Teaching Science Effectively: A Case Study on Student Verbal Engagement in Classroom Dialogue[1]

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Abstract: The present case study illustrates a teacher who participated in a one-year, video-based, teacher professional development (TPD) program on classroom dialogue. This study expands the field of research on TPD by presenting the longitudinal results of Laura's teaching performance, her students' engagement in classroom dialogue, and their higher order learning perceptions. Additionally, a reflection of her participation in the TPD provides more insights into the role of TPD programs for individual teacher learning. Results revealed that Laura constantly changed her questioning and feedback behavior in terms of providing her students with more questions that foster elaboration of knowledge and feedback, which scaffolds students' learning processes. As a consequence, more students in Laura's classroom elaborated on their knowledge, which was reflected by a positive change in student higher order learning perceptions. Her reflection showed that the video tool and a mindful facilitation of the TPD program were of great value for Laura's positive learning experience.

Keywords: classroom dialogue, students' higher order learning, teacher professional development, video, case study

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1 Classroom dialogue: An effective tool to teach science?

Classroom dialogue is the predominant interaction pattern in many science classrooms (Seidel & Prenzel, 2006). However, several studies report tight communication structures in the classroom, where teachers ask narrow-focused questions and students can only provide short answers instead of rich scientific argumentations in a dialogic setting (Hugener et al., 2009; Jurik, Gröschner, & Seidel, 2013; Osborne et al., 2013). This interaction pattern places students at a risk of not being provided learning opportunities that allow the acquisition of knowledge and deep understanding (Alexander, 2005) and that awake young people's interest in a career in science, technology, engineering, and mathematics (STEM), which is in demand (OECD, 2007).

Therefore, it seems important to learn more about the elements that create a meaningful learning opportunity in classroom dialogue as well as to train teachers

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in implementing such purposeful elements in their teaching. From a research perspective, it is highly relevant to empirically examine how teachers realize their gained knowledge about productive classroom dialogue and what students' engagement in those classrooms look like.

The present case study examines the classroom of a science teacher who took part in a newly designed video-based teacher professional development program (*Dialogic Video Cycle*; DVC) (Gröschner, Seidel, Kiemer, & Pehmer, 2015). As previous results revealed that teachers in the DVC changed their performance on feedback and questioning behavior (Pehmer, Gröschner, & Seidel, 2015a), this case study provides more descriptive data regarding the central aspects of productive classroom dialogue (Chin, 2006). We examine a teacher's case who in individual analysis revealed the most significant changes regarding both questioning and feedback. We describe the case in a quantitative way by following the teacher's performance changes and the development of her students' contributions and their higher order learning perceptions throughout the duration of the DVC. This detailed case description aims to expand the field of case studies in terms of presenting a longitudinal development of performance data in connection with students' learning perceptions after her participation in the DVC program on classroom dialogue. Additionally, an interview excerpt with the teacher – whose pseudonym is "Laura" – provides support for the quantitative findings and illustrates her perception of the role of the DVC as an opportunity for professional learning. We asked the following research questions:

1. How does Laura's fostering (by means of questioning) and scaffolding (by means of feedback) of student contributions change throughout the DVC?
2. What "student talking types" can be found in Laura's classroom and how do they change throughout the DVC?
3. How do her students' perceptions of their situational learning processes and elaboration strategies change throughout the DVC?
4. What role does Laura attribute to the DVC as an opportunity for professional teacher learning?

2 Theoretical background

2.1 Productive classroom dialogue: A learning setting that fosters and scaffolds students' elaborations and higher order learning perceptions

There is a consensus in current education research that the teacher provides students with certain learning opportunities they can use, ideally with a maximum effect regarding construction of knowledge and learning outcome (Klieme & Rakoczy, 2008). In this context, there is ample evidence that classroom dialogue is a learning setting that can provide these opportunities (Furtak, 2006; Kovolainen & Kumpulainen, 2005; Mercer, 2008; Oliveira, 2010). Often classroom dialogue follows the routine of the initiation–response–follow-up (I-R-F) pattern (Cazden, 2001; Lemke, 1990), which typically starts with a teacher's question to initiate the conversation, a student responding to the teacher's question, and finally a follow-up by the teacher. Previous research found that the quality of the elements of the described conversation pattern is crucial and can be significantly influenced by the teacher (Chin, 2006; Mercer & Dawes, 2014).

Teachers' questions and feedback: Tools to frame student verbal engagement in science

There is a high demand for science teachers to create learning situations in which students can give explanations, come up with ideas, and present evidence (Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Osborne, 2010). One tool to do so is asking cognitively activating questions that challenge students to think profoundly and to use reasoning skills (Alexander, 2005; Lee & Kinzie, 2012; Wragg & Brown, 2001). Such questions prevent science from appearing to be a rigid body of knowledge (Duschl & Osborne, 2002) that can be correctly answered with one key word (Jurik et al., 2013; Mercer & Dawes, 2014). Oliveira (2010) states that questions that only allow students to give one correct key word come with students' expectations that in case of failure the teacher would provide them with the correct answer anyway. Also, students are triggered for reproducing knowledge instead of developing new ideas and concepts. She emphasizes the importance of questions to be open-ended with multiple answer possibilities, challenging to trigger students' further exploration and connecting to include students' prior knowledge (Oliveira, 2010). Thus, the quality of the question has an important function in classroom dialogue and influences how students are activated and get engaged in the conversation (Chin, 2006).

Besides teachers' questions – which foster students' verbal engagement in classroom dialogue – teacher feedback has been shown to be an important tool to scaffold students' contributions (Hattie, 2008; Hattie & Timperley, 2007). Although feedback is crucial for students' learning and motivation, studies have shown that it is rarely given but when present is often of low information content (Kluger & DeNisi, 1996; Voerman et al., 2012). In the context of "productive" classroom dialogue, it is therefore relevant whether feedback is provided and what level of feedback is included. Feedback has been shown to positively influence students' learning when it helps to restructure students' understanding by giving students hints, reinforcement, and strategies that guide students in a direction worthwhile pursuing (Hattie & Timperley, 2007). In their review, Hattie and Timperley (2007) distinguish between four different levels of feedback; these have been shown to be of different effectiveness regarding students' learning and achievement. In the present study, we focus on three of these (feedback about the task, the processing of the task, self-regulation) and not on feedback about the self.

Feedback about the task gives information on how well a student accomplished a task by differentiating wrong and right answers. It is claimed that this type of "corrective" feedback is most common because most teacher questions aim for students to give "right" or "wrong" answers. Problematic about this pattern is that students try to "pick the right answer" and equip themselves with the right strategy to achieve that aim. In comparison, *feedback about the processing of the task* concentrates on learning processes that need to be passed through to resolve a task. This type of feedback directs students in rethinking and reusing certain strategies or asking for concrete help. It can be seen as more "cueing" instead of "corrective" feedback and is more likely to enhance students' deep understanding of tasks. This type of feedback is seen as one important productive component of classroom dialogue. Harks and colleagues (2014) back this finding and found in the context of process-oriented feedback compared to feedback by a grade (which can be interpreted as "corrective" feedback) that process-oriented feedback was perceived to be more useful with an indirect effect on students' achievement. Another type of feedback is *feedback on self-regulation,* which promotes students' monitoring and regulation of the learning processes. It has shown to influence, for example, students' perceived autonomy and self-efficacy. In this context, van den Bergh and colleagues (2014) investigated whether primary school teachers' attitude toward feedback as well as their feedback behavior would change after a video-based intervention on feedback. Results showed that teachers provided more confirmative and metacognitive feedback to reinforce their students' learning. Additionally, teachers' reported finding less difficulty in giving feedback to activate their students' thinking. These findings provide another relevant hint that video-based working on a specific criterion of productive classroom discourse can change teachers' performance and attitudes.

The listed components of productive classroom dialogue that are relevant for students' learning and therefore should be considered for a fruitful conversational setting, independent of the content that is taught, are also highlighted by Walshaw and Anthony (2008). They integrate the aspect of student activation (e.g., through productive questioning) in their Activity 1 and the aspect of scaffolding students' ideas (e.g., through productive feedback) in Activity 2. In the present study, those two activities served as the basis for the conceptualization of the DVC (see Section 2.2) as both activities embed central components that are highly relevant for productive student engagement (e.g., through students' elaborations). In the present case study, we aim to provide insights to how Laura implemented her gained knowledge regarding activities 1 and 2 from the DVC into her individual teaching context.

Students' elaborations: An indicator for students' higher order learning in science

As stated previously, students' elaborations are a relevant indicator of productive science teaching (Duschl & Osborne, 2010) in general. In this context, the question is: When is a student response "productive" for gaining new knowledge and improving student learning? Educational researchers agree that knowledge is co-constructed by a community of learners (Mercer & Littleton, 2007; Osborne et al., 2013; Wells & Arauz, 2006), meaning that students are to be engaged in a dialogic learning situation where they can explore and justify ideas. Thus, it is relevant that students are involved in the dialogic learning setting, and furthermore, that they are facilitated with opportunities to elaborate their reasoning (Osborne et al., 2013) rather than just reproducing knowledge – an aspect that is especially requested in the current constructivist understanding of teaching and learning. It is argued that engaging in such argumentative and interactive discourse settings allows students to construct their own scientific knowledge by challenging their own thinking, which in the long run leads to a significant rise in students' conceptual understanding (Chi, 2009; Mercer, Wegerif, & Dawes, 1999; Resnick, Michaels, & O'Connor, 2010; Webb et al., 2014). Additionally, student reasoning highlights that students' understanding of science might diverge from the teacher's expert domain knowledge, wherefore it seems reasonable that teachers facilitate students' ideas rather than just transferring knowledge to their students (Waldrip, Prain, & Sellings, 2013).

Recent approaches in teacher professional development (TPD) aim to improve students' verbal engagement in classroom dialogue. In *Accountable Talk*, for example, teachers learn about concrete *talk moves* that actively engage and connect students in conversation (Michaels & O'Connor, 2012). In the *Cam Talk* program, Higham and colleagues (2014) worked with teachers to open up their classroom dialogue so students could co-construct knowledge. In both TPD programs, case studies were conducted that provided valuable qualitative excerpts of student contributions to classroom dialogue in individual teachers' classrooms (Michaels, O'Connor, & Resnick, 2008; Van de Pol & Elbers, 2013). With the present case, we expand the field of case studies by exploring the development of "student talking types" in Laura's classroom throughout her participation in the DVC. Previous research has focused on the teacher being the main talker in classroom dialogue (Howe & Abedin, 2013), but studies rarely investigate how many students are involved in classroom dialogue and if involved, how many are elaborating on their knowledge. The present case study addresses this research gap.

How classroom dialogue affects students' higher order learning: Students' perceptions of situational learning processes and cognitive elaboration strategies

Research on TPD has found that effective interventions should lead to changes in teaching (Desimone, 2009) that also address student learning (Fishman, Marx, Best, & Tal, 2003). In this context, we concentrate on performance changes of the teacher and students as well as on students' higher order learning perceptions. Higher order learning can be characterized by *situational learning processes* that focus on the question of how students perceive their learning in a current lesson and *cognitive elaboration strategies* that determine students' use of certain strategies to support their learning in a more habitual and constant way (Vermunt, 1996; Vermunt & Verloop, 2000).

Situational Learning Processes

A positive perception of situational learning processes is an important prior condition for student learning (Donovan & Bransford, 2005). In this context, the question is whether a student is able to follow and process the lesson (processing), activate and integrate knowledge (elaborating), and structure and organize the gained knowledge (organizing). The procedures of processing, elaborating, and organizing are basically characterized as the essential *situational* elements of higher order learning (Collins, Brown, & Newman, 1989; de Corte et al., 2003; Donovan & Bransford, 2005).

Cognitive Elaboration Strategies

Beyond situational learning processes, cognitive elaboration strategies are relevant for higher order learning (Weinstein & Mayer, 1986). Cognitive learning strategies, of which elaboration strategies are a part, are assumed to be more enduring (Vermunt, 1996) and are intentionally used by learners (Zimmerman & Martinez-Pons, 1990). In the context of productive classroom dialogue in which students are verbally challenged to offer explanations and evidence (Duschl & Osborne, 2002), *cognitive elaboration strategies* are regarded as students' intentional use of strategies to connect existing knowledge to previous knowledge and using knowledge in a new context (Weinstein & Mayer, 1986).

Both facets of higher order learning are particularly relevant for deeper student understanding of learning content (Donovan & Bransford, 2005). In a previous study on the DVC, results of a pre–post comparison revealed that the whole sample of teachers participating in the DVC improved the productivity of classroom dialogue (compared to a control group), which was positively expressed by students' higher order learning (Pehmer, Gröschner, & Seidel, 2015b). In the present study, we provide more fine-grained analysis of Laura's classroom dialogue (questions, feedback, and student contributions on a speaker-turn basis) during four measuring points (instead of only pre–post analysis) and connect the findings to students' higher order learning perceptions. Based on the feasibility check of the previous study, which was conducted with a high inference rating (Pehmer et al., 2015b), it can be assumed that teachers' questions that foster students' elaboration of knowledge might positively influence their process of *elaborating* as well as their cognitive elaboration strategies on an enduring level. Due to its cuing character, which encourages students to think deeper and structure their learning (Hattie & Timperley, 2007), it can be expected that feedback on students' learning processes and self-regulation positively addresses the crucial situational learning procedures of *processing* and *organizing*. The case study, therefore, connects individual teacher performance with students' perceptions in the same classroom – a connection that is rare in case analysis and might provide informing insights for teacher educators (Grossman, 2005).

2.2 Designing an effective teacher professional development program on productive classroom dialogue in science

Components of effective teacher professional development

The demand to improve young peoples' willingness to choose careers in STEM comes with the need to enhance classroom dialogue to give students opportunities to develop a deeper understanding of STEM material and have a positive learning experience. Therefore, we aimed to develop an effective TPD program that would have an impact on classroom dialogue and as a consequence on students' higher order learning. In the conceptualization of the program, we considered evidence from previous research on effective TPD programs by implementing Desimone's (2009) components. Teachers in the program should have the opportunity to actively improve their practical knowledge and experience opportunities to apply concrete classroom dialogue activities to their daily teaching practice. We explicitly addressed effective components, such as reflecting upon their own practices related to classroom dialogue in a close community of learners (Gröschner et al., 2015). Research has shown that changes in teacher learning are more likely if teachers recognize improvement in their students' learning resulting from their newly implemented practices (Opfer, Pedder, & Lavicza, 2011).

Video is a promising tool for stimulating teacher reflection and change because purposeful excerpts can show a rich pool of (new) teaching techniques and help teachers understand their students' thinking by watching their colleagues' videos (Sherin & Han, 2004). In this context, a trustful community of learners forms an important basis for an appreciative but critical exchange about the presented video material (Gröschner et al., 2015; van Es, 2012). Video provides a connection to teachers' daily routines and opportunities for active and collaborative learning, both important aspects of a successful TPD program (Opfer et al., 2011). Video allows teachers to watch themselves from a third-person perspective without being in an active situation in a complex classroom setting. In addition, it provides a promising source of teaching examples (Tripp & Rich, 2012) and has been proven to be effective (e.g., Borko, Jacobs, Eiteljorg, & Pittman, 2008; Santagata, 2009; Sherin & van Es, 2009) for a TPD program.

With the fourth research question, this study aims to provide some insight into Laura's learning experience in the DVC by presenting an excerpt of a final video interview in which she was asked to reflect on the participation in the DVC. With this third source of data material, we intend to complete a more comprehensive picture of how TPD affects an individual teacher and learn more about how TPD is perceived individually (Buczynski & Hansen, 2010).

The Dialogic Video Cycle

Laura, the selected teacher case, participated in a TPD program with two iterations of the DVC, each cycle including three workshops and one lesson that was videotaped. The central topic of the year-long intervention was "productive classroom dialogue." As mentioned, Walshaw and Anthony's (2008) activities 1 and 2 served as the basis for each cycle. In Workshop 1, teachers received input on productive classroom dialogue from a facilitator and learned about the importance of activating students to engage in learning processes. Elements they learned, for example, were how to provide room for students' elaborations, make learning goals transparent, ask cognitive activating questions, and connect new information to students' previous knowledge. These elements were expected to activate and scaffold students' higher order learning. After the theoretical input, teachers were asked to adapt concrete techniques for student activation and scaffolding for a lesson plan each of them had provided. Next, teachers were videotaped by the research team while teaching the lesson they had revised in the first workshop. The facilitator chose video excerpts based on the criteria for productive classroom dialogue and therefore the elements teachers had worked on during the Workshop 1 in the DVC. These clips were used as a basis for the teacher reflections in workshops 2 and 3 (Gröschner, Seidel, Pehmer, & Kiemer, 2014).

Workshop 2 of each cycle concentrated on *student activation and clarifying discourse participation rights*, while Workshop 3 focused on *scaffolding student ideas and feedback*. In both workshops, teachers participating watched selected clips, posed questions about productive classroom dialogue, and jointly reflected on their experiences. In Workshop 2, teachers reflected on teaching routines that motivate students to engage in the learning process, while Workshop 3 focused instead on ways to scaffold students' learning. Here, teachers reflected, for example, on the importance of student elaborations to their statements and cognitively demanding questions as well as on making learning goals clear. Guiding questions were posed by the facilitator to support the teachers' reflections (in the case of Laura, e.g., "Which strategies of the teacher to promote student activation are discernible in the video clip?").

The second iteration of the DVC followed the same course of action, differing slightly with regard to Workshop 1 having more opportunities for transfer during Cycle 2, as teachers were more familiar with the concept of the DVC and the applicability of its elements in their classroom. The facilitator had to give more guidance for video-based reflection in Workshop 2 during the first cycle as teachers were just being introduced to working with video. Less planning elements for future lessons in Workshop 3 took place during the second cycle as this was the final workshop of the whole TPD program (for detailed implementation findings regarding DVC 1 and DVC 2, see Gröschner et al., 2015).

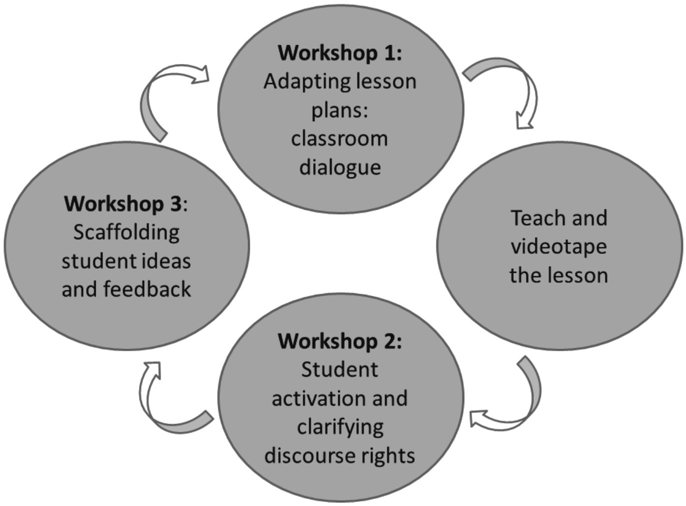

Figure 1 Dialogic Video Cycle

3 Methodology

3.1 Longitudinal mixed-method design

The DVC took place in the school year 2011/12. Its impact on teachers' classroom practice and therefore Laura's case was examined by analyzing both quantitative and qualitative data sources (see Figure 2).

Research question 1:
All participating teachers' lessons were videotaped at the beginning (pre) and end (post) of the school year along with the lessons they prepared in the course of the two DVC iterations (DVC 1 and DVC 2). Laura's case was extracted from the cohort of six teachers (for detailed case extraction and context description see Section 3.2).

All video codings related to teacher classroom practices were determined by five independent raters using the software Videograph (Rimmele, 2002). The raters were trained using video material that came from the same study but was excluded from the final data analysis. To examine changes in teachers' classroom practice, the video material was first subdivided into speaker turns (i.e., teacher, student, and no speaker) based on the event-sampling method (Bakeman, 1997).

To answer research question 1, teachers' talking turns were first coded in terms of whether the teacher was providing feedback or asking a question, independent of the instance's level. Subsequently, each teacher question was coded in relation to its level of fostering, and each teacher feedback was coded based on its level of scaffolding. The used low-inference coding systems were developed by applying

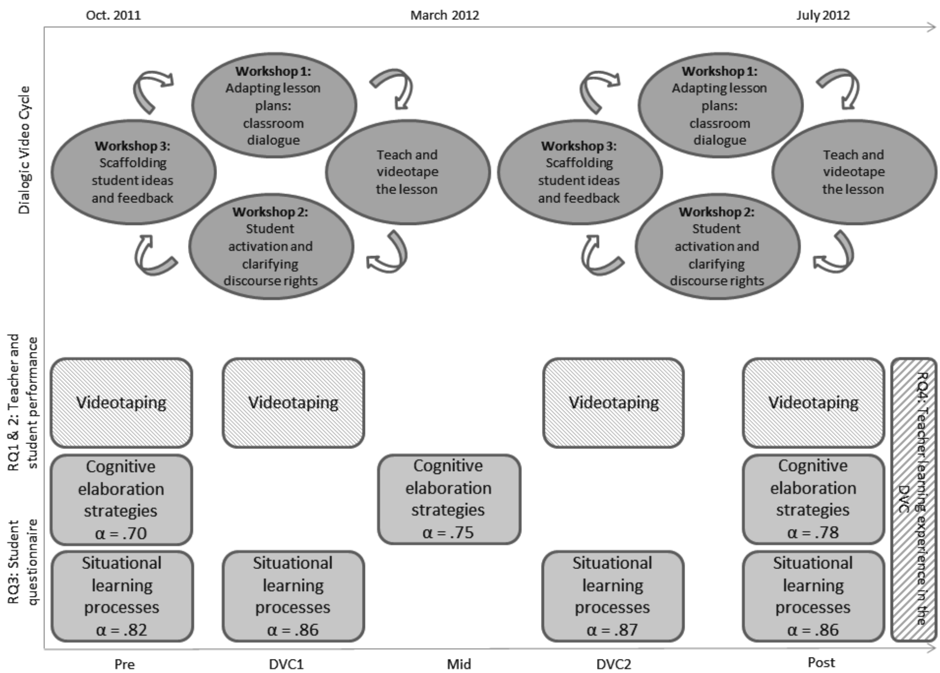

Figure 2 Design

disjunct categories (see Table 1) based on previous video studies (Seidel et al., 2003) and the literature review, which allowed for the analysis of elements of productive classroom discourse as they related to teachers' questioning and feedback (Pehmer, Kiemer, & Gröschner, 2014). The described procedure of coding pre-set talking turns according to the levels of the questions, answers, and feedback allowed for the quantification of a qualitative video analysis (Schümer, 1999). Because the study focused particularly on classroom dialogue, only talking units in whole-group classroom dialogue were considered in our analysis. Both kappa and direct consensus calculations reached satisfactory levels and are presented in Table 1.

Research question 2:
Besides teacher talking turns, each instance of student talking was coded regarding the level of students' answers (see Table 1). Additionally, each student talking turn was coded with a given number on the seating plan; this enabled a summation of the duration of each individual student for each measurement point. In a final step, each student was then categorized according to his or her "talking type," and the class composition of "talking types" was calculated for each measurement point as follows:

- *Non talking:* 0 seconds of talking
- *Only reproducing:* Aggregated duration only included reproduction of knowledge

- *Mainly reproducing:* Aggregated duration mainly included reproduction of knowledge
- *Mainly elaborating:* Aggregated duration mainly included elaboration of knowledge
- *Only elaborating:* Aggregated duration only included elaboration of knowledge

Research question 3:
For the third research question, students were questioned regarding their situational learning perceptions via a questionnaire directly after each videotaped lesson. Cognitive elaboration strategies were also measured by a questionnaire after the videotaped pre- and post-lesson as well as in the middle of the school year (mid). Due to the small sample size (28 students) nonparametric Friedman tests were applied to examine significant changes.

The following scales were applied; reliability is based on the whole student sample of a previous study (Pehmer et al., 2015b):

Situational learning processes
Students were asked about their situational learning processes during instruction directly after a lesson with their teacher. The instrument included 14 items and had a four-point Likert scale format (Seidel, Prenzel, & Kobarg, 2005). The scale comprised items reflecting basic processing ("I was able to follow the lesson the whole time"), elaborating ("I had a lot of ideas concerning the topic"), and organizing ("I was aware what was more or less important"), and had good reliability at all measurement points (α = .82−.87).

Cognitive elaboration strategies
To examine more stable and enduring aspects of higher order learning, students were asked what kind of cognitive elaboration strategies they applied during instructions. The cognitive elaboration strategy scale included five items (e.g., "I try to understand new things better by connecting them to things I already know") that were rated on a four-point Likert scale (Ramm et al., 2006), the reliability of which was satisfactory (α = .70−.78).

Research question 4:
In addition to Laura's practice changes and her students' development of higher order learning perceptions, how Laura had experienced the DVC as a professional learning opportunity was of interest. Laura conducted a short video interview on her learning experience at the end of the study; the interview clip was transcribed and qualitatively interpreted.

Table 1 Overview of video-codings and inter-rater reliability

Element of TPD program	Unit of analysis*	Categories	Example	Cohen's Kappa**	Direct consensus [%]
Preliminary work					
Speaker turn	–	– teacher – student – no one/other			98.1***
Classroom setting	T & S	– classroom dialogue**** – group/partner/single student work			85.7***
Activity 1					
I: Productive initiation: Cognitive level of question	T (frequency)	– No question		.79	89.7
		– Fostering of reproduction of knowledge	"How is this box called?"		
		– Fostering of elaboration of knowledge	"How can you manage to increase the picture on the screen?" "What is the explanation for your finding?"		
R: Productive response: Cognitive level of answer	S (duration)	– Reproduction of knowledge	"Power source"	.68	79.9
		– Elaboration of knowledge	"I think, that when I add cold water to warm water, the warmer body delivers warmth to the colder body"		

Element of TPD program	Unit of analysis*	Categories	Example	Cohen's Kappa**	Direct consensus [%]
Activity 2					
F: Productive response: Level of feedback	T (frequency)	– No feedback		.68	82.2
		– Feedback on task	"Yes", "No", "Right", "Wrong"		
		– Feedback on learning processes	"Think again, what do the results of the experiment tell us."		
		– Feedback on self-regulation	"I know that in the test you will be able to manage the task."		

* T = Teacher statement; S = Student statement.
** 784 units of analysis.
*** Only direct consensus can be reported because each rater set up own speaker turns to validate whether all raters would agree on the same amount of talking units in a video; for Kappa calculations video material with pre-set speaker turns by one person is needed.
**** Only elements of setting "classroom dialogue" are included in the analysis.

3.2 Case extraction and context description

Based on the described codings regarding teacher talking turns, Laura's case was extracted from a cohort of six teachers taking part in the DVC due to her showing a positive pre–post change regarding the level of questions and feedback in her classroom (Pehmer et al., 2015a).

Laura is 33-years old, has two years of in-service teaching experience, reportedly has experience with video-based reflection, and teaches physics (in the German context, science teachers are explicitly qualified for physics, chemistry, or biology as distinct subjects) and math in a lower secondary school (*Realschule*) within the tracked German system. For the study she participated with her ninth grade physics class of 28 students who were 15.25 years old (*SD* = .93) and 75% male. In the year before her participation in the study, she attended four hours of TPD.

Teachers participating in the DVC could freely choose the curriculum-based lesson content they wanted to teach as the DVC was not addressing a certain science topic but the activities of student activation and scaffolding of student ideas as components of productive classroom dialogue. Table 2 gives an overview of Laura's lessons for the four measurement points.

Table 2 Lesson context

MP	Topic	Lesson goals
Pre	**Volume changes** – Bullet and containers as examples: Influence of temperature on 3-dimensional enlargement	– Students develop formula for volume changes
DVC1	**Mixing temperature** – Student-centered experiment: Mixing coffee and milk and measuring temperature	– Students develop formula for mixing temperature – Students explain differences between results from experiment and calculations – Students know the energy flow from the warmer to the colder body
DVC2	**Electric current** – Example from everyday life: Policeman counting traffic flow as an example to visualize current flow	– Students are able to define electric current – Students notice physical variables that influence electric current
Post	**Electric tension** – Comparison of electric flow and water flow	– Students are able to explain the difference between electric current and electric tension – Students know how to measure electric tension

4 Results

4.1 Development of Laura's fostering and scaffolding of student contributions

In terms of teacher behavior, Laura showed a constant increase regarding both her fostering and scaffolding behavior. Regarding research question 1 (see Figure 3), results revealed that Laura entered the study with 34% of her questions fostering students' elaboration of knowledge. Throughout her participation, she constantly improved her questioning behavior (DVC 1 41%; DVC 2 48%) up to 65% of her questions fostering students' elaborations.

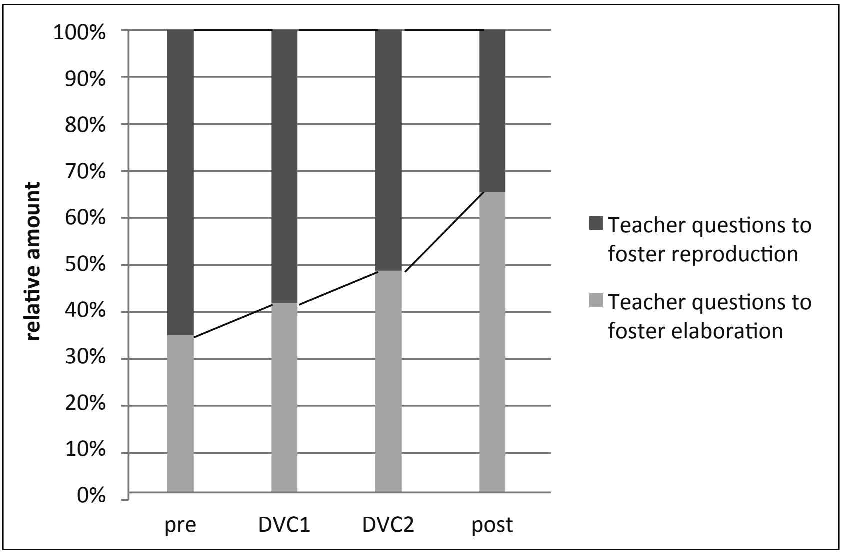

Figure 3 Fostering of student contributions in Laura's classroom

Regarding scaffolding of students' contributions, she initially gave 5% feedback on students' learning processes. During the school year, she changed her scaffolding by providing her students with 13% (DVC 1), 12% (DVC 2), and 16% (post) feedback on their learning processes. The level of feedback on self-regulation slightly changed during the DVC, starting with a relative frequency of 17% up to 21% (DVC 1), 22% (DVC 2), and 22% post.

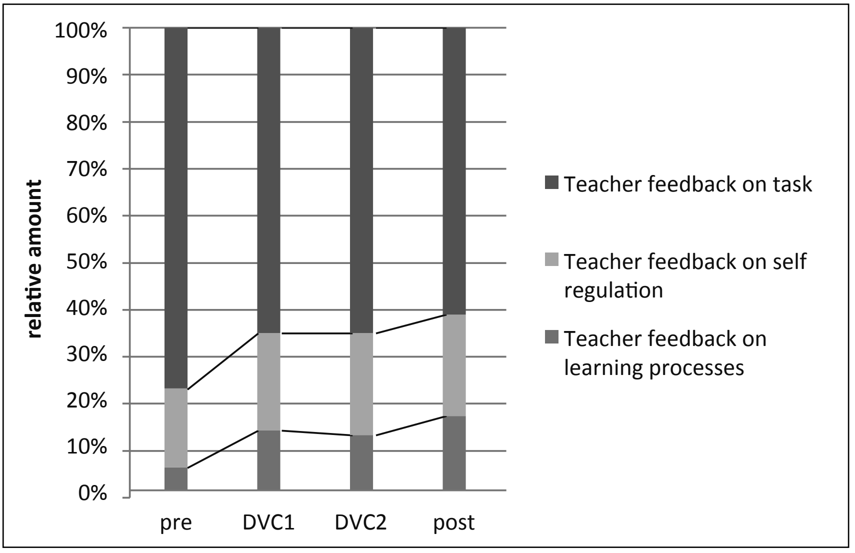

Figure 4 Scaffolding of student contributions in Laura's classroom

4.2 Development of student "talking types" in Laura's classroom

Whereas for research question 1, results revealed a constant positive development; during the first half of the academic year, composition of student talking type was comparable and no development from pre to DVC 1 could be shown. As illustrated in Figure 5, results of research question 2 showed that when entering the study, 15% of Laura's students were not talking during the videotaped lesson; 41% were only and 15% mainly reproducing knowledge; and 19% were mainly and 11% only elaborating on their knowledge. During DVC 1, the talking type composition of Laura's classroom was similar with again more than half of students either not talking (29%) or only reproducing knowledge (29%); 14% of students were mainly reproducing knowledge and 14% mainly and 14% only elaborating knowledge.

In comparison, the second iteration of the DVC revealed a changed talking type composition. During DVC 2, non-talkers (8%) and only reproducing knowledge (27%) declined to one-third of students, which is in parallel with half of Laura's students mainly (46%) or only elaborating knowledge (4%). Post measurement showed – in comparison to the beginning of the study – improvement in terms of 27% of students mainly and 12% only elaborating knowledge. At the end of the study, 23% of students remained non-talking and 23% only and 15% mainly reproducing knowledge.

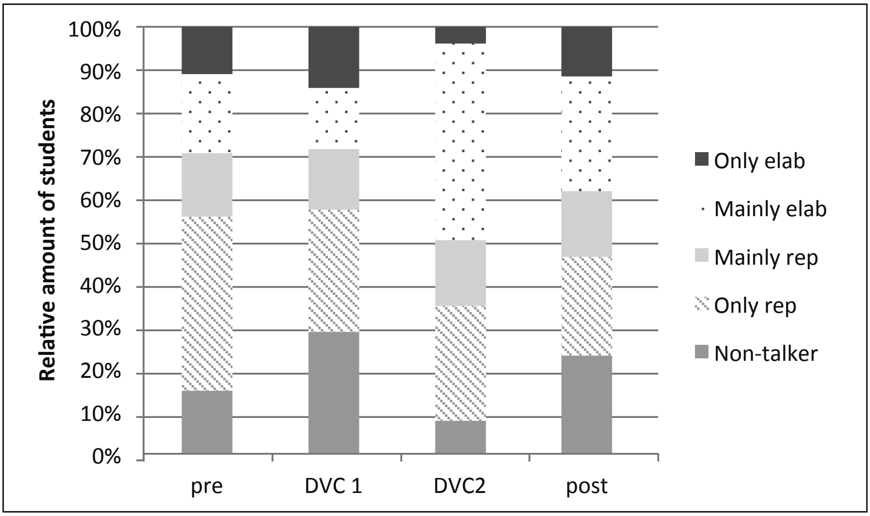

Figure 5 Development of student talking type composition in Laura's classroom dialogue

4.3 Development of Laura's students' higher order learning perceptions

Results of the third research question partly mirrored composition of student talking types. The examination of students' higher order learning perceptions showed that students reported their situational learning processes more positively during DVC 1 (*M* = 2.03, *SD* = .45) and highest during DVC 2 (*M* = 2.11, *SD* = .47). These were the les-

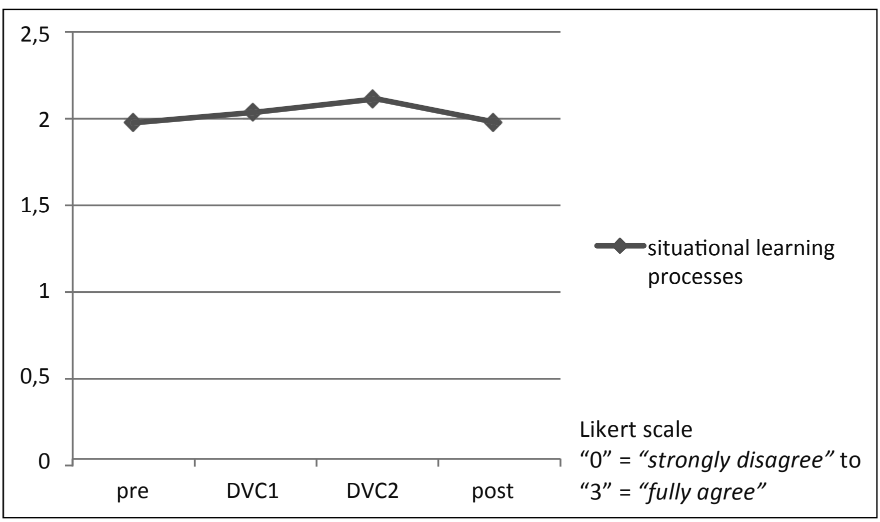

Figure 6 Development of students' perceptions of situational learning processes

sons teachers had planned collectively and for which DVC 2 showed more productive talking type compositions with more students elaborating on their knowledge. At post-test, students perceived their situational learning processes on the same level as at the beginning of the study (*M* = 1.97, *SD* = .59). The Friedman test did not reveal a significant effect (x^2 (3, 17) = 3.88, *n.s.*) and neither did post-hoc tests.

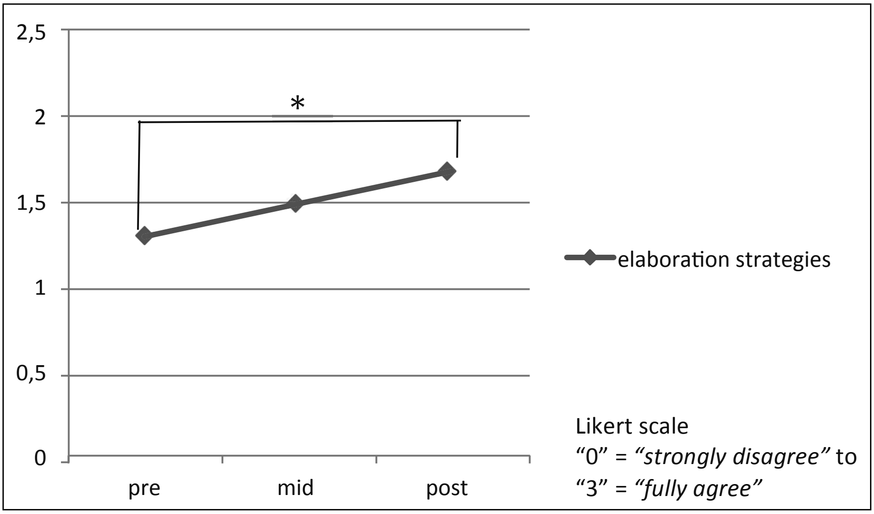

Figure 7 Development of students' perceptions of cognitive elaboration strategies

Regarding students' cognitive elaboration strategies, students showed a constant positive change throughout the intervention (M_{Pre} = 1.29, *SD* = .58; M_{Mid} = 1.48, SD = .54; M_{Post} = 1.67, *SD* = .49). An overall effect (x^2 (2, 23) = 14.28, *p* = .00) could be shown for the stable facet of higher order learning, which, based on the post-hoc testing, was due to the increase from pre to post. The more enduring cognitive elaboration strategies seemed to positively stabilize throughout the DVC.

4.4 Laura's learning experience in the DVC

In a final short video interview in which Laura was asked to talk about her learning experience in the DVC, she responded as follows:

> I would definitely participate again. I think it was great because by watching oneself and getting feedback one learned a lot, especially student activation and giving praise. And I remember this in several situations, especially with the younger ones [her younger classes]. […] The atmosphere in the group was good. There was not a single moment where I thought I'd rather say nothing. All of the colleagues were really fair and constructively critical, if even. Often I judged my teaching much worse and thought "Oh my God" [puts hands on her head] but they [the other participants] found aspects I was doing well. That was phenomenal […]. Also the amount of meetings was good. And it was facilitated in a great way, really kind of a family atmosphere.

In her statement, Laura appreciated working with the video tool because it gave her the chance to watch herself; also video stimulated her to think about her teaching where she experienced herself to be the most critical teacher. Video also allowed her to open her classroom to the rest of the group who highlighted her teaching strengths. In the given excerpt, she also mentioned the aspects of student activation (e.g., questioning) and praise (e.g., as a form of feedback on self-regulation) and that she learned a lot about those components. She also provided insight that the aspects she learned were not only relevant for the class she was participating with in the DVC but also for other classes she teaches as she could transfer her newly gained knowledge. At the end of the excerpt, she referred to the duration of the TPD and that this was appropriate for her. She also emphasized how important the mindful facilitation (Gröschner et al., 2014) was for her learning experience in the DVC.

5 Discussion

The present study illustrated the case of a science teacher who participated in a video-based TPD program on classroom dialogue. Our aim was to illustrate a teacher who successfully changed her questioning and feedback behavior in a previous pre–post comparison (Pehmer et al., 2015a). Therefore, we examined in a first research question how Laura's questioning and feedback behavior would develop throughout the participation in the DVC (all four measurement points) (research question 1). In research question 2, the change in student talking types in terms of elaboration of knowledge was explored. Research question 3 examined how Laura's students would perceive their situational learning processes and cognitive elaboration strategies differently throughout their teacher's participation in the DVC. To summarize the case study, we examined in research question 4, how Laura experienced her learning in the DVC.

The quantitative exploration of Laura's performance development aimed to expand the field of mainly qualitative case study research. Also the connection of individual teacher and student performance with student learning perceptions is rare in this context. For a rather "holistic" picture, Laura's learning experiences in the DVC were examined, and thus this study helps to better understand how TPD affects individual classrooms (teacher and students) to generate knowledge, not least for teacher educators and prospective research (Grossman, 2005).

Results regarding Laura's performance development revealed constant changes in her questioning and feedback behavior. Throughout the participation over the period of an academic year, Laura constantly worked on the productivity of classroom dialogue with regard to components she, as a teacher, could influence decisively. She entered the study with a third of her questions fostering student elaboration and almost no feedback on students' learning processes. Her questioning changed to a level of two-thirds of her questions fostering her students to elaborate on their knowledge at the end of the academic year. Analysis of the composition of student talking types in her classroom showed that changes on the students' side needed longer establishment as no changes occurred during the first iteration of the DVC but improvement was seen in DVC 2 and a slight decrease for the post-measurement point; essentially a higher level of student elaborations occurred compared to the beginning of the study. During the lesson in DVC 2 that teachers had collectively planned, half of the students elaborated on their knowledge in classroom dialogue. The fact that many students were elaborating on their knowledge in classroom dialogue during DVC 2 is also reflected by students' perceived situational learning processes, which were most positive during DVC 2. Regarding cognitive elaboration strategies, students reported an increase throughout the school year and perceived them as reasonably higher at the end of the study. The qualitative analysis of her interview showed that video was a fruitful learning tool for Laura because it encouraged critical self-reflection but also opened her classroom to other colleagues who highlighted her teaching strengths. She particularly highlighted the duration and facilitation of the DVC, two components that were carefully considered when designing the DVC (Gröschner et al., 2015).

The attempt of a systematic, multiperspective case description provided further important knowledge regarding the impact of TPD on individual teaching contexts. It is known that TPD is practiced in very different contexts (Vescio et al., 2008) due to teachers implementing their gained knowledge in their individual teaching setting (Pennings et al., 2014). Buczynski and Hansen (2010) report that it was individually challenging for teachers to implement aspects they had learned in the TPD program. With the present case, we illustrated a teacher who successfully implemented two central components she had learned – questions that foster student elaborations and feedback that scaffolds students' contributions. At the beginning of the study, Laura's questioning behavior supports previous results regarding German classroom dialogue; these are often tight interaction patterns with questions that trigger students to reproduce knowledge and to serve as key word givers rather than equal conversational partners (Hugener et al., 2009; Jurik et al., 2013; Lipowsky et al., 2009). Working with teachers on classroom dialogue that underlies routine and establishment (Morton, 2012) is challenging because new teaching techniques are required to overcome given patterns. Throughout the participation in the DVC, Laura managed to break this tight interaction routine by opening her questioning in terms of fostering her students to elaborate on their knowledge. Her changing routines constantly improved, whereas student talking types followed a slightly different route. Throughout the TPD, students in Laura's classroom tended to elaborate more on their knowledge, which was at its peak during DVC 2. The peak can be explained by Laura's chance to reflect on her teaching in the first DV cycle and apply this to her teaching during the second iteration of the DVC. In addition, teachers were already familiar with the concept of collective lesson planning, which can be interpreted as another supportive factor (Desimone, 2009) for a more productive classroom dialogue in terms of students' elaborations during DVC 2. For the last videotaped lesson, there was no collective planning, which might have caused less productivity in students' contributions, although still more productivity in Laura's fostering and scaffolding. Teacher questioning and feedback are facets of classroom discourse that are directly influenced by the teacher and therefore, with regard to our findings, might underlie a more constant development manner. As a consequence Laura's students contributed to classroom dialogue in a more elaborative way throughout the study but not in the exact same development curve. The importance of teachers' questions as triggers for students' answers (Alexander, 2005; Lee & Kinzie, 2012; Wragg & Brown, 2001) and feedback as an important scaffolding tool (Hattie & Timperley, 2007) are emphasized in the research literature. Additionally, the importance of establishing a certain communication culture in terms of participation rights and responsibilities is highlighted (Walshaw & Anthony, 2008). In this context, students' talking type composition needed the first half of the academic year as establishment time and showed a slight variation during the second half.

This development is also mirrored by students' reported perceptions. There is ample evidence that elaborating and arguing knowledge is essential for the development of students' understanding (e.g., Webb et al., 2014) and positive learning perceptions (Pehmer et al., 2015b). The examination of Laura's students' learning perceptions showed that at DVC 2, where half of her students' were elaborating on their knowledge, students reported their situational learning perceptions the highest. At the end of the school year, slightly fewer students in Laura's classroom elaborated, which is also expressed in students' situational learning perceptions. They reported their situational learning perceptions to be on the same level as when entering the study. The DVC, therefore, helped the teacher to prevent students from showing decreases of positive learning perceptions in science, which are of concern in educational research (Häussler & Hoffmann, 2000; Sjøberg, 2002). Students' cognitive elaboration strategies developed positively throughout the school year. Laura's case confirms previous findings that students' perceptions of situational learning processes are, as expected from their designation, dependent on momentary learning environments (de Corte et al., 2003; Donovan & Bransford, 2005). Cognitive elaboration strategies are more stable (Vermunt, 1996), and several positive learning experiences are needed for students to become manifest in their positive perceptions of learning strategies. The increase in the post-test can be explained by positive situational learning perceptions during DVC 2 that positively influenced students' cognitive elaboration strategies in the long run.

Laura's case furthermore showed that efforts in TPD can be successful, a fact that is not given per se, particularly when teacher performance and student learning outcomes are addressed. Vescio and colleagues (2008) stated in their review of studies on the effectiveness of TPD that well-developed programs have a positive impact on teaching practice and student outcomes. In this context, the DVC was carefully designed with regard to providing teachers with options for active learning and reflection in a community of learners who worked together for an entire school year (Gröschner et al., 2015). From TPD research in Germany, it is known that teachers often visit single workshops that are not necessarily connected to daily teaching routines (Richter et al., 2011). Laura especially appreciated working with video in a trustworthy community of learners with a professional facilitator (Gröschner et al., 2014). This learning environment can only be created if TPD takes place over a certain period of time (van Es et al., 2014). With regard to the duration of the TPD program (in total 22 hrs.), Laura emphasized that the number of meetings was appropriate. These insights into her learning experience help to further press efforts of TPD conceptualization in the direction of designing programs that take place over a longer period of time in a constant learning community. In her case, the DVC, as an effective TPD program approach (Gröschner et al., 2015), could lead to positive performance changes, changes to student higher order learning perceptions, and a positive learning experience for herself.

Besides positive changes, her case analysis also delivered results that helped to further improve the DVC and its elements. In future TPD efforts, teachers need to obtain better awareness about the rather proximal teacher talking elements, like questioning and feedback which teachers can directly influence by changing their own behavior, which serve as important triggers for student engagement in classroom dialogue. Additionally, teachers need to develop an awareness of establishing a productive participation culture, which means breaking routines and introducing students to discourse structures they might not be familiar with from other lesson contexts. For example, one problem regarding her communication culture that Laura could not solve was the non-talking students in classroom dialogue. The topic of non-talkers and also the question of how a large number of students can be activated in classroom dialogue need to be addressed in future DV cycles. Future research could, therefore, investigate the frequency of student activation and balance of different students engaging in classroom dialogue as the current study does not reveal results on individual engagement and learning perception changes. In a future project, we aim to follow Howe and Abedin's (2013) assertion for more knowledge on the value of certain dialogic settings, and the topic of non-talkers will be a focus in the DVC, which will address the choice of dialogic settings as one important tool to engage all students in the conversation. Also the question of individual student engagement in different dialogic setting will be examined as the current study is limited to engagement in whole group discussions. The present results cannot provide a conclusion about Laura's timing of different levels of questions and feedback, which is highlighted as an acknowledgeable aspect by Hattie and Timperley (2008). In future research, this will be addressed in the DVC program, which will train teachers in becoming facilitators of classroom dialogue who are aware of the timing and function of different types of feedback and questions. Finally, a benefit and limitation at the same time is the fact that we chose a teacher who successfully implemented components of the TPD in her classroom. As stated at the beginning, classrooms are complex individual settings and teachers are confronted with different conditions that might allow for easier or more difficult implementation of gained knowledge from TPD (Buczynski & Hansen, 2009). The question is therefore, how a successful change in dialogic teaching could be transferred to other classrooms – with a different group of students and their individual pre-requisites. More empirical evidence is therefore needed that addresses how TPD can be successfully conceptualized to lead to performance changes as well as positive student learning outcomes, including in other domains of knowledge and beliefs.

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