed that learning scientific language is important for pupils' scientific understanding and reasoning and therefore a first step seems to establish a basis of awareness at the side of the teacher. According to Smit and Van Eerde (2011) the latter appears also necessary in order for teachers to implement scientific language learning during teaching on a more structural basis.

Limitations and Future Research

The findings of our study should be interpreted in the light of some limitations. An obvious limitation is that the results of our case study can only be generalized analytically, not statistically (Yin, 1994). Yet as a case study it gives insight into what can be expected regarding the application of scaffolding strategies and teacher challenges and what may become feasible when such an approach is disseminated to a larger number of teachers.

Another limitation is that we primarily focused on the process of the teacher and not on the possible effects the approach had on pupils' learning. A logical next step would be to investigate to what extent the pupils were supported toward increased use of scientific language. During the presentations of their experiments, most groups of pupils included some scientific vocabulary, such as *research question*, *hypothesis*, *materials, conclusion*, *slope*, *light*, *heavy* and *shape*. In addition, they made attempts to include scientific formulations, such as hypothesis and research questions. We would encourage future research to empirically investigate how handover to independence takes place with respect to scientific language learning in the context of inquiry-based science and technology education.

Although we gained in-depth information about how Emma used scaffolding strategies while participating in the research project, we did not include a follow-up measurement to investigate whether Emma kept focusing on scientific language afterwards. In addition, it might be interesting as well to investigate what would happen regarding the number and distribution of implemented scaffolding strategies when Emma participated again in a similar project. Subsequently, it can be questioned whether Emma would experience the same challenges during a second experiment.

An important finding of this study appeared the role of PCK&S in applying scaffolding strategies during inquiry-based science teaching. To support teachers in implementing a repertoire of scaffolding strategies during teaching, it would be helpful if future research can search for patterns in the use of scaffolding strategies concerning the appropriateness of specific strategies related to the phase of the empirical cycle, teaching approach or to support low versus high achieving pupils. Such knowledge can enhance teachers' PCK(&S) which they can use to make more deliberate choices in implementing specific strategies during teaching.

CONCLUSIONS

This study provided empirical evidence that a teacher can learn to apply a repertoire of scaffolding strategies for supporting pupils' scientific language development in an inquiry-based science classroom with native Dutch speakers. Patterns in the use of the various scaffolding strategies arose related to the aim and complexity of a specific strategy and to the specific situation during the lesson (i.e., phase of the empirical cycle and teaching approach). Moreover, our study indicated that scaffolding pupils' scientific language development is a complicated process requiring comprehensive knowledge and skills of the teacher. In addition to teachers' PCK, the teacher's skills to apply this PCK in various situations with various pupils (PCK&S) appeared to be of importance. The teacher's PCK&S seemed especially relevant in the inquiry-based context central to the lessons. These lessons are characterized by student directed learning and require in-action responsiveness of the teacher to support pupils to learn the scientific language they need and introduce themselves. The findings of this study provide insight into what can be expected when using this approach in similar conditions at larger scales.

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