PROMOTING TEACHERS' SCAFFOLDING OF STUDENTS' MATHEMATICAL LANGUAGE IN A PROFESSIONAL DEVELOPMENT PROGRAMME

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ABSTRACT

To promote students' acquisition of language required for mathematical learning, the employment of language-supporting scaffolding strategies (Smit, 2013) has proven to be effective. So far, little is known about how this teaching approach can be upscaled in educational practice. This study investigates the features of a professional development programme focused on teachers' scaffolding of students' mathematical language. In design-based implementation research seven professional development sessions for two professional learning communities in different parts of the Netherlands (consisting of 5 and 10 teachers) were shaped and enacted by four researchers-educators. Over time, all participants (researchers, educator, and teachers) collaboratively identified both process and product features of the professional development programme. Besides insights into these features, this study also yielded professionalized language-oriented primary teachers and a course programme that these teachers and others can employ to further upscale the language-oriented approach in primary mathematics classrooms.

INTRODUCTION

Primary school students' mathematical proficiency is considered an important key for success in education and, more generally, in 21th century society (Keijzer, 2013). Being or becoming mathematically proficient includes learning the language of mathematics and the language of participating in mathematical discourse (Moschkovich, 2010). An example from one of the Dutch mathematics textbooks (figure 1) shows the language students need to participate in mathematics lessons.

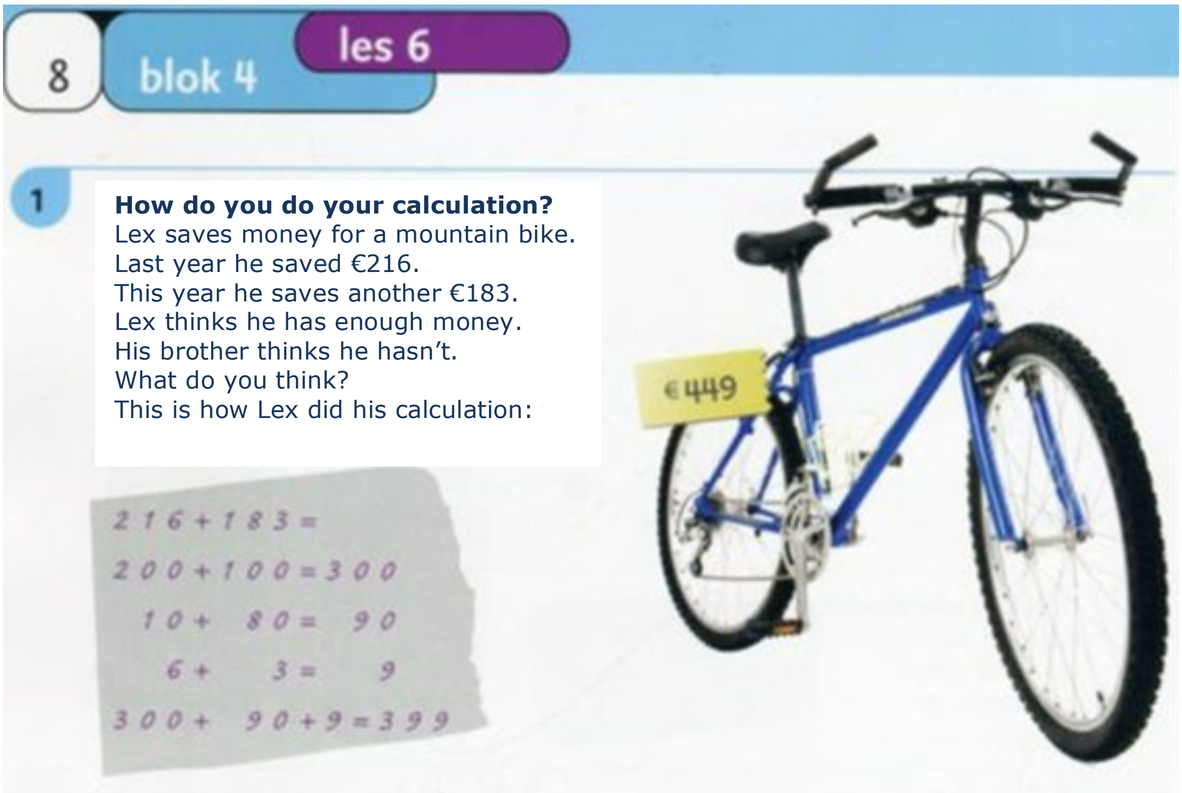

Figure 1: Example from the textbook series 'Alles Telt' book 5B (translation by authors)

When doing the problem in figure 1 proficiency in everyday language is required. For example a student should know what saving money is, what a year is, what a brother is and that the picture depicts the mountain bike in the problem. Academic language is language that is typically used in school. We find this in the problem in sentences like 'This is how Lex did his calculation' and even more prominently in 'How do you do your calculation?' Subject-specific language, which is the language typical for mathematics, is found in the calculation shown below the text. However, there is more language in the problem that is specific for the subject of mathematics. The problem encourages students to formulate how Lex solved the problem. In adding the two numbers he splits the numbers in hundreds, tens and ones. In tackling the problem students need to know how to use words like 'spliting numbers' and 'hundreds', 'tens' and 'ones'. Moreover, they do not only need to know the words, but also how these are used in particular formulations.

Language is omnipresent in mathematics teaching (Morgan, 2007). This is not only the case in mathematics teaching where contexts are used to teach students, like realistic mathematics education (Treffers, 1987; Freudenthal, 1991; Gravemeijer, 1994). It is therefore needed that teachers learn to support students in learning mathematical language.

BACKGROUND

The research presented here builds on Smit (2013). Drawing on sociocultural and content-based language instruction theories, the main question of this thesis was how teachers in primary classrooms can scaffold students' language required for mathematical learning (Vygotsky, 1962; Brinton, Snow, & Wesche, 2003; Janzen, 2003). Scaffolding refers to responsive help based on a diagnosis (Smit, Van Eerde, & Bakker, 2013), in this study directed at students' gradual acquisition of mathematical language. To this end, a repertoire of scaffolding strategies was developed, employed and evaluated (e.g., reformulating, asking students to formulate more precisely; see Table 1).

Table 1
Strategies for Scaffolding Language and Examples for Each Strategy

1	Reformulate pupils' utterances (spoken or written) into more academic wording	[In response to the graph goes higher and higher up:] *Indeed, the graph rises steeply.*
2	Ask pupils to be more precise in spoken language or to improve their spoken language	*What do you mean by 'it'?*
3	Repeat correct pupil utterances	*The graph descends slowly indeed.*
4	Refer to features of the text type (e.g., interpretative description of a line graph)	*Into how many segments can we split the graph?*
5	Use gestures or drawings to support verbal reasoning	E.g., gesturing a horizontal axis when discussing this concept
6	Remind pupils (by gesturing or verbally) to use a designed scaffold (i.e. word list or writing plan) as a supporting material	*Look, the word you are looking for is written down for you here.*
7	Ask pupils how written text can be produced or improved	*How can we rewrite this in more mathematical wording?*

The language to be scaffolded was specified in terms of a curriculum genre, for example the academic and subject-specific language students need for reasoning about line graphs. Each genre can be captured in terms of particular structure and linguistic features. Genre pedagogy (Gibbons, 2009) was employed, as it explicitly focuses on the development of academic and subject-specific language needed for participating in different school subjects. The development of such language is of particular importance for language-weak and second language learners, as they cannot build on the same foundations as their native peers. Although genre pedagogy has been successfully implemented in particular areas of the curriculum, its possibilities for mathematics education have been hardly investigated (an exception is Mousley & Marks (1991)). Smit (2013) showed how genre pedagogy could be made productive for mathematics education (in the case of line graphs). In the research described here, teachers were encouraged to identify genres for different mathematical domains themselves as a preparation for language-scaffolded, interactive mathematics teaching.

The professional development course central to the current study originates from the scientifically grounded insights into how language-oriented mathematics education can be designed, enacted and evaluated as yielded by Smit (2013). Moreover, this current study originates from leading questions amongst primary teachers in the participating schools. They formulated the problematic nature of language in mathematics lessons in several questions, namely:

- How can I promote classroom interaction instead of merely focusing on the textbooks?
- How do I prevent students from increasingly failing to participate in mathematical discussions?

- How can I consider the role of language in problem solving, and what are suitable ways of identifying the required language and centralizing it in maths lessons?

RESEARCH QUESTION

Many students in classrooms worldwide face the challenge of participating in subject-specific (mathematical) discourse, in which in some cases the language of instruction is not their first language. Teachers have shown to insufficiently meet this challenge (e.g., PISA studies). Furthermore, reform efforts in mathematics education have stressed the importance of ample classroom discussion in which mathematical concepts can be shared and inteachersvestigated (e.g., NCTM, 2000). Despite reform efforts, many mathematics classrooms still hold a traditional and teacher-dominant nature in which there is a lack of student contributions and little room for language development (Van Eerde, Hajer, & Prenger, 2008).

Both problems are addressed in the current study. Moreover, insights into how teachers can be professionalised in the realisation of language-oriented, interactive mathematics lessons are developed. The question central to this study is: *What are features of a professional development programme that realises interactive, language-scaffolded mathematics education by the participating teachers?*

METHOD

The research method applied was design-based implementation research (Penuel, Fishman, Cheng, & Sabelli, 2011). Its starting point is collaboratively formulated goals (by teachers, educators, and researchers). It has an iterative nature and aims for both theory development and sustainable change (concerning, in our case, the 15 teachers and their colleagues). The design of the professional development course was initiated and carried out by four researchers-educators, based on frequent discussions with and feedback from three of the participating teachers.

During the professional development course, we capitalized on four learning activities that were found to be effective for developing teacher expertise: learning by experimenting (e.g., trying out lessons), learning in interaction with others (teachers, researchers), using external sources (e.g., publications, exemplary materials), and reflection (Bakkenes, Vermunt, & Wubbels, 2010). We aimed at teachers' increasing independence (according to the idea of scaffolding), and draw on the textbooks and approaches used in teachers' schools. Scaffolding language was thus explored on two interconnected levels. On the one hand we discussed several aspects of scaffolding student language in mathematics lessons in the course. On the other hand we used scaffolding strategies to support participating teachers. Doing so facilitated teacher educators' modelling scaffolding for these teachers.

To answer the main research question concerning features of the programme, we analysed questionnaires, teacher logs filled out after each session, video recordings (transcribed verbatim), as well as our own researcher logs, which were based on the design-based research instrument of a hypothetical learning trajectory (HLT) (Simon, 1995) which was used to formulate learning goals, teaching activities and testable conjectures about teacher learning. Questionnaires focus on the teachers' starting position. The HLTs initially were developed from researcher logs. Teacher logs were used to develop or adapt HLTs. We used teacher logs and the video recordings also to find out how teacher skills in scaffolding language developed. Details about the data analysis procedure can be found in Mackay (2015).

RESULTS

During the first meetings of the professional development course the notion of language scaffolding is introduced and teachers and teacher educators discuss genres for specific domains. As a consequence of this introduction the teachers become aware of the importance of language in mathematics lessons. They also gradually start thinking through students' thinking. Moreover, they experience that mathematics textbooks hardly focus on language. One of the teachers in this initial stage writes in her log about how she changed working with the textbook: 'I noticed that I select words from the textbook and discus them before I start the actual lesson.' In thinking through problems from the textbook teachers find that every problem in a sense provided a genre on its own.

Following these initial experiences with language in mathematics lessons, expert teachers start experimenting with scaffolding strategies for scaffolding students' language provided in the course. The teachers are eager to exchange experiences of their scaffolding enactment by sharing and discussing video fragments from their lessons. This proves helpful for enacting these strategies in their classrooms. Therefore researchers-educators decide to centralize video watching in the professional development sessions. After three months one of the teachers writes in her log where her development leaded her. She shows how she now is able to use scaffolding strategies like repeating and emphasizing correct use of mathematical language: 'When a student uses the right language, I repeat what he or she said and tell the child he or she formulated a beautiful sentence. I thus hope that students come to see the importance of reasoning about mathematical problems, rather than merely focusing on the answer itself.' When the teachers become proficient in the enactment of scaffolding strategies in their own mathematics lessons, a new perspective opens up.

The teachers' participation in the course was not only aimed at improving their own teaching. It also was meant as a means to improve practice throughout the school. After about half a year, team development therefore becomes a key issue during course meetings. Participating teachers discuss during the professional development sessions how they shared their knowledge and newly developed skills with their colleagues. They did this by discussing the subject with peers in informal meetings, discussing language in mathematics lessons in a specific groups, and/or put it on the agenda for the whole team. Some of their strategies included:

- sharing videos from their own mathematics lessons,
- discussing language in mathematics textbooks,
- sharing language scaffolding strategies.

In doing so the professional development course provided a model for in-school activities. As such, the scaffolding role that at first the researchers-educators had during professional development sessions, was now transferred to the participating teachers in their own schools.

In the end all participating primary teachers developed proficiency in realising interactive, language-scaffolded mathematics lessons. They improved their preparation of lessons in terms of language learning goals, increasingly enacted language-supporting scaffolding strategies, and became more aware of language use by students and language required to learn mathematics. The participating teachers formulated a dissemination plan for professionalising their own colleagues and took first steps in this direction.

The design-based implementation approach in professional learning communities, combined with the focus on the aforementioned learning activities, as well as shaping the course according to the idea of scaffolding, thus proved a successful way of professionalising teachers in realising language-oriented mathematics lessons. In particular, teachers stressed the importance of designing and preparing language-oriented lessons for a specific mathematical domain (e.g. percentages), discussing each other's video fragments, being exposed to examples of good practice, and interacting with each other and the researchers-educators.

DEVELOPING PRACTICE

This study shows how mathematics education in primary schools can be improved by joint investments by participating teachers, researchers and educators. It shows the field of educational practice how professionalising teachers on this relevant topic can be a source of inspiration for others, and can thus form a germ for future development of students, teachers and educators. Participating teachers can benefit from this study in several ways. Firstly, they developed knowledge and skills that they can directly apply in their classrooms. Secondly, they received materials and insights as to how their colleagues can be professionalised. Thirdly, the established professional learning communities can help them to support the dissemination of interactive, language-scaffolded mathematics teaching in their own schools.

One of the materials used in the schools was developed during the course as a coproduction of teachers, teacher educators and researchers. The 'mathematical language guide' (figure 2) was made to provide a means that would help teachers realize language scaffolding in mathematics lessons. In short this guide shows steps participating teachers undertook every time they adapted a problem from the mathematics textbook. As such it developed from discussing various genres needed in a variety of mathematics domains. The guide suggest taking four steps in preparing a language informed mathematics lesson. Participating teachers hope these steps in the end become a habit preparing each mathematics lesson.

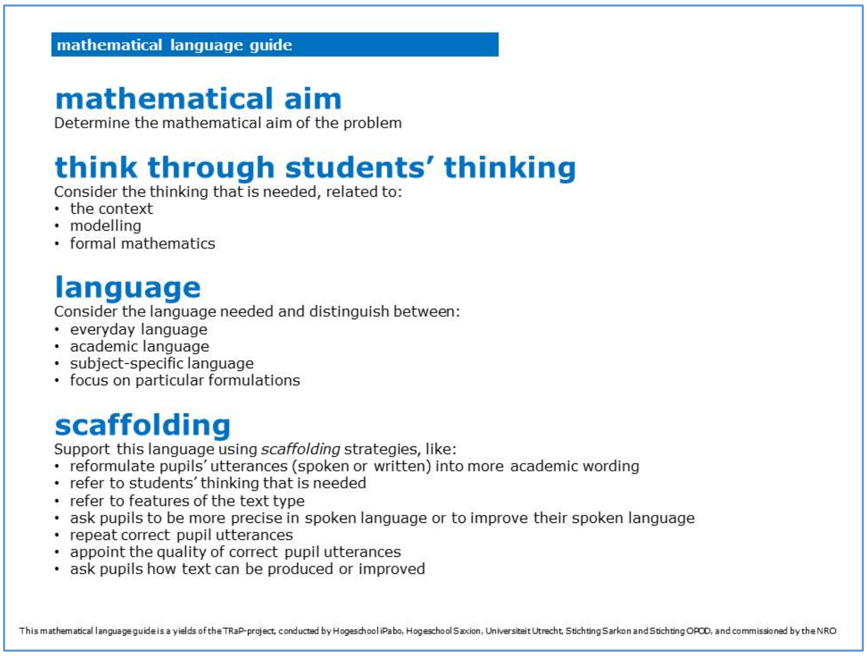

Figure 2: Mathematical language guide

CONCLUSION

This study aimed to identify features of a professional development programme that helped participating teachers to realise interactive, language-scaffolded mathematics education. Analysis of the professional development programme yielded the following features:

- there is an analogy between the support participating teachers receive, the support that teachers' colleagues receive, and the support that is intended for students (scaffolding),
- the professional development course is highly adaptive and a result of a shared responsibility of researchers, teacher educators and teachers,
- in the professional development course the teachers, teacher educators and researchers function as a professional learning community,
- video is used to share experiences and to learn from other course participants,
- teacher development follows the following stages: awareness of mathematical language and the importance of centralizing this language in mathematics lessons, scaffolding mathematical language in classroom interaction, sharing knowledge and skills in supporting (scaffolding) colleagues in the participating teachers' schools.

This study thus showed that it is possible to upscale insights into how primary teachers can realise scaffolding of language in interactive mathematics lessons. The results show that all teachers became substantially more aware of the role of language for mathematical learning, and that they also grew capable of realising meaningful classroom interaction in which they scaffolded students' language. Crucial features for shaping the professional development include the aforementioned four learning activities four: learning by experimenting (e.g., trying out lessons), learning in interaction with others (teachers, researchers), using external sources (e.g., publications, exemplary materials), and reflection (cf. Bakkenes et al., 2010), the idea of scaffolding underlying the programme, and the professional learning communities in which teachers could increasingly become more independent and more knowledgeable.

DISCUSSION

Adequate use of language in mathematic lessons is not an aim in itself. However mathematical language is needed to gain proficiency in mathematics (Sfard, 2008). We here note that teachers were able to improve language in their mathematics lessons, as they learned using language scaffolding strategies (Mackay, 2015). One therefore might expect that the result of the professional development course analysed here would for example lead to higher scores on standardised mathematics tests. Studying this, however, was not possible within the scope of this research. This can be a subject for future research, but one can wonder how to value the results of such a study. Namely, the adaptivity of the professional development trajectory makes that a new group of teachers will adapt the course to one of its own. In a sense the next group improves the results of the first one, by taking the next cycle in designing the course. This is in the nature of design research whereof also the professional development course described here is a result (cf. Penuel, Fishman, Cheng, & Sabelli, 2011).

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