Scaffolding teachers to scaffold students' language for mathematical learning

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Abstract

Mathematical learning can be advanced over time by applying language scaffolding strategies in a whole-class setting. However, there is a paucity of research on how to effectively equip groups of teachers with knowledge and skills to scaffold language. The aim of this paper is to explore how scaffolding of teachers can be enacted within a professional development program focused on teachers' scaffolding of students' language required for mathematical learning. The enactment of three key characteristics of scaffolding – diagnosis, responsiveness, and handover to independence – were traced through a 7 month professional development program for five Dutch primary school teachers within a design-based implementation study. The analysis yielded two narratives of the two main themes that the participants were scaffolded in; 1) the identification of language for mathematical learning and 2) scaffolding strategies for language development. To gain insight into what a teacher could learn during the program, one case study teacher was randomly chosen and interviewed mid- and post-program. An analytical framework for teachers' reported learning outcomes was used to analyze the mid- and post-interviews. The analyses showed that not only can scaffolding be deployed within a professional development program; it can successfully achieve noteworthy changes in a teacher's knowledge and skills in relation to scaffolding of students' language for mathematical learning.

1 Introduction

It has been increasingly acknowledged that active participation in discourse is fundamental to the development of mathematical understanding (e.g., NCTM, 2000). Key to this discourse is the usage of subject-specific language required for mathematical learning (Schleppegrell, 2007; Van Eerde, Hajer, & Prenger, 2008). For learners with low language proficiency, shortcomings in subject-specific language can impede their development of mathematical understanding and thus they need support within this domain (Moschkovich, 2010). One approach that has been advocated within content-based language approaches is the scaffolding of language (Gibbons, 2002).

The idea of scaffolding as an educational concept originally referred to the adults' role in dyadic adult-child interaction (Wood, Bruner, & Ross, 1976). Nowadays, scaffolding is typically associated with the temporary, adaptive support that is provided to a learner with the intention to enable a learner to eventually accomplish unaided, a previously unattainable goal (Maybin, Mercer, & Stierer, 1992). Smit, Van Eerde and Bakker (2013) argued that the concept of scaffolding is not restricted to one-on-one interaction, but can be extended to a whole-class setting. They showed that mathematical learning can be advanced over time by applying language scaffolding strategies in a whole-class setting. A design-based study with one teacher who successfully learned to scaffold students' learning of language for mathematical learning , provided insights into the mechanisms that promoted the teacher's learning on this topic, such as experimenting and reflection that were identified by Smit and Van Eerde (2011). They also developed a repertoire of scaffolding strategies to promote

students' language for mathematical learning. A following step in this field of research is to investigate how these insights can be successfully applied to groups of teachers.

It is plausible that by explicitly experiencing scaffolding in the PD program, teachers are enabled to deepen their knowledge and skills relating to scaffolding their own students in the classroom. In addition, professionalization of teachers is a long-term process and thus is more likely to have an impact when it is sustained over a period of time (Garet, Porter, Desimone, Birman, & Yoon, 2001). Therefore a PD program designed to promote teachers' scaffolding of language in the classroom preferably would deploy long-term scaffolding. Despite the potential of this idea, there is a paucity of research on the use of scaffolding for the professional development (PD) of teachers. The aim of this study is to explore how scaffolding of teachers can be enacted within a PD program focused on teachers' scaffolding of students' language required for mathematical learning.

2 Theoretical background

In order to explore the scaffolding of teachers to scaffold students' language required for mathematical learning (LML), there are three facets that need to be characterized. This section introduces the notion of the importance of language in learning and as such the LML. It then discusses scaffolding and how this can be applied to language development in the mathematics classroom. Finally, it considers the structure of a PD program that focuses on scaffolding LML.

2.1 Language required for mathematical learning

Vygotsky's (1978) innovative shift of focus from the individual to the social context for the understanding of human intellectual development informed his development theory emphasizing the role of social interaction in the attainment of knowledge. In particular, there is the need for at least two participants in this interaction, one being more knowledgeable to escort the second to a new level of conceptual understanding. Key for this interaction to be effective is the role of language. Vygotsky views language not only as a medium to share knowledge and participate in social interaction, but also for an individual to think and reflect. Over the last decades mathematical classrooms have transitioned from concentrating on individual, silent activities (Stodolsky, 1988) to classrooms where mathematical discourse receives attention (NCTM, 2000). Similarly, the expectation of learners has evolved from that of individually mastering mathematical procedures to include the ability to communicate mathematically and be able to describe suppositions and solution. Therefore to foster an environment that allows learners to interact and communicate at a mathematical level, a teacher must explicitly pay attention to LML in the classroom (Goos, 2004; Lampert & Cobb, 2003).

When referring to subject-specific language, each subject not only has its own vocabulary, but also its own formulations which learners need to be proficient in to successfully participate to mathematical classroom interaction (Moschkovich, 2010; Schleppegrell, 2007).

Within the context of learning mathematics, this article will frame LML as the conditional proficiency required to enable interaction to gain mathematical knowledge.

Smit (2013) drew on the approach of genre pedagogy to identify the language required for learning about graphs. Genres have been defined as "socially recognized ways of using language that enable people to say things about the world, establish relationships, and accomplish tasks" (Martin & Rose, 2008, pp. 240-241). Genre pedagogy is an approach that explicitly attends to how language is composed and structured throughout the curriculum. It aims to support learners in acquiring proficiency in school-bound textual genres (e.g., narratives, reports). Each genre to be taught and learnt comprises a set of linguistic and structure features. Linguistic features consist of the everyday language, general academic language and subject-specific mathematical language. Structure features refer to the schematic structure within a text that illustrates how meanings are ordered in reasonably predictable ways in order to fulfill the purpose of this text (e.g. a report).

As the genres used within genre pedagogy proved too broad for mathematical learning, Smit (2013) introduced the notion of pedagogical genre which consisted of two components, the linguistic and structure features. The linguistic features included not only subject-specific vocabulary and formulations (e.g., the graph rises), but also general academic language to be employed when interpreting the graph (e.g., his weight increases). The structure features were the desired interpretation of the actual structural components of line graphs and their relation to changes in reality (e.g., Uncle Kees' weight decreases between his 25^{th} and 30^{th} birthdays). As such a pedagogical genre acts as linguistic learning goal within a specified mathematical domain in order to enable the learner to adequately communicate about this domain

2.2 Scaffolding

2.2.1 Scaffolding strategies

To support students' development of the LML, Smit (2013) developed a *repertoire of strategies for scaffolding language for mathematical learning* (see Table 1) in several rounds of design-based research. These strategies, used as part of a language-oriented approach, contributed to the promotion of pupils' proficiency in the pedagogical genre needed for reasoning about line graphs.

Table 1: *Strategies for scaffolding language for mathematical learning*

	Strategies	Example
1	Reformulating 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	*Indeed the graph descends slowly*
4	Refer to features of the text type	*Into how many segments can we split the graph?*
5	Use gestures or drawings to support verbal reasoning	For example gesturing a horizontal axis when discussing a topic
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 using mathematical wording?*

The scaffolding conceptualization underlying this repertoire acknowledges the long-term nature of many learning processes, such as language learning. We will first discuss this conceptualization and its origin, and subsequently propose to employ this conceptualization for shaping PD of teachers.

2.2.2 Long-term scaffolding

Over the years, the original notion of scaffolding as introduced by Wood et al. (1976) has been reinterpreted by scholars in different ways and situations resulting in numerous forms within the educational landscape. Smit et al. (2013) conceptualized scaffolding for whole-class settings, based on the scaffolding literature (e.g., Van de Pol et al., 2010) and empirical data. They formulated the following key characteristics:

1. *Diagnosis* – assessing the capabilities of the learner and the level of support required

2. *Response* – adaptation of the support to what the learner's needs

3. *Handover to independence* –fading of support as the learner's independence increases

Through the analysis of enactment of whole-class scaffolding, Smit et al. (2013) also expressed three features of whole-class scaffolding that capture its long-term nature

1. *Layered* – the scaffolding characteristics are not restricted to the interactive level of whole-class discussions, but also apply outside whole class discussions. For example, teachers can also diagnose a student's level on the basis of the student's written work.

2. *Distributed* – scaffolding characteristics may occur distributed over several sessions. For example, a response to a student's need for support may be enacted in another lesson than when the teacher diagnosed this need.

3. *Cumulative* –the process of handover is the cumulative effect of distributed diagnosis and responsiveness over time

2.3 Promoting teachers' professional development

The PD of teachers is generally considered the process of teachers enhancing their knowledge, recognizing how to learn, and transforming their own knowledge into practice for the benefit of their students' growth (Avalos, 2011). Bakkenes, Vermunt, and Wubbels (2010) list possible learning outcomes of teachers participating in formal and informal learning environments as changes in knowledge and beliefs, intentions for practice, changes in practice and changes in emotion. To realize these learning outcomes, teachers in a PD program should be exposed to four types of learning activities including learning by experimenting (e.g., trying out instructional materials or scaffolding strategies), learning in interaction with others (other teachers, researchers), using external resources (e.g., publications), and consciously reflecting on one's own teaching practice (Bakkenes et al., 2010; Smit, 2013).

It is plausible that a PD program to promote scaffolding would preferably also overtly contain the three characteristics of scaffolding: diagnosis, responsiveness and handover to independence. Although there are a few studies of PD programs that adopted the scaffolding metaphor (e.g. Buxton, Lee, & Santau, 2008; Schartz et al., 2008; Van Der Valk & De Jong, 2009), until now very few, if any, have explicitly referred to or empirically evaluated the key characteristics of scaffolding. Without this emphasis there is the high risk that the concept of scaffolding becomes overgeneralized and loses its meaning. As such, explicit scaffolding of teachers within a PD program has hardly been employed and there is little scientific literature on how this process can be enacted, what it looks like or what its effects may be.

1.2.4 Aim and research questions

The aim of this study was to explore how scaffolding of teachers can be enacted within a professional development program to support teachers' learning of scaffolding students' language required for mathematical learning. The following research questions are addressed:

1) How were *diagnosis*, *responsiveness* and *handover to independence* enacted by course leaders in a professional development program on scaffolding of language for mathematical learning in the classroom?
2) What can a teacher learn from participating in a professional development program on scaffolding of language for mathematical learning in the classroom?

3 Methods

3.1 Overall research project and set-up of the PD program

The study presented in this paper is part of a larger research project that has been instigated in the Netherlands with the aim of identifying the key features required to successfully deploy scaffolding of LML within primary schools. To fulfill this aim, the overall research project has been set up as design-based research in order to develop both innovative materials and the further development of theory within this field. As such, a Professional Learning Community (PLC) in the domain of scaffolding of LML has been established, consisting of 5 primary school teachers and a researcher, whom is also the course leader. The PLC was constructed with two purposes in mind: provide the necessary environment to enable effective PD of the participating teachers and as a means of disseminating the information to other teachers in the schools of the participants.

The PD program comprised of seven monthly group sessions of 2.5 hours each. The design of the program was informed by the concepts of scaffolding and LML as well as learning activities that promote successful learning outcomes (Bakkenes et al., 2010; Smit, 2013). To achieve this, the course covered a number of topics including the importance of scaffolding of LML, diagnosis of LML used in class, sharing of literature and research results about scaffolding of language and assisting the teachers to start sharing their knowledge with colleagues in their own schools.

The first six sessions addressed the two main themes for the scaffolding of students' LML:

- Identification of LML
- Use of the seven strategies to scaffold students' LML (Table 1)

In the final session, which was designed as a dissemination session within the PLC, the participating teachers were asked to invite colleagues from their schools and other institutions and presented the main concepts of the course.

The researchers used the three characteristics of scaffolding to structure and adapt the PD program. Prior to the PD program the participants completed questionnaires and their lessons were observed to diagnose the level of scaffolding of LML in their instruction. The teachers were encouraged in the group sessions to reflect on their scaffolding of language in the classroom and supported to experiment with different techniques. Throughout the PD program the teachers were required to fill in logbooks reflecting on their learning (Bakkenes et al., 2010). This consisted of open questions designed to stimulate the teachers to reflect on their own learning and classroom practice in the context of scaffolding of language. By analyzing and therefore diagnosing the development of the teachers, the researchers adapted the contents of the subsequent session in response to the diagnosis. The researchers intended for handover to independence to occur as the participating teachers became more independent in the application of the scaffolding-strategies for LML.

A hypothetical learning trajectory (HLT; Simon, 1995) is an instrument to capture the intended and hypothetical learning of the participating teachers for each group session and is often used in design-based research projects (Bakker & Van Eerde, 2015; Smit, 2013). For this PD program a HLT consisted of the learning goals for the session, a description of the teachers' prior knowledge and skills including diagnosed gaps in knowledge and skill, the planned activities and the expectation of how the planned activities would support the teachers learning process. The researchers wrote the HLTs after considering the previous group session and analyzing the participants' logbook responses and was completed prior to every session.

The reflection document was HLT- informed and comprised of a set of questions used to identify the teacher's learning during the session, any observations the researchers made about the course itself and was completed after the session.

3.2 Participants

The five participants in the PD program were all employed in Dutch primary schools. One participating teacher (female, 25 years of experience) who taught grade 3 was randomly selected as a case study to allow for deeper insight into the learning processes and development of the participants occurring within the PD program. The second participant (female, 13 years of experience), taught grade 4. A third participant (female, 27 years of experience), taught mathematics in a one-on-one setting supporting special education in a main stream primary school. The first three participants were also the mathematics coordinators for their respective schools. The final two participants came from the same school where one (female, 29 years of experience) was a language coordinator for the school and held no teaching post and the other (male, 10 years of experience), taught grade 6 and was also a team leader within the school.

3.2 Data Collection

Data collection consisted of mid-course questionnaires and lesson observations, participant personal logbooks, HLTs and reflection documents for each session, completed exercises by

the participants and verbatim transcription of the interaction between the researchers and participants from video recordings of each group session.

Two semi-structured interviews of the case study teacher were conducted, one between the fourth and fifth group session and the second after the final session, to gain insight into the responses in the logbooks and sessions by asking them to elaborate on points of interest. The timing of the first interview was chosen to coincide with the moment that the teacher had some knowledge of scaffolding but still required substantial support from the course leader. This allowed the course leader the opportunity to characterize the teachers learning during the scaffolding process. The timing of the second interview was within a week of the last group session. Audio recordings of both semi-structured interviews were made and transcribed verbatim.

3.3 Data Analysis

3.3.1 Research question 1: Enactment of scaffolding within a PD program

To identify scaffolding of within the PD program, the three characteristics of scaffolding needed to be identified. The PD program consisted of two main themes: identification of LML and scaffolding strategies. The progressions of these two themes were analyzed to determine if the three characteristics could be recognized. To detect these progressions, within the PD course, the HLTs and reflection documents were analyzed to identify explicit comments relating to that specific theme and these were ordered chronologically. For each theme, the comments relating to diagnosis and response by the researchers were identified. It became clear that further sub-categories for response were required in order to ascertain the critical responses that shaped the PD program and enabled learning in the participants. A list of all response comments was generated for each theme and the course leader categorized these responses as critical or uncritical. *Critical responses* were those that the researchers recognized as realizing learning and therefore handover to independence at the end of the course. *Uncritical responses* had an incidental nature and were judged as not crucial to handover to independence. For each of the critical responses, the diagnoses that triggered the response were identified from the list of diagnoses for the relevant theme. A second researcher reviewed the coding of responses to ensure consistency; there was no disagreement.

To determine the validity of the diagnoses made by the researchers, we applied data triangulation: The participant logbooks and transcripts of the video recordings of the sessions were analyzed to identify the source(s) of each diagnosis and determine if the diagnosis was underpinned by the participants' writings and utterances.

In order to identify and trace the relevant narrative for the two main themes of the PD program, a web of critical responses with related diagnoses, logbook and video transcript segments was then constructed. This was achieved by creating a map where the critical responses for each narrative were placed in the chronological order left to right. Subsequently the diagnoses were added to the map. Each diagnosis was examined with respect to each

critical response and where the diagnosis informed the response a connection was made creating the web of the theme (Figure 1).

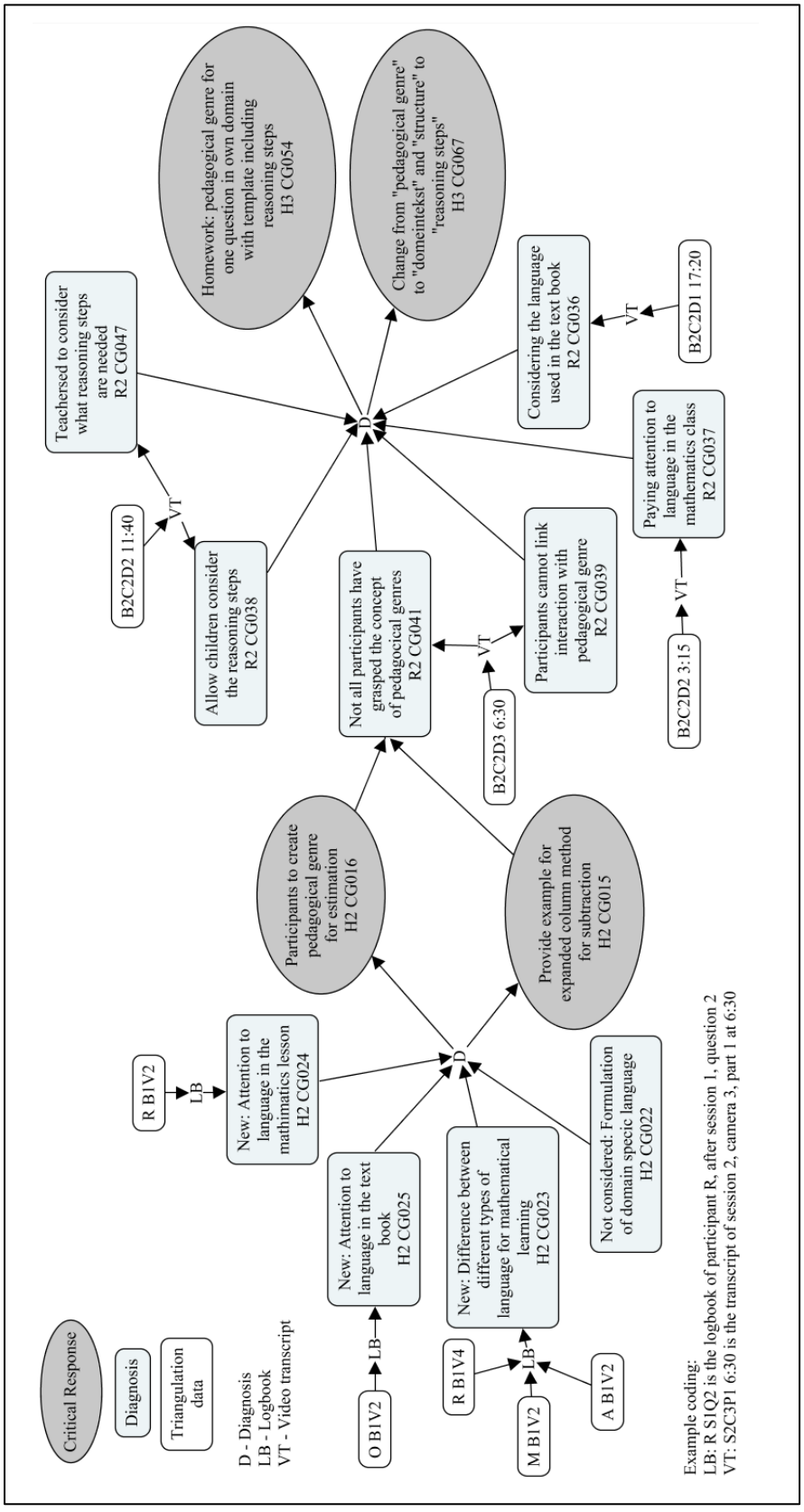

Figure 1. Excerpt from identification of LML narrative web

In this way it could be seen if a response was informed by one or more diagnoses and if a diagnosis in turn informed one or more responses. As such the web of critical responses and related diagnoses identified within the narrative validated how diagnosis, responsiveness and handover to independence were enacted by course leaders over the duration of the PD program. The identification of the three characteristics gave insight in how scaffolding was enacted in the PD program.

3.3.2 Research question 2: Teacher learning within the PD program

To gain insight into the teachers' learning during the course, semi-structured interviews with Mary (pseudonym) were analyzed based on Bakkenes et al.'s (2010) analytical framework for teacher's self-reported learning. Bakkenes et al.'s (2010) included *changes* of emotion in their framework but in subsequent usage of the framework it had been noted the rarity of teachers reporting changes in emotion (Smit, 2013). Therefore it was chosen to extend "changes of emotion" to "emotion" where any utterance relating to emotion with regards to applying the knowledge of the course in the classroom was included. The framework therefore consisted of four categories: changes in knowledge and beliefs, changes in practice, intentions for practice, and emotion. These categories (Table 2) were used as the basis of the coding scheme for the interviews.

Table 2: Coding scheme for reported learning outcomes

Code	Global description	Example
CKB	Change in knowledge/beliefs: The teacher reports on growing awareness, acquired knowledge; or the teacher reports on confirmation of already existing beliefs	I am more aware of the roll language plays in the mathematics class.
CP	Change in practice: The teacher reports that things have changed in his/her way of teaching or in students' participation in the mathematics lessons.	I now prepare my lessons with a language goal in mind.
IP	Intention for practice: The teacher reports that he/she wants to teach differently in the future or reports that he/she wants to hold on to certain teaching practices	I want to spend more attention on the reasoning steps in the future.
E	Emotions: Teacher reports on emotions related to using the knowledge in the course in the classroom, or reports on being surprised	I was surprised to see the level of interaction increased in the class.

All utterances in the transcripts of the interviews, in which Mary reports on a learning outcome, were identified by one researcher. Two independent raters then coded the utterances to the inter-rater reliability of the coding process. The coding by the first and second coder resulted in 120 agreements in coding of 126 utterances (95.2%; Cohan's kappa = .91), meaning the four categories could be reliably distinguished.

In order to gain insight into the nature of the reported learning outcome, the utterances were placed in chronological order by category. The utterances were analyzed and a summary of changes in the four categories was generated. The course leader then read the ordered data to validate the conclusions drawn from the analysis; minor updates for clarification were made.

4 Results

4.1 Enactment of scaffolding within a PD program

The analysis of the enactment of scaffolding within the PD program yielded two separate chronological narratives focused on the two main themes of the program, identification of LML and scaffolding strategies.

4.1.1 Narrative of identification of LML

The participants were introduced to the concept of pedagogical genre to identify LML by using an example from the domain of line graphs in the first session of the PD program. However, based on the reactions of the participants, the researchers diagnosed that since line graphs are not regularly taught in primary school, that this example was not close enough to their own teaching practice. As such the line graph example did not provide sufficient scaffolding for the teachers to understand the concept of pedagogical genres in relation to LML.

The researchers responded by providing the participants in the second session with two other pedagogical genres for domains that were closer to their own teaching: estimation and expanded column method for subtraction. During the analysis of these pedagogical genres, attention of the participants was drawn not only to the language but also to the structure, in other words the required ordering of the steps by students in order to give mathematical meaning. While reviewing the completed task, the researchers diagnosed that the participants were still struggling with the concept of pedagogical genre. This diagnosis was corroborated when two participants contacted the course leader to report that they could not grasp how to complete the homework assignment of creating their own pedagogical genre for estimation. The researcher diagnosed that not only was the term pedagogical genre too far away from the teachers' own educational experiences but that also the notions of linguistic and structure features of pedagogical genres were not as fully understood as the researchers had anticipated they would be at this stage in the PD program.

In response, in the third session the researchers took five steps to assist the participants' grasp of the component concepts. The first step was to replace the term "pedagogical genre" by "domain text". The terms "domain" and "text" were chosen as they were terms the participants regularly used that when used collectively gave an equivalent meaning as what was intended with "pedagogical genre". In order to address the issue of structure features within the context of mathematics, the researchers' response was to shift focus from identifying the structure of spoken or written mathematical text to identifying the reasoning steps needed to solve mathematical problems. Structure features and reasoning steps were seen as equivalent to the researchers as they both provide the necessary steps for the purpose of the genre to be fulfilled – solving a particular problem. Both changes were introduced to the participants by means of an explanatory list of terms within the PD program at the start of the third session. Along with the change in names, as a second step, there was a shift from developing domain texts that would identify global language for a particular domain, to focusing on the language for solving a particular mathematical problem within a domain.

The researchers had diagnosed prior to this third session that participants had understood the importance of language in the mathematics classroom: "the influence of language on mathematics is greater than I expected" and "with students who are weak in language I usually simplify my language usage. In fact it is important not to simplify language usage". Therefore, the third step in response to the conceptual issues with identification of LML was to build on this awareness and highlight the importance of identification of language, and as such the importance of developing a domain text. In order to achieve this, the participants analyzed a segment of interaction in which there was miscommunication between a teacher and a student. The fourth step was that the participants were given an assignment to develop a domain text for one mathematical task in a domain of their choice. As a fifth step the researchers scaffolded this by providing the participants with a template (Figure 2) that specifically included the identification of reasoning steps and required language in that domain.

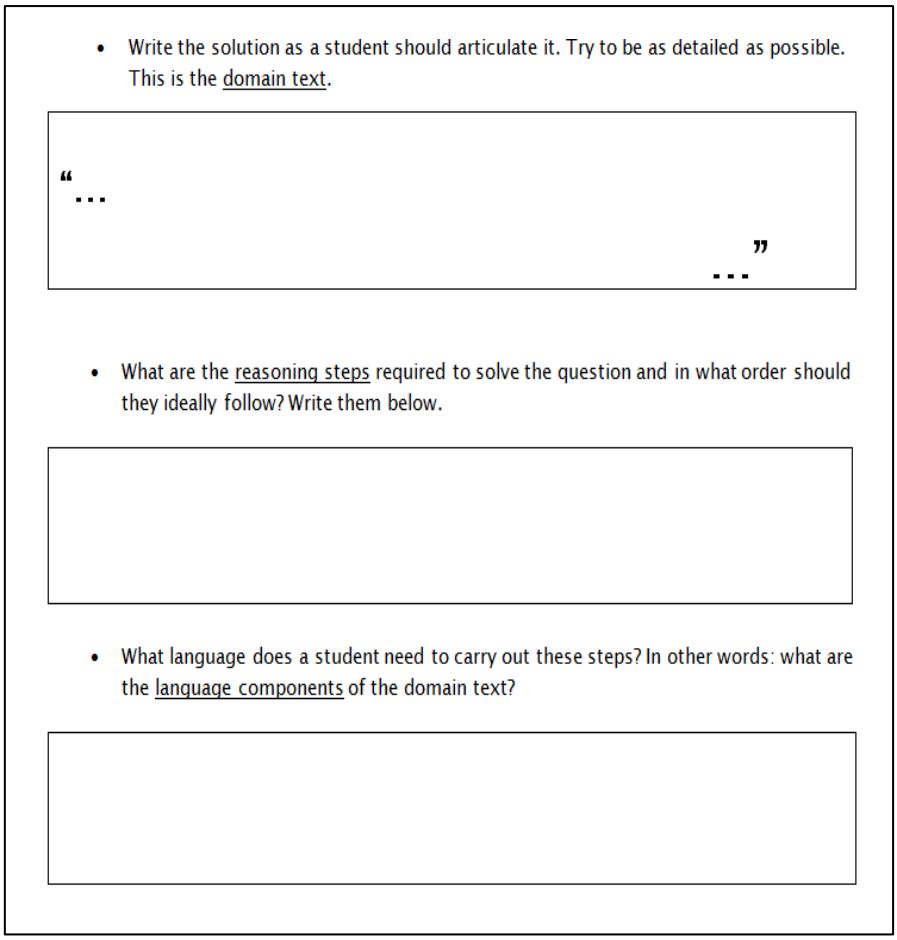

Figure 2. Excerpt from template for domain text (translated from Dutch)

The researchers, based on the assignments from the third session, diagnosed that the participants needed additional practice in identifying domain texts. In the fourth session the participants were set the assignment to use the template (Figure 2) in order to prepare and implement a language focused mathematics class. The participants also reported changes in knowledge and intentions for practice while analyzing videos of language-focused mathematics classes during the session and the related domain text. The analysis of videos in this way had not been done in previous sessions. In response to the positive effects the analysis of videos had on the participants' self-reported learning, it was decided that from the fourth session onwards every participant should have at least one of their language-focused mathematics classes and associated domain text analyzed in a session.

In the homework assignments from the fourth session the researchers diagnosed an increase in handover to independence with respect to identifying vocabulary for their chosen domain. However, the participants were unable to successfully place the students thinking central in their analysis of the reasoning steps and instead placed the student's procedural steps central. As such they had been unable to combine the linguistic and mathematical goals. In response the course leader led a discussion with the participants on the differences between the instruction of procedural steps and the awareness of the reasoning steps that a student requires to solve a problem. This clarified the concept for a number of participants with

comments such as “Reasoning steps stimulate thinking”, “maybe we give too little attention to reasoning steps” and “normally language in the mathematics lesson is focused on the mathematical procedures, not the reasoning steps of a student”.

By the end of the sixth session most of the participants showed some form of handover to independence with respect to thought process during the session “You get closer to the thinking of the children” and with respect to language and reasoning steps “They support each other. You see the thought process in the children”.

One of the goals of the PD program – as part of handover to independence and indication of the success of long term scaffolding – was to enable the participants to disseminate the knowledge in their own schools. Based on logbook entries and utterances in the session the researchers diagnosed that the participants were lacking in both time and confidence. In response, the researches proposed to also scaffold the participants’ dissemination of knowledge to their colleagues. This was achieved by allowing the participants to invite their colleagues to the final session where the participants themselves presented the key concepts from the PD program. In this way the researchers were providing the participants with the time to start the dissemination of knowledge as well as supporting them in the creation of the material prior to the session and support them during the session.

In the final session, one participant gave a presentation on identification of LML. During the presentation, not only was the identification of language covered but also the reasoning steps “from A to Z, how you can get to the solution”. The participant made it clear that in order to enable a student to articulate how they are solving a problem, they must be equipped with the vocabulary and phrases required to describe their reasoning steps.

4.1.2 Narrative about scaffolding strategies

In the second session of the PD program, the participants were introduced to the broad concept of scaffolding. Scaffolding strategies (Table 1) were then introduced as a repertoire that participants could draw on in their classrooms for supporting students’ language development in whole class interactions. This was achieved by means of analyzing a video segment and transcript that contained scaffolding of language.

Based on the participants’ analysis of the video segment and transcript the researchers diagnosed an awareness of participants in a number of aspects of the scaffolding strategies. For example the participants indicated that interaction could be changed by asking a variety of questions or taking a different approach “Oh I thought afterwards, I could have repeated that”. The researchers also diagnosed that the participants were not yet able to articulate and name the precise strategies being used, and that the participants could not quite yet link interaction in the classroom with the identification of LML and scaffolding of spoken language. The researchers’ response was to conclude that not only did the participants need additional exposure to identifying scaffolding strategies but attention had to be drawn to the fact that pedagogical genre provide an insight into what language precisely has to be

scaffolded in the class (it should be noted that at this point in the PD program the shift to domain text had not yet occurred).

In the third session, to fulfill this response, the participants were asked to identify scaffolding strategies from a transcript of an imaginary lesson about estimation. The participants' indicated development in their understanding of scaffolding LML through this task. The researchers diagnosed that the example used was not realistic enough for the participants and in response decided that future analysis should be conducted on video segments of the participants' own lessons. This third session also contained the change from pedagogical genre to domain text and it was stressed to the participants that the domain text constituted the language to be scaffolded.

Before the fourth session, the researchers diagnosed that there was an increase in confidence in the understanding of and ability to apply scaffolding strategies. This diagnosis was confirmed when participants also reported using a number of scaffolding strategies in their own lessons. However, one participant reported that her lessons were taking substantially longer and that the students were being somewhat resistant to paying attention to language. In response the course leader discussed how language-oriented mathematics lessons require a substantial change in the expectations of the students to the required level of interaction and thus the social norms in the class. It was discussed that changing the social norms within the class enables the teacher to change the established interaction norms. As such establishing the interaction norms is conditional to the enactment of scaffolding.

In the fourth session the participants also analyzed a participant's video segment, first by watching the video and then by analyzing the transcript to identify scaffolding strategies. The researchers diagnosed that although the participants were able to discuss the enacted strategies not all the participants' could identify enacted scaffolding strategies. For example, the participants needed to analyze, as part of a larger segment about the use ratio tables to calculate percentages, the following segment:

> Student (S): ...and I put the whole amount here.
>
> Teacher (T): You said that really well. Did you hear what he said: the whole amount. What do you mean with this?
>
> S: What the whole is.
>
> T: What the whole is. And what is the whole?
>
> S: 500.
>
> T: And what is that?
>
> S: 100%.
>
> T: 100%. Can you say this in another way?

S: 500 is … uhh…

T: Try again using the amount 500....

S: The amount is 100%, but we need to know 20%.

In the analysis of the transcript, although the participants recognized that the teacher was continuing to ask questions, they failed to identify the use of two scaffolding strategies (i.e. asking the students to be more precise in their language, repeating correct student utterances).

> Participant 1: You got the [linguistic] answer you wanted from the student. By continuing to ask, you did get it.
>
> Participant 2: Yes that is what you did. You kept asking.

Despite the participants not being able to explicitly identify the scaffolding strategies, the researchers did note that participants reacted positively to seeing and analyzing each other's video segments as it gave them clear examples of what scaffolding in practice can look like. In response, and in conjunction with the related response in the identification of LML narrative, the researchers proposed that all participants should have at least one video segment analyzed by the group. In this way each participant would receive personal feedback on the interaction in their class and their enactment of the scaffolding strategies.

In the final dissemination session, two participants gave a presentation on scaffolding strategies. During the presentation, and indicating handover to independence, both presenters covered scaffolding strategies and clearly communicated that in order to increase interaction in the classroom the language to be scaffolded should first be identified. Therefore in order to use the scaffolding strategies, the vocabulary and phrases which are required to describe reasoning steps of the students must be identified in order to be able to scaffold them in a whole-class setting.

4.2 Teacher learning within the PD program

Table 3: *Distribution of reported learning outcomes among four categories*

	Mid-interview (Mid)	Post-interview (Post)	Total
Changes in knowledge and beliefs	15	16	31
Changes in practice	30	31	61
Intentions for practice	13	20	33
Emotions	1	0	1

Table 3 shows the distribution of utterances among the categories of reported learning. With 126 utterances in total, the majority of the reported learning outcomes fell into the category changes in practice. Emotion was only reported once, in the mid-interview, and as such this category was excluded from the analysis of changes in reported learning.

Mary's development over time based on the reported learning outcomes in the mid- and post-interviews are summarized in Table 4.

Table 4: *Mary's development over time as deducted from reported learning outcomes*

	Summary of developments over time
Changes in knowledge and beliefs	Mary developed the belief that language, in its different forms, plays an important role in the mathematics lesson. Mary became aware of the importance of identification of language in different domains. She grew in her understanding of scaffolding strategies for students' LML development. Mary also identified a number of activities in the PD program that supported her learning including the video analysis of whole-class scaffolding of LML, and applying what she had learned in the session to her next class both with regards to preparation and execution.
Changes in practice	Mary reported that she now prepares her mathematics lessons to include attention to the identification of LML required by her students. Mary's self-reported interaction with the students has changed immensely from initially focusing on the words and phrases the students use to later also paying attention to discussing the reasoning steps involved to solve a problem. Mary reported these alterations have led to an increase in interactions with and in between her students and have changed the atmosphere in the class in a positive manner.
Intentions for practice	Midway through the PD program, Mary's reported intentions were related to her own development in using specific scaffolding strategies in the mathematics class and continuing to formulate a domain text for her chosen domain (measurement). However, by the end of the PD program Mary's reported intentions were not limited to her own further learning in domain text and the continued attention to language in her mathematics classes. She also wanted to extend the attention to language to other subjects. Moreover, Mary wanted to disseminate the knowledge within her school and considered the content and the techniques that should be used to assist her colleagues' learning.

In the following subsections, quotes from the interviews (from which interview is cited in parentheses) and observations are presented to illustrate Mary's development from the mid- to post-interview for each category of reported learning.

4.2.1 Changes in knowledge and beliefs

The changes in knowledge and beliefs primarily concerned the overarching intention of the PD program for scaffolding language for students' mathematical learning. The most noticeable change in Mary's beliefs was the importance of language in the mathematics classroom and that "language in a mathematics lesson is not separate, mathematics and language belong together" (Mid). For Mary the concept of the scaffolding strategies seemed

easy to understand as early in the course she had formulated for herself that *"*they are strategies I can use to help the students use more precise language"(Mid).

However with the theme of identification of LML, Mary had a number of conceptual issues. Although Mary understood that the required language consisted of subject-specific words as well as the mathematical meaning of natural language, she struggled in shifting her view from considering that LML consists only of vocabulary to viewing LML as a means to allow a student to fully articulate his or her reasoning steps. Mary noted that her difficulties in comprehending the concept of reasoning steps may have been due to her choice of domain. The domain of measuring – at the age of Mary's class – does not involve a large amount of reasoning knowledge but does involve substantial procedural knowledge of how to measure. For Mary this was confirmed when she reflected on another participant's domain text where she could immediately identify the reasoning steps.

Mary reported that the learning structure within the PD program where participants spent time analyzing their own assignments and video recordings of their classroom interaction as a group was for her valuable and crucial to her own learning as "You cannot do that alone. And also not by reading a book" (Post).

4.2.2 Changes in practice

Mary reported a number of changes in practice as a result of the PD program. She changed the preparation of her mathematics lessons to include a language goal. Specifically Mary now considers "what language is important to focus on in the lesson and how they (learners) can use it" (Post).

There were also changes in how Mary interacted with her students. From the early phases of the course Mary made use of a number of scaffolding strategies that were covered in the course and included providing, asking for and repeating correct formulations.

By the end of the course Mary reported how a number of the scaffolding strategies had become embedded in her class: "how can we say that using mathematical language? That is a standard sentence I use often" (Mid) and "discussing with each other how to word it more precisely" (Post). Mary also recognized the benefits of not only confirming that her student has used the correct articulation but asking another student to also try as "it may help the student who had not yet understood it" (Post).

The focus in Mary's mathematics class shifted from finding the answer to allowing the students to articulate their reasoning steps:

> The students articulate their reasoning steps. You then know: the answer is not correct but in how you tried to get there one small step is missing. If you can explain something then you understand it. They previously had not been able to articulate that. (Mid).

Mary also observed changes in the form of interaction she had with the students: “I noticed I have a lot more dialogue with the students” (Mid), “they use the required terms and often say ‘oh we need to say that using mathematical language’” (Post).

Mary reported that the changes implemented with respect to language in her mathematics class resulted in changes in the social norms and the atmosphere in her class.

> It is warmer. It is as if you are having a conversation with them but you are also teaching them something…it is no longer to and fro but more rounded. (Post)

4.2.3 Intentions for practice

In the mid-interview, Mary’s intentions for practice were focused on her own development with respect to scaffolding students’ LML. By the end of the course in the post-interview, Mary reported the intention of continuing to work on components of the domain text, the identification of the articulation of the reasoning steps. Mary also reported that she intended to use the knowledge she gained in the PD program, not only in the mathematics class, but to extend scaffolding of language to other subjects that she teaches: “I think that I will try it in other subjects.” (Post)

In the post-interview, Mary’s reported intentions were not limited to her own learning and practice, but included the dissemination of knowledge to her colleagues so that in can be implemented in the other classes. Mary also noted that the dissemination of the knowledge related to the scaffolding of LML is not something that can be achieved in the short term “but slowly as this is something that must be absorbed. This cannot be done in a couple of months. This is something where you need a year to become more confident about it.”(Post).

5 Discussion

The present study aimed to explore how scaffolding of teachers can be enacted within a professional development (PD) program to promote teachers’ scaffolding of language required for mathematical learning (LML).

5.1 Enactment of scaffolding within a PD program

Tracing of the occurrences of the three characteristics of scaffolding throughout the PD program indicates that scaffolding can be employed to shape the PD of teachers. By analyzing the web-like nature of the scaffolding characteristics, a number of components in the PD program were identified as central to the development of the participants’ knowledge and skills of scaffolding LML by the participants. The keystone of the PD program with respect to LML was the scaffolding of teachers with regard to the identification of a domain text for their chosen domain. Although it was initially intended to develop a number of domain texts encompassing different mathematical domains, it turned out that developing domain texts for an entire mathematical domain was overwhelming for the participants.

Researchers chose to restrict the development of a domain text to a mathematical problem within the participants chosen domain and linking didactical choices to the domain text itself. This ensured that participants could focus on the key components of the domain text and identify the required LML in their class. Without the identification of the LML, the participants would not be able to successfully scaffold students' learning through LML. The identification of LML was realized by providing the participants with a template that was not limited to identifying vocabulary for their chosen domain related mathematical problem, it included the identification of the reasoning steps required and how a participant expects a student to articulate those steps and creating a link between the linguistic and mathematical goals. The development of the participants' knowledge on domain text continued throughout the program where participants received not only feedback from researchers but also from their peers. As a result of this PD program the researchers have not only gained insight into more efficient ways of enabling teacher learning with respect to domain texts, but have identified a larger number of domain texts, covering a range of domains, that have been used by teachers and can be used as material in future PD programs.

In order to scaffold students' usage of LML, the crucial link between language, interaction and social norms needed to be appreciated and understood by the participants in the PD program. In order to scaffold LML in the classroom the interaction between teachers and students, as well as between the students themselves, can be supported by applying the LML scaffolding strategies (Table 1). For this interaction to be successful, the social norms within the classroom must allow this interaction to take place and participants' attention must be drawn to this necessary condition. To successfully scaffold LML, not only should participants be aware of the possible scaffolding strategies but they must also successfully apply them in their classroom. Crucial in the participants' development was the analysis and feedback on the interaction in one another's video segments with respect to LML and the use of the scaffolding strategies. As such this form of group analysis was a key component within the PD program.

5.2 Teacher learning within the PD program

By analyzing the reported learning outcomes of one of the participants, a deeper insight was gained into the possible development of the participants over the duration of the PD program. In the case of Mary, the doubling in the number of intentions for practice between midway and the end of the PD program is illustrative of the handover of independence taking place from the course leader to the participant herself. Importantly these intentions for practice were not limited to her but also included the dissemination of the knowledge within her school and the extension of a focus on language to other subjects. The most noticeable impact of scaffolding of LML that Mary reported was the change in social norms around the types of interactions that occurred within her class, both between Mary and the students and between the students themselves. Mary noted that these achievements transpired over the duration of the seven month program and as such scaffolding of teachers to scaffold students' LML requires time to be effective.

5.3 The merits of scaffolding teachers to scaffold language for mathematical learning

5.3.1 The concept of scaffolding teachers

The scaffolding enacted within the PD program was dependent on the diagnoses made by the researchers' based on their awareness and intentions relating to scaffolding of LML. Of note was the evolution of the scaffolding of identification of LML from pedagogical genre to domain text over the course of the PD program. A pedagogical genre, compared to the scaffolding strategies, is a relatively abstract concept for teachers. The scaffolding strategies are close to what teachers enact in class (e.g. reformulation) and as such may be easier to recognize as teaching strategies and therefore making them easy to conceptually understand. However the identification of the LML is much less familiar to the participants, especially when asked to consider the linguistic and structure features which require an awareness of grammar that they may not be equipped with. The scaffolding of identification of LML required a redesign midway through the program when it became apparent participants' were having conceptual difficulties and there was a conceptual shift to domain text. This ability to adapt both the course program and the materials themselves ensured that the actual scaffolding was responsive to the knowledge and skills of the participants themselves. This provided the temporary support required by the participants until they could accomplish the task unaided, which is the essence of scaffolding.

Learning, by its very nature, is a function of the individual's experiences and as such a PD program needs to be responsive. Unlike ready-made, formulaic PD programs, by explicitly scaffolding the participants, justice is being done to the responsive nature of learning. Therefore the merit of scaffolding of teachers allows for adaptively not only to the participants but also to the content itself. However, these adaptations will only be effective if they are made in response to a diagnosis and with the intent of handover to independence. When the three characteristics of scaffolding are present in the PD program, it can be considered that scaffolding has been enacted and the merits of scaffolding apply.

5.3.2 Scaffolding language for mathematical learning as the gateway to reasoning

One noticeable change to the material in the PD program was the shift from pedagogical genre to domain text, specifically the shift from structure features to reasoning steps. As such participants were asked to combine the linguistic and mathematical goals and consider their students' reasoning when identifying LML. It has been recognized that teachers' understanding of children's reasoning is not always effortless, even in cases where the teachers are engaged in a PD setting (Ball, 2001). Visnovska (2009) analyzed a 5 year middle school teacher PD program which placed students' reasoning at the centre of mathematical instructional decision making and reported that two years into the program "supporting the teachers to focus on students' reasoning continued to be a challenge".

Within the course of the seven month PD program, the case study teacher reported a shift away from focusing on the answer and the procedural steps (method) students should use, to

centralizing the reasoning of her students and discussing the reasoning steps with them. Also, as was noted in the narrative of identification of LML, the other participants of the PD program indicated growth in awareness of the reasoning steps that students require to complete a mathematical problem within duration of the PD program.

Results of the current study show that by requiring the participants of the scaffolding LML PD program to consider not only the required reasoning steps but the language required for students to articulate these steps, seem to have had a positive influence on the participants' considerations of students' reasoning. Not only was participants' attention drawn to students' reasoning, they were also equipped with the skills needed to enable their students to discuss the reasoning steps.

5.4 Recommendations and future research

I interpret the findings as reinforcing that scaffolding as a concept can be extended to include long-term development of groups of teachers. I propose that the explicit use of scaffolding within a PD program should not be restricted to the topic of scaffolding language for mathematical learning. By explicitly employing the three characteristics of scaffolding – diagnosis, response and handover to independence – a PD program can be successfully adapted not only to the participants themselves but to the content of complex concepts and the deployment of innovative educational strategies where there is little or no research on how to effectively train teachers in that strategy. Further research in the use of scaffolding of PD programs to deploy complex concepts or innovative educational strategies is required to confirm this conjecture.

One limitation of this study is that the impact of the PD program on the students' of the participating teachers was not observed. A next step in assessing the effectiveness of the PD program would be to extend the study to include the students of the participants. Based on the findings of this study, an area of special interest for further research is the influence the linguistic attention to reasoning steps has on students' mathematical understanding, especially compounded over multiple academic years. Could paying linguistic attention to students' reasoning steps pave the road to students' mathematical understanding?

References

Avalos, B. (2011). Teacher professional development in Teaching and Teacher Education over ten years. *Teaching and Teacher Education, 27*(1), 10-20.

Bakkenes, I., Vermunt, J. D., & Wubbels, T. (2010). Teacher learning in the context of educational innovation: Learning activities and learning outcomes of experienced teachers. *Learning and Instruction, 20*(6), 533-548.

Bakker, A., & van Eerde, D. (2015). An introduction to design-based research with an example from statistics education. *Approaches to Qualitative Research in Mathematics Education* (pp. 429-466). Springer Netherlands.

Ball, D. L. (2001). Teaching, with respect to mathematics and students. In T. Wood, B. S. Nelson & J. Warfield (Eds.), *Beyond classical pedagogy: Teaching elementary school mathematics* (pp. 11–22). Mahwah, NJ: Lawrence Erlbaum.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. Educational researcher, 33(8), 3-15.

Buxton, C., Lee, O., & Santau, A. (2008). Promoting science among English language learners: Professional development for today's culturally and linguistically diverse classrooms. Journal of science teacher education, 19(5), 495-511.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American educational research journal*, *38*(4), 915-945.

Gibbons, P. (2002). *Scaffolding language, scaffolding learning: Teaching second language learners in the mainstream classroom*. Portsmouth, NH: Heinemann.

Halliday, M. A. K. (1978). *Language as social interpretation of language and meaning*. University Park Press.

Martin, J. R., & Rose, D. (2008). *Genre relations: Mapping culture*. Equinox.
Maybin, J., Mercer, N., & Stierer, B. (1992). 'Scaffolding' learning in the classroom. In K. Norman (Ed.), *Thinking voices: The work of the national oracy project* (pp 185-195). London: Hodder & Stoughton.

Moschkovich, J. (2007). Examining mathematical discourse practices. *For the Learning of Mathematics*, 24-30.

Moschkovich, J. N. (2010). *Language and mathematics education: Multiple perspectives and directions for research*. IAP.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics* (Vol. 1). National Council of Teachers of Mathematics.

Schleppegrell, M. J. (2007). The linguistic challenges of mathematics teaching and learning: A research review. *Reading & Writing Quarterly*, *23*(2), 139-159.

Simon, M. A. (1995). Reconstructing mathematics pedagogy from a constructivist perspective. *Journal for research in mathematics education*, 114-145.

Smit, J. (2013). Scaffolding language in multilingual mathematics classrooms. Utrecht University.

Smit, J., & Van Eerde, H. A. A. (2011). A teacher's learning process in dual design research: learning to scaffold language in a multilingual mathematics classroom. ZDM: The International Journal on Mathematics Education, 43(6-7), 889-900.

Smit, J., Van Eerde, H.A.A, & Bakker, A. (2013). A conceptualisation of whole-class scaffolding. *British Educational Research Journal*, *39*(5), 817-834.

Smit, J., Van Eerde, H.A.A., Kuipers, M., & Bakker,A. (2013). Development of pedagogical genre and evaluation of pupils' genre proficiency: A linguistic turn in educational design.

Stodolsky, S. S. (1988). *The subject matters: Classroom activity in math and social studies*. University of Chicago Press.

Van Eerde, H., Hajer, M., & Prenger, J. (2008). Promoting mathematics and language learning in interaction. In J. Dean, & M. Hajer, *Interaction in two multicultural mathematics classrooms. Processes of Inclusion and Exclusion*, p31-69. Amsterdam: Aksant.

Van de Pol, J., Volman, M., & Beishuizen, J. (2010). Scaffolding in teacher–student interaction: A decade of research. *Educational Psychology Review*, *22*(3), 271-296.

Van Der Valk, T., & De Jong, O. (2009). Scaffolding science teachers in open-inquiry teaching. *International Journal of Science Education*, *31*(6), 829-850.

Visnovska, J. (2009). *Supporting mathematics teachers' learning: Building on current instructional practices to achieve a professional development agenda* (Doctoral dissertation). Vanderbilt University, .

Vygotsky, L. S. (1978). Mind and society: The development of higher mental processes.

Vygotsky, L. (1978). Interaction between learning and development. *Readings on the development of children*, 34-41.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of child psychology and psychiatry*, *17*(2), 89-100.