# PRACTICALIZING PRINCIPLED KNOWLEDGE WITH TEACHERS TO DESIGN LANGUAGE-ORIENTED MATHEMATICS LESSONS: A DESIGN STUDY

Arthur Bakker[1], Farran Mackay[2], Jantien Smit[3], Ronald Keijzer[4]

[1]Utrecht University, [2]Eindhoven University of Technology, [3]Utrecht University of Applied Sciences, [4]University of Applied Sciences iPabo

*It has been argued that teachers need practical principled knowledge and that design research can help develop such knowledge. What has been underestimated, however, is how to make such know-how and know-why useful for teachers. To illustrate how principled knowledge can be "practicalized", we draw on a design study in which we developed a professional development program for primary school teachers (N = 5) who learned to design language-oriented mathematics lessons. The principled knowledge we used in the program stemmed from the literature on genre pedagogy, scaffolding, and hypothetical learning trajectories. We show how shifting to a simple template focusing on "domain text" rather than genre, and "reasoning steps" rather than genre features made the principled knowledge more practical for the teachers.*

## THE NEED FOR PRACTICAL PRINCIPLED KNOWLEDGE

On the one hand, knowledge generated in research is often not practical enough for designers and teachers to use productively in their educational practice. On the other hand, there is a need for principled knowledge that goes beyond local, situational, or contextual heuristics. It is for these reasons that Bereiter (2014) made a call for *practical principled knowledge* (PPK), knowledge that combines "practical know-how and scientific theory"; it offers practical guidance but also "meets standards of explanatory coherence" (p. 4). Research on what such PPK may look like is scarce (e.g., Kidron & Kali, 2017), and studies on how to develop PPK are even rarer. Bereiter suggests that design research could be extended to the creation of PPK, but this effort should not be underestimated: Janssen, Westbroek and Doyle (2015) argue that what researchers consider PPK is often not very practical in the eyes of teachers. To ensure practicality, we involved teachers in making adaptations to a professional development program. The research question addressed in the current paper is: What does "practicalizing" principled knowledge with and for teachers look like? An answer allows us to reflect on what supported this process.

The principled knowledge that we draw on comes from the literature on genre pedagogy (Hyland, 2004; Martin & Rose, 2008), scaffolding (Gibbons, 2002), and hypothetical learning trajectories (Simon, 1995). To create PPK that teachers consider practical, the methodological approach we use is that of design research. Note that both the theory of scaffolding informing our design approach and the methodological orientation of design research are inherently adaptive, allowing for continuous



2019. In M. Graven, H. Venkat, A. Essien & P. Vale (Eds.). *Proceedings of the 43rd Conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 56-64). Pretoria, South Africa: PME.

monitoring of the practicality of knowledge from the literature and responsiveness to teachers' needs.

## DESIGN RESEARCH

Design research has grown out of the need to bridge the aforementioned theory–practice gap (Bereiter, 2014; Janssen et al., 2015), and to move beyond the typical emphasis of educational research on description, explanation, comparison, and evaluation (Bakker, 2018). It aims to realize and study education as it *could be* rather than as it was or currently is. The type of knowledge that design researchers are after is actionable knowledge about how something can be realized (e.g., achieving particular educational goals) or how particular problems can be solved. To do so, a design approach to mathematics education seems more appropriate than basic research (Wittmann, 1995). Design research adopts an iterative and adaptive stance by using and developing theory and using this to do real work (Cobb et al., 2003).

A useful methodological and design instrument, one often used within mathematics education, is Simon's (1995) notion of hypothetical learning trajectories (HLTs). An HLT specifies the starting point, the learning goals, learning activities, and hypotheses about how these learning activities help students achieve the desired goals; the hypotheses are based on practical experience and refined after scientific analysis. Being informed by educational research and practical experience, HLTs thus serve as an intermediary between theory and practice.

## PRINCIPLED KNOWLEDGE DRAWN ON

To illustrate the process of practicalizing principled knowledge that is useful to teachers, we report on a design study that aimed to develop a teacher professional development program (PDP). The topic of the PDP was designing language-oriented mathematics lessons in primary education. The PDP was a sequel to an earlier design study that used genre pedagogy and other theoretical resources to scaffold students' mathematical language development in primary education (Smit et al., 2016). The earlier study (co-design with one experienced teacher) had delivered a set of strategies for scaffolding mathematical language, exemplary teaching materials, and theoretical insight into whole-class scaffolding and features of a genre of interpreting line graphs.

Genre pedagogy is a promising approach that explicitly addresses the language required for learning, in that it provides learners with metalinguistic knowledge about how (both spoken and written) language is structured and used to achieve particular communicative goals (e.g., describing or persuading) (Hyland, 2004). The notion of genre is typically associated with certain literary forms, for example a poem or a novel. In genre pedagogy, the concept of genre is particularly used for academic text types used throughout the curriculum. Commonly distinguished genres are report, explanation, procedure, discussion, recount and narrative (e.g., Derewianka, 1990), each with specific communicative goals. Genre pedagogy explicitly attends to how schematic structures help speakers or writers to accomplish their communicative goals within each specific genre. Furthermore, it centralizes how linguistic features (e.g., general academic language and subject-specific language) operate in a particular genre. As such, genre pedagogy supports learners in acquiring proficiency in school-bound genres (e.g., narratives, reports), with the ultimate aim of students' independence in these genres.

Informed by genre pedagogy, Smit et al. (2016) formulated linguistic and structure features needed for describing and interpreting line graphs. The linguistic features included, for example, the subject-specific vocabulary and phrases (e.g., the *graph rises*), and also the use of expression of gradations of steepness (as in "the graph descends *gradually*"), as well as general academic language to be employed when interpreting the graph (e.g., *the number* of people *increases*). The structure features comprised the stages of students' reasoning about graphs. For example, students are expected to identify all parts of the graph and underpin each interpretation (e.g., "his weight decreased quickly") with a description related to the course of the graph ("you can tell as the graph shows a steep fall"). Such explicit attention for linguistic and structure features of genres is assumed to help learners understand and participate in mathematical discourse.

The PDP design was informed by the theoretical idea of scaffolding—temporary adaptive support, which requires repeated diagnosis and responsiveness with the long-term goal the handover to independence (in our case independent design of language-oriented mathematics lessons).

## METHODS

To develop the professional development program (PDP), we used design research and we intended to practice what we preach: being explicitly adaptive to learners' needs by constantly making predictions about the participants' learning (using HLTs), diagnosing their levels, and responding adaptively in line with the scaffolding idea. The *PDP* consisted of seven sessions (2.5 hours each), for which course materials were developed and adapted during the course of the program. The total number of hours spent by each participant, including preparing the sessions and completing assignments, was approximately 40 hours. The *participants* were five in-service primary teachers with a variety of backgrounds, years of teaching experience (a range of 10 to 25 years), and roles within the school (three mathematics specialists, one language specialist who did not have her own class, one general teacher). Four worked in regular primary schools, one in special education. Their students were of low to middle socio-economic status, attending Grades 3 to 6 (age 6–11). All five teachers entered the program voluntarily and were committed to become more knowledgeable in the enactment of language-oriented mathematics education.

*Data collection* consisted of participants' personal logbooks, our own HLTs, our own reflection documents written after each session, completed exercises by the participants and verbatim transcription of the interaction between the researcher-educator and participants from video recordings of each group session; and two semi-structured interviews of one of the teachers conducted by the researcher-educator. The teacher was chosen based on the completeness of her logbooks and assignments, with the first interview between the fourth and fifth group session and the second after the final session. Audio recordings of both semi-structured interviews were made and transcribed verbatim.

*Data analysis* focused on the diagnoses of what teachers struggled with, which led to what we considered critical responses by the design team in the PDP, in particular the teacher educator. Diagnoses (D) were based on the reflection documents and were triangulated with the logbooks (LB) and video transcripts (VT). Incidental responses, less relevant ones such as organisational decisions, were left out of the webs (cf. Figure 1). A second researcher reviewed the filtering of responses to ensure consistency of the coding of critical vs. incidental ones; there was no disagreement. Figure 1 shows an example of a web about diagnoses and the team's responsive changes in the program. Next, the second researcher checked all diagnosis response relationships and triangulated them with the interview data.

## EXAMPLES OF PRACTICALIZING PRINCIPLED KNOWLEDGE

In the first sessions, the researcher-educator explained the key ideas of genre pedagogy (principled knowledge from the literature). The notion of genre is rather broad (e.g., explanation, discussion), so she narrowed it down to what she then called pedagogical genres and showed concrete examples of such genres of interpreting line graphs, estimation, and expanded column method for subtraction. During the analysis of these genres, she drew the attention of the participants to the linguistic and structure genre features (structure features refer to the required ordering of the steps to be taken by students). While reviewing the first completed task of identifying a genre for a particular domain, the researcher-educator diagnosed that the participants were still struggling with the concept of genre. This diagnosis was corroborated when two participants contacted the researcher-educator to report that they could not grasp how to complete the homework assignment related to the estimation genre. The researcher-educator concluded that the notions of linguistic and structure features of genres were not well understood and that the term "genre" was too theoretical for the participants.

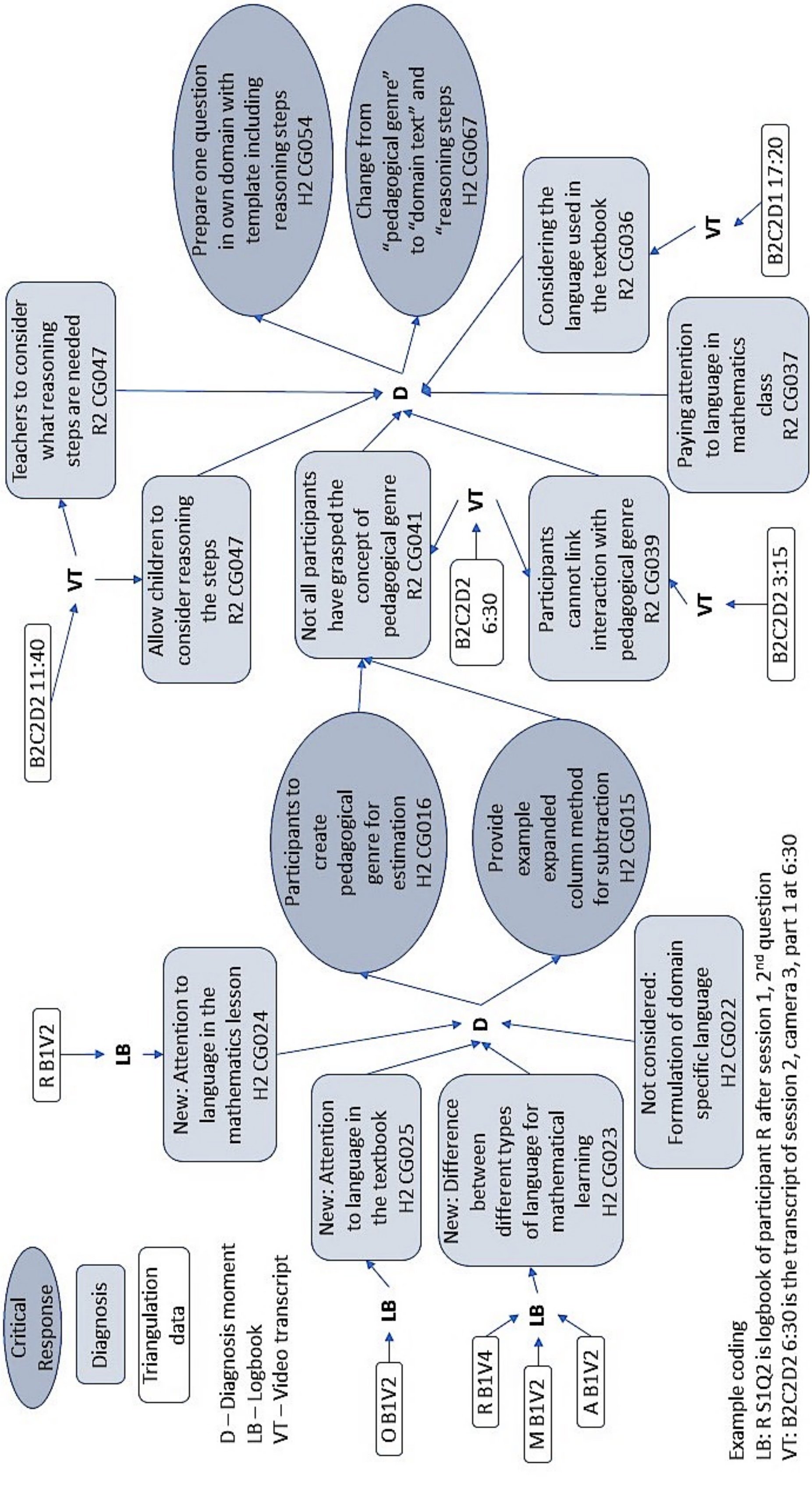


Figure 1: Example from the analysis showing the transition from pedagogical genre to “domain text.”

In between two sessions, during a conversation with the language specialist (who brokered between the participants and the team), the researcher-educator explained the concept of genre in the context of language for mathematical learning as the text that includes the specific language and reasoning that is particular to that domain. It was in this conversation that the term "domain text" as a domain-specific prototypical text was first coined as an alternative to the more technical concept of genre: our first example of practicalizing.

To address the issue of structure features of genres within the context of mathematics, the researcher-educator's next response was to shift focus from identifying the structure of spoken or written mathematical text in a domain to identifying the "reasoning steps" needed to solve mathematical problems. This was regarded as crucial by both the participants and the researcher-educator, as each mathematical problem, even within one and the same domain, requires its own language to be discussed and resolved that is associated with the reasoning steps for that (type of) problem: our second example of practicalizing.

Based on participants' completed assignments, prior to the fourth session, the researcher-educator diagnosed that the participants needed support with identifying domain texts. As a response, in the fourth session the participants were set the assignment to use a domain text template that specifically included the identification of reasoning steps and the required language components for solving the mathematical problem at stake in order to prepare and enact a language-focused mathematics class. The new template included three steps:

1. Write the solution as a student should formulate it. This is the *domain text*.
2. What are the *reasoning steps* required to solve the problem?
3. What language does a student need to take these reasoning steps?

This template was also an attempt to capture the thinking behind HLTs, another notion that the participating kept struggling with, and that hence needed to be practicalized: our third example.

From teachers' homework and input during the last session there is some evidence that using the template worked well for the teachers. They made 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 independence with respect to identifying reasoning steps during the session: "You get closer to the thinking of the children," and, with respect to language and reasoning steps, "[language and reasoning steps] support each other. You can see the thought process in the children."

In the final session, one participant gave a presentation on identifying language required for mathematical learning. During the presentation the reasoning steps were also addressed: "from A to Z, how you can get to the solution." The participant made it clear that, in order to enable students to articulate how they are solving a problem, they must be equipped with the vocabulary and phrases required to describe their reasoning steps.

## DISCUSSION

To continue the discussion between Bereiter (2014) on practical principled knowledge (PPK) and Janssen et al. (2015) on the practicality of PPK for designers and teachers, we ask in this paper what "practicalizing" principled knowledge with and for teachers may look like. We illustrate this process in a design study that aimed at a professional development program to help teachers (re)design language-oriented mathematics lessons. The principled knowledge that we used stemmed from the literature on genre pedagogy, scaffolding language, and HLTs.

Our illustrations show that technical key terms from the literature such as genre, including the structure and linguistic features of genres, proved confusing and impractical for teachers. Our scaffolding approach of repeated diagnosis and responsiveness in combination with the methodological orientation of design research ensured that we stayed in touch with the participating teachers. We collaboratively developed notions and a template that were much more practical for teachers to work with. The term "domain text" replaced the term genre, and we focused on "reasoning steps" rather than "structure features." Moreover, thinking through how students may formulate solutions of mathematics problems engaged teachers in HLT-type thinking without being intimidated by the background theories. Yet all of these developed notions were still connected to the scientific underpinning of genre pedagogy, scaffolding, and design-research thinking. No so-called "lethal mutations" (Brown & Campione, 1996, p. 291)—fatal changes contradictory to original intents—had taken place. Hence we think it is fair to speak of a process of practicalizing principled knowledge.

Admittedly, it is possible that teachers learned from struggling with the technical concepts. We do not know what the PDP had looked like if we had started with the more practical terminology from the start. Yet our study provides a proof of principle how a process of practicalizing can be elicited. We last speculate on the relevant mechanisms to allow for theoretical generalization. The methodological approach we took was design research, which is aligned in the sense that it deliberately aims to be adaptive to local circumstances, iteratively working towards what works best. In retrospect, we came to consider the teacher with whom the researcher-educator invented the idea of domain text as a broker between the other teachers and the design-research team. She was more experienced than her colleagues, which presumably helped in understanding the scientific literature enough to engage with the researcher-educator and take her colleagues' perspectives. We agree with Janssen et al. (2015) that PPK is not enough to ensure practicality; hence we argue that the need for practicalizing will always exist.

## Acknowledgment

The research reported here was funded by NRO under grant number 405-14-501.

## References

Bakker, A. (2018). *Design research in education: A practical guide for early career researchers.* London, UK: Routledge.

Bereiter, C. (2014). Principled practical knowledge: Not a bridge but a ladder. *Journal of the Learning Sciences*, *23*(1), 4–17.

Brown, A. L., & Campione, J. C. (1996). Psychological theory and the design of innovative learning environments: On procedures, principles, and systems. In L. Schauble & R. Glaser (Eds.), *Innovations in learning* (pp. 289–325). Mahwah, NJ: Erlbaum.

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher*, *32*(1), 9–13.

Derewianka, B. (1990). *Exploring how texts work*. Portsmouth, NH: Heinemann Educational Books.

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

Hyland, K. (2004). *Genre and second language writing*. University of Michigan Press.

Janssen, F., Westbroek, H., & Doyle, W. (2015). Practicality studies: How to move from what works in principle to what works in practice. *Journal of the Learning Sciences*, *24*(1), 176–186.

Kidron, A. & Kali, Y. (2017). Extending the applicability of design-based research through research-practice partnerships. *EDeR – Educational Design Research, 1(2),* 1–27. http://dx.doi.org/10.15460/eder.1.2.1157

Martin, J. R., & Rose, D. (2008). *Genre relations: Mapping culture*. London: Equinox.

Simon, M. A. (1995). Reconstructing mathematics pedagogy from a constructivist perspective. *Journal for Research in Mathematics Education*, *26,* 114–145.

Smit, J., Bakker, A., van Eerde, D., & Kuijpers, M. (2016). Using genre pedagogy to promote student proficiency in the language required for interpreting line graphs. *Mathematics Education Research Journal*, *28*(3), 457–478.

Wittmann, E. C. (1995). Mathematics education as a 'design science'. *Educational Studies in Mathematics*, *29*(4), 355–374.