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Planning and implementation: the impact of a professional development program on teachers' and learners' oral manifestations

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This paper investigates a professional development program's (PD) effect on classroom discourses. The PD was based on problem-based curriculum processing and intensive use of classroom discourse. The authors analyze seven pilot lessons of one of the teacher training's participants, providing an example of how a teacher with 20 years of experience in mathematics teaching, but using traditional teacher-centered methods, can apply the new approach in the classroom. Our analysis is based on a combined theoretical approach that starts from students' mathematical thoughts and examines the teacher's responses. We found numerous possibilities for starting classroom discussions building on students' thinking, and the teacher responded to most of them. Furthermore, the teacher's responses also included several invitations for students to classroom discourse, although these elements were almost absent before the PD.

Keywords: Professional development, problem-oriented instruction, student-centered teaching, class discussion.

Introduction

Based on the Hungarian tradition and inspired by the ideas of Tamás Varga in mathematics teaching (Varga, 1988), the second and third authors have developed a research-based professional development (PD) program. This program was piloted in 2018-2019, with four voluntary teachers as participants. One teacher's lessons are the basis for this paper, since the authors analyze the PD's effect on classroom discourses during the PD's lessons.

The PD program's two main basis points were problem-oriented curriculum processing and the systematic use of classroom discourses. Kónya and Kovács (2021) characterized the problem-oriented approach to learning mathematics by three attributes: (1) students analyze mathematical problem situations; (2) students critically adapt their own and their classmates' thinking; (3) students learn to explain and justify their thinking. This approach is very close to the idea of Roh's definition of problem-based learning: it describes a learning environment in mathematics, where problems drive learning (Roh, 2003).

Cirillo et al. (2014) believe that mathematics classrooms' discursive nature impacts students' identities as mathematical knowers and doers. Leatham et al. (2015) hypothesize that high cognitive demand tasks support the emergence of mathematically significant moments as possible starting points of mathematical discourses in the classroom. However, teachers' and students' proper reactions are

crucial. Whether the active knowledge construction takes place in a discourse is decided by the teacher's reaction. Sfard (2003) points out "a productive mathematical discussion (...) turns out to be an extremely demanding and intricate task. The role of discussion coordinator is particularly difficult" (p. 375). Teachers tend to teach and make decisions by routine (Shavelson & Stern, 1981), and it is challenging to change this routine. One of the PD's aims was to break the teacher-centered pattern among practiced teachers and create more complex and precious whole-class discussions.

Therefore, this paper concentrates on two aspects: firstly, the possible starting points of classroom discussion generated by students' thoughts identified by Leatham et al.'s (2015) framework. The second focus is the teacher's reactions to these, analyzed by Sohmer et al.'s (2008) framework. With these tools, our research question is: *How does a problem-oriented professional development with additional focus on classroom discourses impact an experienced teacher's lessons with teacher-centered instructional habits?*

Theoretical frameworks applied for the analysis

A student's action is characterized as a *Mathematically significant pedagogical Opportunity to build on Students Thinking* (MOST) moment when it fulfills six criteria built on each other – each represented by a question (C1...C6) (Leatham et al., 2015), see Figure 1. "In their analytic process, the unit of analysis is an instance (...) Typically an idea unit is one conversational turn or physical expression (such as writing a solution on the board)" (Leatham et al., 2015, p. 92).

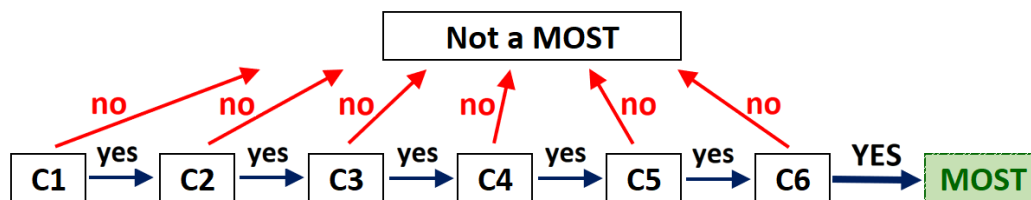


Figure 1: The MOST Analytic Framework

This framework was used to identify MOST moments in the videotaped and transcribed lessons. To find these moments, one should examine each student's utterances with six questions. These questions are built on each other, starting from the very basic point: whether the student's utterance contains understandable mathematical thoughts or not (C1, C2), then examining whether it is accessible for the students (C3) or whether it is the central goal of the lesson (C4). The fifth criteria (C5) can be described by the following question: Does the expression of the student mathematics seem to create an intellectual need (called opening) that, if met, will contribute to understanding the mathematical point of the instance? These expressions can classify into one of the following five groups: (a) a correct answer with novel reasoning, (b) an incorrect answer that involves a common or mathematically rich misconception, (c) a mathematical contradiction, (d) incomplete or incorrect reasoning, (e) why or generalizing questions. The sixth criterium (C6) is about the timing, whether it is worth taking advantage of the student's opening. Later, these criteria will be presented through an example.

Identifying MOST moments provide a quantitative description of a lesson, which can inform about the active and meaningful participation of the students. However, this framework does not provide information about the quality of the teacher's reactions. Therefore, the authors added Sohmer et al.'s

(2008) framework to analyze the teacher's reactions to the MOST moments. This framework seems to provide supportive information to assist teachers in making in-the-moment decisions about whether or how to react to those MOST moments. The authors found the combination of these two frameworks highly fruitful.

Researchers try to identify how some types of teacher interaction influence the following student's utterances to support teachers in activating students more effectively (Dahl et al., 2019). Sohmer et al. (2008) identified talk move as

a turn at talk that (1) responds to what has gone before; (2) adds to the ongoing discourse; and (3) anticipates or 'sets up' what will come next. A talk move is inextricably tied to the context. It reaches beyond a single turn (p. 107).

They studied teachers who have been effective in using talk to promote learning. Six moves were identified that can be useful to model and to elicit academically productive talk: (1) revoicing students' utterances, (2) asking to restate someone else's reasoning, (3) asking students to apply their reasoning to someone else's reasoning, (4) prompting students for further participation, (5) asking students to explicate their reasoning and provide evidence, and (6) challenging or providing a counterexample.

The professional development program

The analysis of this research concentrates on a teacher with 20 years of experience in teaching mathematics. She joined the PD program voluntarily, out of an inner urge to renew her practice. The researchers visited her before the PD, observed her class, and discussed the teacher's professional view as a starting point. She used to prefer a teacher-centered way of teaching: explaining the new material, driving the students with direct questions, and rarely initiating open classroom discussions.

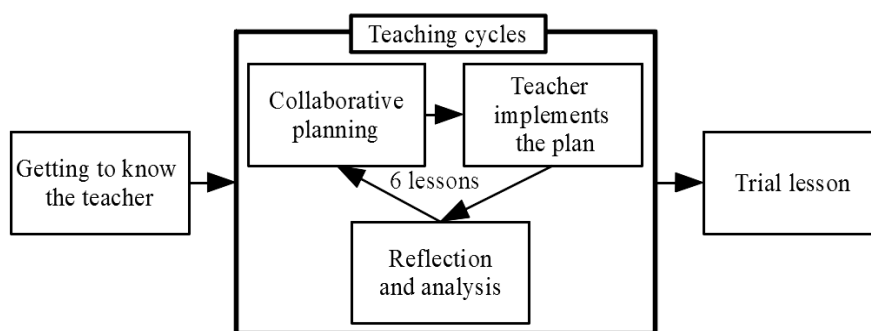


Figure 2: Scheme of the PD-program

In an opening workshop, the researchers explained the design of the program and the principles based on work by Varga (1988). The most important of them were the followings:

1. Problem-solving both alone and in pairs or small groups.
2. Improving students' oral and written communication skills encourage independent opinions.
3. Let students learn through experience and using heuristic strategies.

4. The teacher's role should include encouraging group discussions, planning classroom discussions, and implementing students' proposals into the flow of the lesson.
5. Differentiation and individualized treatment for each student.

After selecting the pilot lessons from the teachers' agenda, the researchers developed detailed lesson plans and provided all the teaching materials. These lesson plans explicitly contained reminders and advice on how to realize the principles of the PD. For example, there were time slots devoted to classroom discussions after solving a problem in small groups.

The teachers gave their opinions and suggestions and finalized the lesson plans. The teacher needed to feel that the lesson plan suited her at the end of the collaborative planning. At the end of the lessons, the teacher should reflect on it both alone and accompanied by the researchers.

The researchers organized six teaching cycles (three per semester during one year of the experiment) and concluded the year-long program with one trial lesson (Figure 2). During the planning for the trial lesson, the teacher had to come up with her own lesson plan.

The whole research process and focus are summarized in Figure 3.

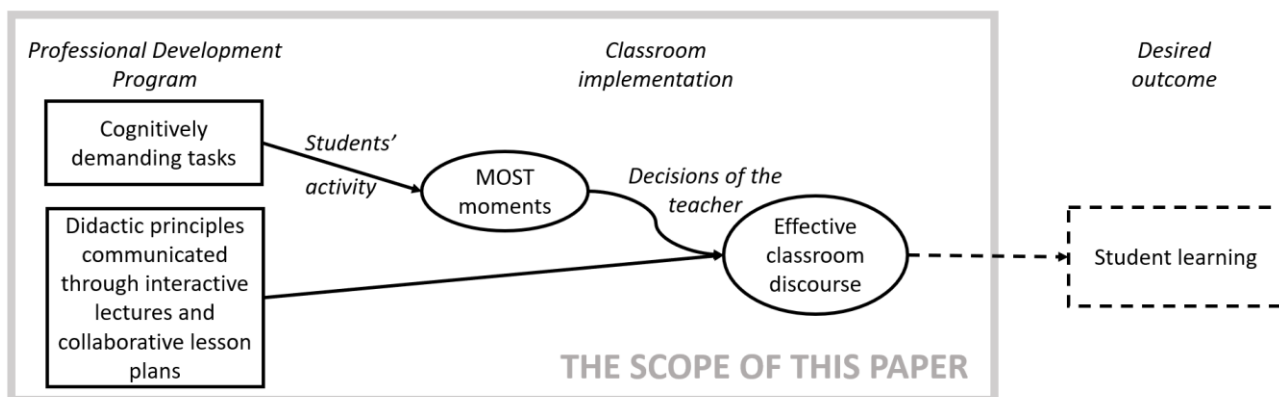


Figure 3: Scheme of the research

The process of analysis

Each 45-minutes lesson was videotaped and transcribed. Two researchers analyzed the transcripts independently and looked for moments where all the six MOST criteria appeared. In a disagreement, the three authors' consensus fixed the MOST moments. The transcripts of each lesson were investigated in the same way:

1. The authors separated those parts of the lesson in which the whole class discussion occurred and identified each observable student utterance according to Leatham et al. (2015).
2. All of these instances were coded according to the six MOST criteria.
3. Further distinctions between the MOST units were made according to the situation that caused it (see criterion C5) and assigned one of the above codes a, ..., e to each unit.
4. After gathering the MOST moments, the authors examined the teacher's response to these MOST moments in a new analysis process according to Sohmer et al.'s (2009) framework. Three categories emerge A) The teacher evaluates the student's action and tells the correct

answer if it was incorrect. B) The teacher starts a classroom discussion. C) The teacher does not notice the MOST moment.

5. Case B was further refined, determining the occurred talk move. In line with the work of Sohmer et al. (2009), the authors used the following codes: the teacher B1) revoicing the student's utterance, or the teacher asks a student for B2) restating someone else's reasoning, B3) commenting on someone else's reasoning, B4) further participating, B5) providing evidence or B6) providing counterexample. The traditional Initiation–Response–Evaluation pattern (IRE) completes the code system as B7.

We illustrate our coding system with an example.

Example - Class 9, fourth pilot lesson

Topic: Divisibility

Episode: Whole class discussion after finding all divisors of 54 in pair work. (Time: 35:49-36:16)

Student: Can I write them as products? (He writes on the blackboard $1 \cdot 54, 2 \cdot 27$)
Teacher: [Please use] semicolon...
Student: (He corrects and writes $1 \cdot 54; 2 \cdot 27; 3 \cdot 18; 6 \cdot 9$)
Teacher: How did you know you had to finish here?

This activity is considered as mathematical problem instead of routine task because the student has to define the procedure itself. The teacher does not present the solution as usual, but it appears as the students' activity, as he uses the structure of products to identify all divisors of 54.

The two student manifestations were considered a single action because the teacher's interruption is mathematically insignificant. However, this interruption demonstrates the teacher's accustomed state of controlling everything. The authors classified this student action as a MOST moment because it meets the C1-C6 criteria:

C1. The student is concentrating on mathematical ideas and not offtopic themes.

C2. The mathematical point of the instance is to determine all divisors of a number and decompose it into two-factor products in all possible ways.

C3. The mathematical point is accessible to all students, but at that point not all students realized it as a helpful tool for the task.

C4. A deep understanding of the above procedure is one of the lesson's goals.

C5. A deeper analysis of the fifth criterion shows that this is the case (d), i.e., incomplete reasoning, as the student wrote the products in a logical order but did not verbalize the reason behind it.

C6. Finally, the timing is considered appropriate as all students were paying attention, and there were still nearly 10 minutes left in the lesson.

The teacher recognized the MOST moment and asked the student to provide evidence, i.e., to explain why the presented procedure is appropriate for finding all the divisors. Therefore, the authors coded the teacher action responding to the MOST moment as B5.

Findings and analysis

The emergence of MOST moments

The analysis found numerous MOST scenes that have emerged applying the problem-oriented lesson plans, which were considered satisfactory from the researchers' point of view (Table 1).

Table 1: The emergence of MOST moments

MOST category	a) Novel reasoning	b) Incorrect answer	c) Mathematical contradiction	d) Incorrect reasoning	e) "Why" question	Total
Occurrence during the 7 lessons	13	22	0	16	2	53

Most of the MOST situations in this research emerged from students' incorrect answers (42%), and "MOST" situations based on the student's novel approach or the student's "why" questions were less frequent while mathematical contradictions did not appear.

Teacher's reactions on MOST moments

The teacher identified the MOST scenes effectively (Table 2). The authors attribute this success to the teacher's 20 years of practice, in addition to the influence of the PD. Leatham et al. (2015) also support this view implicitly, as they stated that novice teachers could miss realizing when a MOST scene has developed more often.

Furthermore, 64% of the identified MOST moments do not end with a simple teacher evaluation but lead to a "talk move." The authors consider this to be the result of the PD's approach, as the teacher was aware of the importance of classroom discourse, which she almost neglected in her previous teaching practice.

Therefore, the PD's result is considered to be the realization of the importance of the MOST moments and the use of the appropriate talk moves in the teacher's reactions. In conclusion, the teacher started using the learner's initiative to guide the lesson.

Table 2: Teacher's reactions on MOST moments

MOST category	A (evaluation)	B (talk move)	C (unnoticed)	Total
Occurrence	18	32	3	53

The subtle structure of "talk move" reactions

The dominant "talk move" reaction was that the teacher involved others in the conversation (B4, 20 out of 32 talk moves, 62.5%), see Table 3. Thus, B4 has become an almost permanent behavior, especially in the case of novel reasoning by the students. However, the teacher has also used it when a more detailed explanation of the student's own thinking, i.e., elaboration (B5), would have also been adequate. Moreover, since the problem-based approach requires the learner to think critically about

his/her thinking, encouraging this elaborative behavior would also have been part of the problem-based learning approach.

Table 3: The subtle structure of "talk move" reactions

MOST category	B1 revoicing	B4 participate	B5 elaboration	B6 counterexample	B7 IRE	Total
a) Novel reasoning	0	7	0	0	0	7
b) Incorrect answer	1	5	3	2	2	13
d) Incorrect reasoning	0	7	3	1	0	11
e) "Why" question	0	1	0	0	0	1
Total	1	20	6	3	2	32

Conclusions and pedagogical implications

During the PD's lessons, when the teacher got support from training, lesson plans, and collaborative lesson planning, numerous MOST moments mainly emerged from students' incorrect answers or incorrect reasoning. Furthermore, the teacher identified MOST scenes effectively. Most of them do not end with a simple teacher evaluation but lead to a talk move, supporting students' activity. Based on one previously observed lesson and the discussion on her professional view of teaching before the PD, the authors believe that this is the result of the PD's approach. Although further research is needed to prove this finding.

Based on the above result, the authors conclude that the PD is probably suitable to improve the amount and the quality of classroom discourse in an experienced teacher's lessons. It would be worth examining lessons after the PD to explore more about the PD's long-term effect.

It is worth to highlight that identifying mathematically valuable moments is insufficient. Teachers must also be aware of the importance of MOST moments and consciously apply potential talk moves. However, we still know little about how the implementation of talk moves unfold and what is needed to enable teachers to apply them effectively in practice. In connection with it, this paper also argues that the two joined frameworks were beneficial to examine how the demanding mathematics gets leveraged into productive discourse.

Acknowledgment

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