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Effects of a classroom discourse intervention on teachers' practice and students' motivation to learn mathematics and science

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ABSTRACT

Student interest and motivation in STEM subjects has dropped significantly throughout secondary education, for which teacher–student interactions are named as a central reason. This study investigated whether a video-based teacher professional development (TPD) intervention on productive classroom discourse improved students' learning motivation and interest development over the course of a school year. The teachers' intervention group (IG; $n = 6$) was compared with a control group (CG; $n = 4$) who participated in a traditional TPD programme on classroom discourse. The teachers showed a significant increase in constructive feedback and decrease in simple feedback as a function of the treatment. Pre- and post-tests revealed that students in the IG ($n = 136$) significantly increased their perceived autonomy, competence and intrinsic learning motivation as compared with those in the CG ($n = 90$). They also showed significantly greater interest changes in the subjects compared with their peers in the CG.

1. Introduction

Motivational concepts such as interest in the subject are important outcomes of educational processes (Krapp & Prenzel, 2011) and are key elements regarding the young generations' preparedness for life-long learning as a core-skill in knowledge-based societies. Motivation and interest development, especially in science, technology, engineering and mathematic (STEM) subjects, also determine adolescents' willingness to choose STEM-related career paths (Organisation for Economic Co-operation and Development, 2007).

Therefore, developing students' interest has to be a main educational objective for schools as well as individual teachers. Interested learners develop more differentiated domain-specific knowledge (Renninger, Hidi, & Krapp, 1992), are more focused and have better attention (Ainley, Hidi, & Berndorff, 2002), pursue mastery rather than performance goals (Harackiewicz, Durik, Barron, & Linnenbrink, 2008) and receive better grades than uninterested learners (Schiefele, Krapp, & Winteler, 1992). However, interest in the subjects decreases significantly throughout secondary education (Eccles et al., 1993; Maulana, Opdenakker, & den Brok, submitted for publication). One reason frequently cited for this decrease is the mismatch between students' needs and classroom practices, especially during secondary education (Eccles et al., 1993).

For positive outcomes of motivated learning, it is the quality of motivation that is decisive (Ryan & Deci, 2000). Interest-based, self-determined forms of learning motivation provide the most favourable learning outcomes (Krapp, 2002; Krapp & Ryan, 2002). Yet, classroom interactions are often dominated by close-formatted classroom discourse (Jurik, Gröschner, & Seidel, 2013; Walshaw & Anthony, 2008; Wells & Arauz, 2006), with negative effects both on students' situational experiences of self-determined learning motivation and their long-term development of more stable orientations (e.g. interest in STEM subjects).

Despite debates about enriching teaching through diverse didactical methods, classroom discourse and verbal teacher–student interactions remain dominant in mathematics and science education (Roth et al., 2006). Typical for practices of classroom discourse is a questioning-developing teaching style in which the teacher dominantly steers the interactions. However, if teachers can actively engage their students in classroom discourse, they are likely to engage them in more meaningful and sustained learning experiences (Walshaw & Anthony, 2008). Therefore, changing

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students' classroom experiences into meaningful ones that develop their interests by changing the prominent routines of classroom interactions and discourse is important. Productive classroom discourse is a key aspect for students' development of interest in the subject.

To improve productive classroom discourse, video examples of classroom interactions are a promising tool for supporting teachers' analysis and reflection on classroom practices and interaction patterns (Tripp & Rich, 2012). Using video in TPD facilitates teachers' (emotional) involvement and makes them more invested in the learning process by activating prior knowledge, building practical knowledge and bridging the theory–practice gap (Santagata & Guarino, 2010).

1.1. Theoretical background

This study focuses on a video-based teacher professional development (TPD) intervention to foster teachers' skills leading to productive classroom discourse, which is compared with traditional TPD in the German context. We investigated the extent to which a newly developed intervention (Gröschner, Seidel, Kiemer, & Pehmer, 2014) positively affected teachers' practices as well as students' experiences of self-determined learning motivation and their development of interest in the subject. Thus, this study sheds light on the benefits of video-based TPD in comparison to more common practices of professional development in the German context (Richter, Kunter, Klusmann, Lüdtke, & Baumert, 2011), as well as on the importance of meaningful classroom discourse (specifically, teacher questioning and feedback) for students' situational and long-term motivational orientations.

1.1.1. Classroom discourse and the role of questioning and feedback

Verbal teacher–student and peer interactions are major means to construct meaning (Mercer, 2010; Oliveira, 2010; Webb, 2009). Language use and interaction quality have important implications for students' learning processes and outcomes (Lipowsky, Rakoczy, Pauli, Reusser, & Klieme, 2007), active engagement, learning motivation and interest (Sierens, Vansteenkiste, Goossens, Soenens, & Dochy, 2009).

Walshaw and Anthony (2008) differentiate two major teaching strategies in productive classroom discourse: *clarifying discourse participation rights and responsibilities between the teacher and students*, where the objective is to engage students in classroom conversation, and *scaffolding students' ideas, e.g. by giving individual feedback,* in a productive way to move thinking forward. Several studies on mathematical argumentation and science inquiry point out the relevance of these activities in creating productive classroom discourse (Furtak, Seidel, Iverson, & Briggs, 2012; Kovolainen & Kumpulainen, 2005). The two activities can particularly be conceptualised through productive forms of teacher questioning and meaningful feedback (Jurik, Gröschner, & Seidel, 2014).

Teacher questioning: Meaningful patterns of teacher questioning leave room for students to explore and express their own understanding. Generally, questioning strategies such as using open questions have been shown to support student motivation and engagement through verbal discourse (Jurik et al., 2014).

Teacher feedback: Teacher feedback is deemed supportive of learning and motivation, not just when it informs students about the correctness ('*yes*', '*right*') of a response, but especially when it includes information about what aspects of the response are correct ('*You did a good job on that graph*') or incorrect and how any flaws can be mended ('*Try concentrating more closely on the transfer of electrons*') or generally supports the learning process ('*No problem. We will get everyone to understand that concept today*') (Hattie & Timperley, 2007).

TPD programmes focussing on productive classroom discourse in STEM subjects are rare. By testing the effectiveness of an innovative TPD programme including its effects on students' motivation and interest (Desimone, 2009; Wilson, 2013), the present study breaks new ground in this line of research.

1.1.2. Classroom discourse and learning motivation

To investigate whether an innovative TPD programme focussing on productive classroom discourse can affect students' motivation to learn, we draw on self-determination theory (Deci & Ryan, 1985, 2004) and person–object theory of interest (Krapp, 2002; Krapp & Prenzel, 2011) to frame the importance of productive classroom discourse for students' learning motivation. Interest is defined as a person's repeated engagement or focused attention on an object, determined by a specific relationship between person and object and shaped by interactions and the environment (Krapp, 2000; Renninger & Hidi, 2011). In self-determination theory (SDT) it is important that students perceive fulfilment of their basic psychological needs during instruction. In this situation, they are more likely to experience self-determined, intrinsic-learning motivation, and over time, these experiences are closely connected with a positive development of interest in the subject (Krapp & Prenzel, 2011). Even though the potential for interest lies within the person, content and interaction define the development of situational and individual interests (Hidi & Renninger, 2006). Thus, significant others, the organisation of the environment and a person's inner motivational resources can support interest development (Renninger & Hidi, 2002; Sansone & Smith, 2000).

SDT proposes that a person's motivation depends on the fulfilment of three basic psychological needs: autonomy, competence and social relatedness. The fulfilment of these needs depends on a person's interpretation of the social context—whether the functional significance of a situation is controlling or informational (Ryan & Deci, 2002). Motivation is conceptualised as a situational construct dependent on a person's moment-to-moment experiences and the interpretation. By changing students' moment-to-moment classroom experiences, e.g. through productive classroom discourse, their need for autonomy, competence and social relatedness is repeatedly fulfilled, leading to self-determined-learning motivation. Thus, teachers can create repeated instances of triggered situational interest (Hidi & Renninger, 2006; Krapp, 2005; Renninger & Hidi, 2011) using teaching strategies that promote productive classroom discourse.

Grounded in the situational beneficial effects of productive classroom discourse on students' self-determined-learning motivation, we presume that prolonged positive experiences with basic psychological need support and the resulting motivational outcomes (intrinsic learning motivation) will crystallise in the more enduring motivational orientation of interest in the subject (Fig. 2). The TPD programme in this study aims at improving teachers' skills of creating productive classroom discourse, which should lead to positive changes in self-determined-learning motivation through repeated instances of basic need fulfilment and thus to positively developing students' interest in the subject.

In conceptualising a study design that measures students' situational experiences at multiple points in time as well as their overall development over the course of a school year, we aim to combine these two stances on students' learning motivation to shed more light on the importance of day-to-day classroom experiences and the learning environment for students' development of self-determined-learning motivation and interest in the subject. Furthermore, we investigate whether TPD programmes can help teachers counter students' decreases in learning motivation and interest throughout secondary school (Turner, Warzon, & Christensen, 2011).

1.1.3. The 'Dialogic Video-Cycle'—an innovative TPD programme targeting productive classroom discourse

Given the predominance of narrowly focused classroom discourse, supporting teachers to change their discourse behaviour is a palpable method of classroom reform. On the basis of the teaching cycle idea of *planning*, *teaching* and *reflecting* (Borko, Jacobs, Eiteljorg, & Pittman, 2008), Gröschner, Seidel, Kiemer, et al. (2014), Gröschner, Seidel, Pehmer, and Kiemer (2014) developed a video-based TPD intervention for redefining classroom discourse practices ('Dialogic Video-Cycle', DVC) and showed how to implement it successfully with mathematics and science teachers (Gröschner, Seidel, Kiemer, et al., 2014).

The intervention group teachers participated in two iterations of the DVC—a newly developed TPD programme adhering to effective components of TPD found in the literature (Desimone, 2009; van Veen, Zwart, & Meirink, 2012; Wilson, 2013). The DVC concentrates on generic aspects of classroom discourse as part of general pedagogical knowledge. It implements productive classroom discourse in the form of two main activities: *student activation and clarifying discourse rights* and *scaffolding student ideas and feedback* (Walshaw & Anthony, 2008). The DVC aims to change teachers' perspective towards student learning processes. Each cycle included three workshops and one lesson videotaping (Fig. 1). In the first workshop, teachers received input on productive classroom discourse by a facilitator, and together with the facilitator and in collaborative practice, they adapted existing lesson plans by taking concrete activities of productive classroom discourse (in accord with Walshaw & Anthony, 2008) into account (Gröschner, Seidel, Kiemer, et al., 2014). Next, they were videotaped by the research team while teaching the revised lesson. The facilitator chose video excerpts on the basis of the criteria of productive classroom discourse and prepared them as a basis for teacher reflection in workshops 2 and 3. Workshop 2 focused on *activity* 1 (*student activation*), and teachers exchanged ideas about the discursive roles of teachers and students and the ways in which students are engaged. Workshop 3 focused on *activity* 2 (*scaffolding student ideas*), and teachers exchanged ideas about how to take up student responses and elaborations (e.g. right/wrong answers, new ideas, misconceptions etc.) and give feedback. During the workshops, they watched selected clips, clarified questions about productive classroom discourse and jointly reflected on their experiences. The facilitator posed guiding questions (e.g. '*Which strategies does the teacher in the video clip use to promote student activation?*'); the group discussed what attracted their attention and gave feedback (including solutions and alternatives), or asked more questions. All discussions were chaired by the facilitator (Gröschner, Seidel, Pehmer, et al. 2014). The second iteration of the DVC followed the same course of action.

The DVC was implemented as a year-long TPD programme (two iterations) in 10 STEM classrooms with the aim to improve teachers' classroom discourse practices and their students' perceptions of motivation-enhancing learning environments. After ensuring the fidelity of implementation (Gröschner, Seidel, Kiemer, et al., 2014), in this paper, we explore the effects of the DVC on teachers' discourse practices (questioning and feedback behaviour) and students' self-determined learning motivation. The aim of the study is, therefore, to investigate in detail the DVC's effect on students' perception of basic psychological needs and self-determined learning motivation as well as the more enduring motivational characteristic of interest in the subject, compared with that in the traditional TPD format in Germany. Thus, we contribute to the research field by applying a longitudinal design, integrating situational student perceptions of the learning environment with long-term developments and fostering dialogue in STEM classrooms by taking into account both teachers' practice and students' perceptions.

1.2. Research questions

Four main questions were addressed:

(1) Do teachers' practices in the IG change towards more dialogic teaching (specifically questioning and feedback) in the course of the DVC, compared with teachers in a CG?

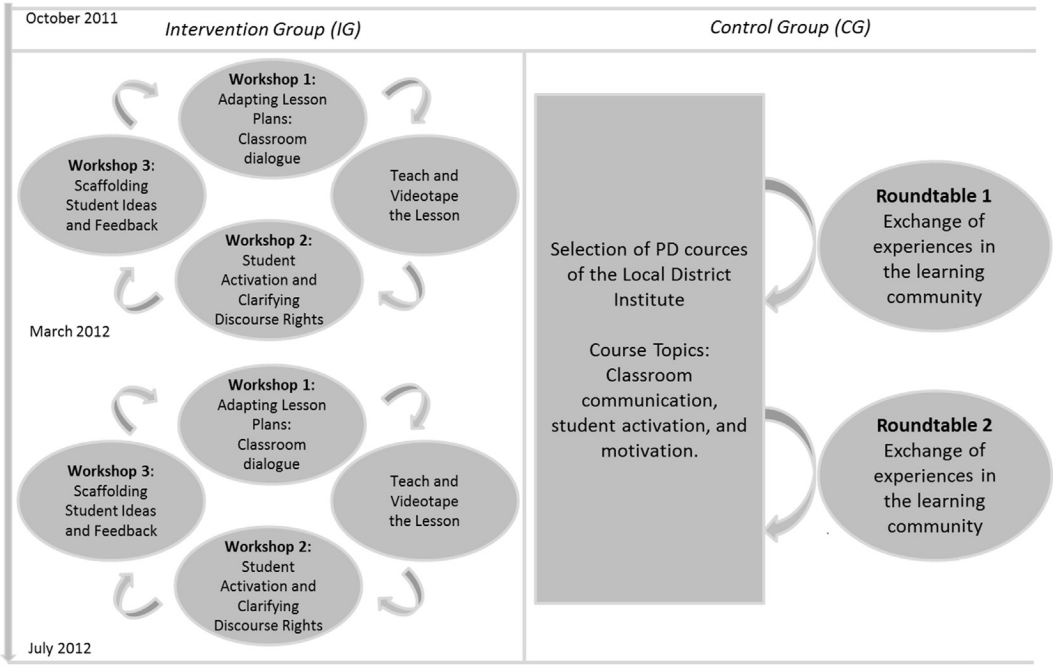

Fig. 1. Treatment conditions in DVC as intervention (left) and the traditional programme as control group (right).

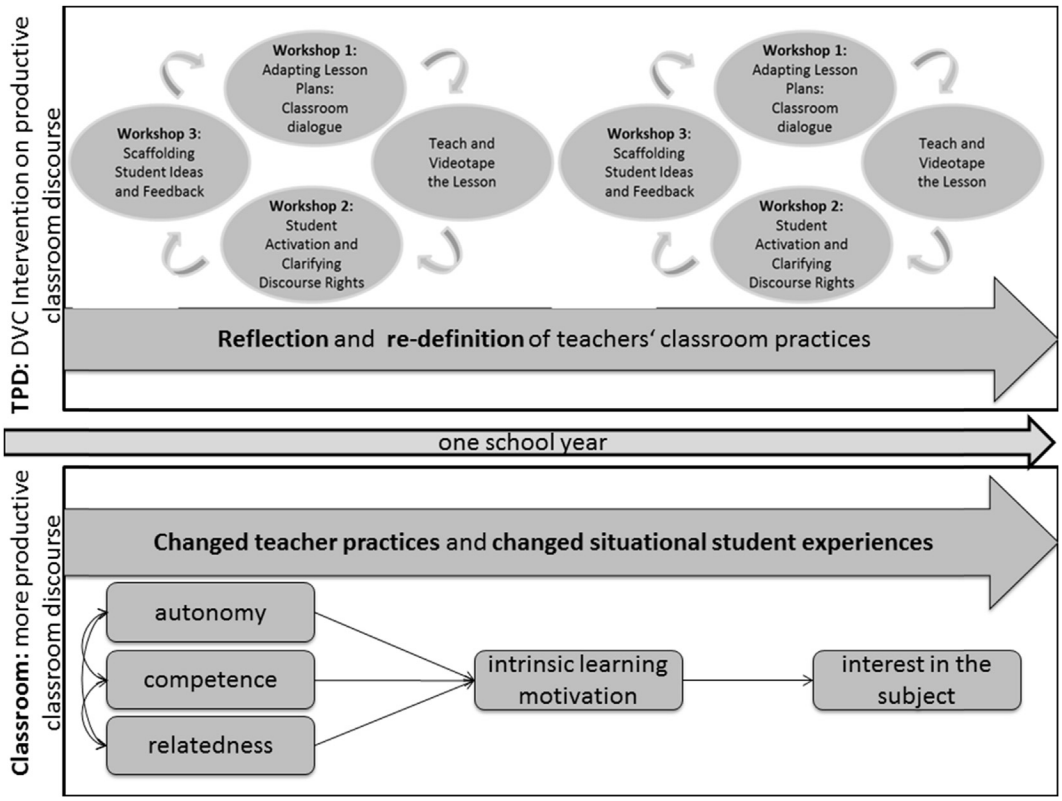

Fig. 2. Relationship between basic psychological needs, intrinsic learning motivation and motivational student orientation over time.

Hypothesis 1: Teachers in the IG will exhibit an increased number of open questions and constructive feedback (Hypothesis 1a) and a decreased number of closed questions and simple feedback in a pre–post comparison (Hypothesis 1b), compared with that for the CG teachers.

(2) Does a one-year DVC intervention show positive effects on students' development of interest in the subject (IG) compared with that for the CG?

Hypothesis 2: The students of teachers participating in the DVC will show a positive development of domain-specific interest at the end of the school year compared with the students of teachers in the CG.

(3) Are positive changes during the DVC intervention in the IG observed regarding
   a. students' perception of their teachers' support of their basic psychological needs?
   b. students' experience of self-determined-learning motivation?

Hypothesis 3: The video-based intervention will lead to positive changes in (a) students' perception of basic psychological needs support and (b) their experience of self-determined-learning motivation over the course of the year.

(4) Are the positive changes in interest in the subject at the end of the school year systematically related to changes in self-determined-learning motivation, which in turn is systematically related to a change in teachers' support of students' basic psychological needs?

Hypothesis 4: Repeated altered experiences with regard to basic psychological need perception (increased fulfilment of basic psychological needs) will lead to an increase in self-determined learning motivation. In turn, the repeated experience of self-determined learning motivation and situational interest will manifest in an increased dispositional domain-specific interest.

2. Method

2.1. Participants

The participants were 10 teachers and their 226 students (47.8% girls, 52.2% boys) in 10 science and math classrooms from German middle- or high-tracked schools. The students' mean age was 15.67 years ($SD = .98$); they were in 9th grade.

In the context of German TPD conditions, the teachers chose whether they wanted to participate in the video-based TPD programme (intervention group, IG) or programme with a set of workshops (control group, CG). They did not know which group served as the intervention and which was the control condition. This avoided having the teachers feel reluctant to participate in the video-based TPD programme or doubt the effectiveness of watching themselves (Fishman, Marx, Best, & Tal, 2003). Six teachers opted for the intervention (DVC), and four chose the traditional TPD programme. The two groups did not differ in age ($M = 38.3$, $SD = 5.56$, $U(6{:}4) = 7.5$, $z = -.97$, $p = .33$), teaching experience ($M = 5.65$, $SD = 2.93$, $U(6{:}4) = 6.0$, $z = -1.30$, $p = .20$) or gender, $\chi^2_{\text{gender}}(df = 1) = .08$, $p = .79$. Both groups showed comparative engagement (and time spent) in prior TPD programmes. They did not differ in their motivation ('*I want to learn more about communication in the classroom*', $M_{IG} = 3.51$, $SD = .47$; $M_{CG} = 3.81$, $SD = .38$; $U(6{:}4) = 7.0$, $z = -1.14$, $p = .25$) for the respective TPD programme

at the outset of the study or any of the other considered background variables such as basic need fulfilment and satisfaction with the programme (Gröschner, Seidel, Kiemer, et al., 2014). Video as a tool for reflection was only used in the IG.

Given their teachers' choices, there were 136 students in the IG and 90 students in the CG. The two groups differed regarding age, $t(224) = 5.20$, $p < .01$, $d = .71$ (IG: $M_{age} = 15.41$, $SD = .98$; CG: $M_{age} = 16.07$, $SD = .85$) and gender, $\chi^2_{gender}(df = 1) = 8.94$, $p < .01$ (IG: 39.7% girls; CG: 60.0% girls), for which reason both variables were accounted for as covariates during the data analysis.

2.2. Research design

Data were collected in a one-year longitudinal two-group-intervention design. Fidelity of implementation was tested and proven successful (Gröschner, Seidel, Kiemer, et al., 2014). The study ran during the school year 2011/2012. The two treatments included the same content (classroom discourse) and had the same duration (22 h). They differed with regard to relating TPD content to actual teaching practice by providing opportunities to reflect on changed practice in a community of learners.

Students in both groups were questioned regarding motivational orientations at the beginning (pre) and end (post) of the study. The IG students were also questioned directly after videotaping one lesson used for reflective purposes in the DVC (DVC 1, DVC 2). Videotaping took place at the beginning and at the end of the school year in both groups, and additionally, twice as part of the intervention (DVC 1, DVC 2) for the IG.

Dialogic Video-Cycle (IG): The IG teachers participated in a TPD programme with two iterations of the DVC (see Section 3.1). Each cycle included three workshops and one lesson videotaping (Fig. 1). In workshop 1, teachers focussed on revising a lesson plan by considering productive classroom dialogue elements and communication strategies. Workshop 2 focused on *student activation*, mainly targeted through teachers' questioning behaviour. *Scaffolding of students ideas*, the focus of workshop 3, was targeted especially through teacher feedback.

Advanced Traditional Programme (CG): The CG teachers chose a set of workshops with a focus on productive classroom discourse offered by the local TPD institute (Fig. 1). They met twice in roundtables (hosted by the same facilitator as in the IG) to share their TPD experiences. They were encouraged to share how they had experienced the central aspects of productive classroom discourse during their TPD and how they would apply their experience to teaching.

2.3. Instruments

All items were answered on a 4-point-Likert scale ranging from 0 = '*strongly disagree*' to 3 = '*fully agree*'.

2.3.1. Questionnaires

The scale for interest in the subject was used prior in the German context of PISA (Ramm et al., 2006) to assess situational perceptions in a national video study (Seidel, Prenzel, Duit, & Lehrke, 2003). Interest in the subject was assessed on the basis of a pre- and post-test. The four scales of perception of basic psychological need fulfilment and self-determined learning motivation were administered after the four videotaped lessons: pre-test, during DVC 1, during DVC 2 and post-test.

Interest in the subject: This scale consisted of five items ('*I am interested in mathematics/science*') and showed good reliability ($\alpha = .84$, $\alpha = .87$).

Basic psychological need fulfilment: Autonomy perceptions were assessed with eight items ('*During this class, I had the feeling that the teacher was open for different student answers*'), competence perceptions with seven items ('*During this class, I had the feeling that the teacher thought us capable of challenging exercises*') and social relatedness with six items ('*During this class, I felt like I was important to the teacher*'). All scales showed satisfactory to good reliability scores: autonomy $\alpha = .75–.82$, competence $\alpha = .71–.83$ and social relatedness $\alpha = .69–.85$.

Intrinsic learning motivation: This scale consisted of three items ('*This class was fun*') with reliability scores ranging from $\alpha = .75$ to .85.

2.4. Video analysis

Using the software *Videograph* (Rimmele, 2002), we analysed teacher–student interactions focussing on their quality of classroom discourse, specifically the facilitation of *activities* 1 (*student activation, characterised by questioning behaviour*) and 2 (*scaffolding of student ideas, characterised by feedback behaviour*) on the basis of the method by Walshaw and Anthony (2008). The video analysis employed event sampling, using speaker turns (teacher, student), as the unit of analysis ($\kappa = 1.0$). A coding system was adapted and developed by the research team (Pehmer, Kiemer, & Gröschner, 2014). All categories focused on discourse behaviour during whole class discussions (teacher questions and feedback). Five months of training preceded independent raters' scoring of the videos:

Teacher questioning: Independent raters classified each question as open ('*What do you think happens if we heat it up?*') or closed ('*Do we have any right angles here?*'). Inter-rater reliability in this category was $\kappa = .79$ (direct agreement: 89.7%).

Teacher feedback: Teachers' feedback was characterised as constructive ('*That's a good strategy; just try to focus more on the mechanism*') or simple ('*Nice job*'). The reliability between coders was $\kappa = .71$, and direct agreement (85.3%) was satisfactory (Landis & Koch, 1977).

2.5. Data analysis

Research Question 1: To answer the first research question, we performed a repeated measure non-parametric analysis of variance (Brunner, Domhof, & Langer, 2002) for the pre- and post-test comparisons, using treatment as the independent variable (IV) and behavioural indicators of teachers' productive classroom discourse as dependent variables (DV).

Research Question 2: A latent growth model, using treatment as predictor variable (dummy coded: IG = 1, CG = −1) over two measurement points (pre-to post-test) was created to account for the nested structure of the data (Duncan & Duncan, 2004; Geiser, 2011). Since only two measurement points (pre- and post-test for IG and CG) were taken into consideration, only a linear growth curve model could be applied. A test of covariance structure showed an autoregressive covariance structure of the first order to fit the data best ($\chi^2(df = 1) = -1.33$; $p < .01$). Age and sex were used as covariates, given the a priori differences in group composition (Shek & Ma, 2011).

Research Question 3: Given the nested data structure, growth curve models (linear, quadratic and cubic) over four measurement points within the IG were run again, both for support of basic psychological needs (perceived autonomy, competence and social relatedness) and intrinsic learning motivation. The information criteria (−2 log likelihood, *AIC*, *BIC*) in each case were smallest for the cubic models, and the χ^2-ratio tests between nested models showed that the cubic model provided a better fit than the more parsimonious counterparts for all variables. The best-fit covariance structure was provided by a first-order autoregressive structure (Shek & Ma, 2011).

Research Question 4: Bivariate correlational analyses between the delta values from pre- to post-test of all basic psychological needs and the delta value of intrinsic learning motivation, as well as interest in the subject, were run. Additionally, we conducted a path analysis modelling the predictive power of the change in perceived autonomy and competence for the change in intrinsic learning motivation and interest in the subject (Geiser, 2011).

3. Results

3.1. Teachers' changed practices

All reported results are relative counts of the respective subcategory in relation to the total in that category. Table 1 gives the descriptive statistics and non-parametric analyses of variance of the video analysis of teachers' questioning behaviour (*activity 1*) and feedback (*activity 2*) for both groups at both measurement points. For the IG teachers' questioning behaviour, the number of open questions increased and the number of closed questions decreased; yet this trend did not reach significance ($F_{open}(1) = .56$, n.s.; $F_{closed}(1) = .56$, n.s.). For their feedback behaviour, there was a significant increase in constructive feedback ($F(1) = 9.20$, $p < .01$) and a significant decrease in simple feedback ($F(1) = 9.36$, $p < .01$).

3.2. Effect on students' interest in the subject

A preliminary inspection of mean values ($M_{IG} = 1.48$, $SD = .67$; $M_{CG} = 1.33$, $SD = .66$) showed comparable scores between both groups at pre-test. Descriptive comparisons between the mean scores of the pre- and post-test show a slight increase in interest in the subject in the IG ($M_{post} = 1.55$, $SD = .75$) but a decrease in the CG ($M_{post} = 1.25$, $SD = .67$).

The unconditional linear growth model exhibited a significant intercept ($\beta = 10.76$, $SE = 1.89$, $p < .01$) suggesting that the level of interest was not constant over time, while the non-significant slope suggests a constant positive growth rate in the level of interest in the subject over time across both groups ($\beta = 3.04$, $SE = 2.70$, n.s.). The inter-class correlation for this model (ICC = .23) showed that 23% of the variation in interest scores is attributable to the inter-individual level. To account for group differences, the factor treatment was introduced into the model as a predictor variable. While treatment was not associated with the initial level of interest in the subjects ($\beta = -2.64$, $SE = 2.07$, $p =$ n.s.), it is a significant predictor of the linear growth rate in interest between the two groups ($\beta = 5.87$, $SE = 2.96$, $p = .05$). There was a differential positive development of interest in the subject in favour of the IG. A change in residual variance of 4.05 between the two models attributes 4.05% of the variation in interest scores to group membership.

Table 1
Descriptive statistics of teachers' questions and feedback.

		Pre-test				Post-test			
		M	*SD*	Mean rank	*RTE*	*M*	*SD*	Mean rank	*RTE*
Closed questions	IG	.59	.21	8.08	.38	.61	.18	12.13	.58
	CG	.75	.14	8.33	.39	.81	.07	15.75	.76
Open questions	IG	.40	.21	12.91	.62	.39	.17	12.67	.61
	CG	.23	.17	8.88	.42	.17	.09	5.25	.24
Simple feedback	IG	.79	.07	13.00	.63	.58	.14	5.08	.23
	CG	.71	.11	9.00	.43	.85	.10	16.38	.79
Constructive feedback	IG	.21	.07	8.00	.38	.39	.14	15.92	.77
	CG	.29	.11	12.00	.58	.15	.10	4.63	.21

Note. n(IG) = 6 teachers, n(CG) = 4 teachers; M = mean, SD = standard deviation; values are relative percentages; *RTE* = relative treatment effect.

3.3. Effects on changes in basic psychological need perceptions and self-determined-learning motivation in the DVC

In answer to research questions (3a) and (3b), we focussed on the IG and investigated trajectories in students' perceptions of their basic psychological need fulfilment and intrinsic learning motivation over four measurement points. Table 2 provides the descriptive statistics for these variables for all measurement points.

An inspection of the mean values of the variables across time suggests curvilinear trajectories. In all cases, curvilinear models fit the data best.

Autonomy perceptions: The cubic growth curve model shows better information criteria than its more parsimonious counterparts (*−2 log likelihood* = 697.88, *AIC* = 711.88, *BIC* = 741.03). A χ^2-ratio test supported the best fit to the data for this model ($\chi^2(df = 2) = -25.47$). The model intercept was significant ($\beta = 1.72$, $SE = .05$, $p < .01$), as was the estimate of the cubic growth ($\beta = 2.39$, $SE = .67$, $p = .01$). The ICC was .33.

Competence perceptions: As in the case of autonomy, the curvilinear growth model for competence had the best values in the information criteria (*−2 log likelihood* = 638.29, *AIC* = 652.29, *BIC* = 681.43). A χ^2-ratio test showed that it is superior to the simpler linear ($\chi^2(df = 2) = -15.19$) growth model. The model exhibited a positive significant estimate for intercept ($\beta = 1.98$, $SE = .04$, $p < .01$) and the cubic growth parameter ($\beta = 2.13$, $SE = .58$, $p < .01$). The ICC of the model was .42.

Social relatedness perceptions: For social relatedness, no significant growth trajectory from pre-to post-test could be found, yet the cubic model showed the best overall model fit (*−2 log likelihood* = 728.67, *AIC* = 742.67, *BIC* = 771.81, $\chi^2(df = 2) = -5.29$). It revealed a significantly positive linear growth between pre-test and DVC 1 ($\beta = .83$, $SE = .42$, $p = .05$). The non-significant trends for a negative quadratic growth ($\beta = -1.77$, $SE = 1.03$, $p = .09$) and a positive cubic growth (indicated by a β-estimate of .92; $p = .17$) showed that after increasing significantly from pre-test to DVC 1, students' perceptions of teachers' social relatedness support remained levelled. The ICC for this model was .36.

Intrinsic learning motivation: A cubic growth curve model provided the best fit to the data (*−2 log likelihood* = 974.19, *AIC* = 988.19, *BIC* = 1017.39, $\chi^2(df = 2) = -11.34$), producing a significant intercept ($\beta = 1.66$, $SE = .06$, $p < .01$) and cubic slope estimate ($\beta = 1.75$, $SE = .83$, $p = .04$). The ICC of the model was .55.

3.4. Student interest and its relation to changes in self-determined intrinsic learning motivation in the DVC

First, bivariate correlations for Δpre−post scores of basic psychological need support and intrinsic learning motivation, as well as interest in the subject were run for the IG. As Table 3 illustrates, the correlational analyses revealed systematic positive relationships between the changes from pre- to post-test for all situational motivational variables and students' interest in the subject, except for social relatedness. Only autonomy and competence were used

Table 2
Descriptive statistics for basic psychological needs and intrinsic learning motivation in the IG.

	Pre-test		DVC 1		DVC 2		Post-test	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Autonomy	1.74	.55	2.06	.52	1.88	.54	1.90	.57
Competence	2.02	.48	2.18	.52	2.02	.57	2.10	.59
Social relatedness	1.92	.53	2.04	.60	1.95	.51	1.91	.61
Intrinsic learning motivation	1.67	.73	1.91	.73	1.73	.74	1.71	.74

Note. $n = 136$ Students; 0 = '*strongly disagree*' to 3 = '*fully agree*'.

in the path analysis because social relatedness did not show significant pre–post changes in the growth curve models nor did it show significant bivariate correlations.

Overall, the model fits the data very well ($\chi^2(df = 2) = .82$, $p = .66$; RMSEA = .00, CFI = 1.0). As expected, the change in situational intrinsic learning motivation is significantly predicted by changes in perceived autonomy ($\beta = .27^{**}$, $SE = .09$) and experiences of competence ($\beta = .31^{**}$, $SE = .08$). Further, the change in situational intrinsic learning motivation is then predictive of the change in interest in the subject over the course of the intervention ($\beta = .48^{**}$, $SE = .08$). Changes in autonomy and competence experiences also have an additional indirect effect on the change in interest via intrinsic learning motivation ($\beta_{auton\_ind} = .13^{**}$, $SE = .05$; $\beta_{comp\_ind} = .12^{**}$, $SE = .04$). Fig. 3 depicts the model with β-weights. The model explained 21% of the changes in intrinsic learning motivation ($R^2 = .21$, $p < .01$) and 23% in interest in the subject ($R^2 = .23$, $p < .01$).

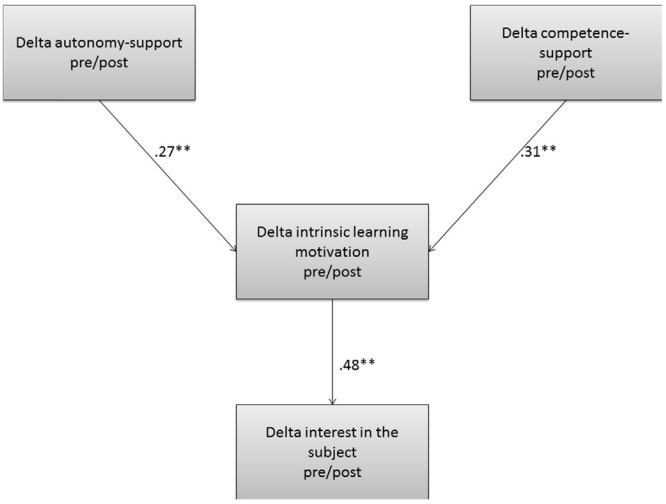

Fig. 3. Path model of changed basic psychological need fulfilment, intrinsic learning motivation and interest in the subject.

4. Discussion

This study investigated the extent to which a video-based TPD intervention targeting productive classroom discourse showed positive effects on teachers' practice and students' motivation to learn mathematics and science. Thus far, the majority of studies targeting productive classroom discourse have focussed on the co-construction of knowledge and achievement as outcome variables (Lipowsky et al., 2007) or qualitative analysis of classroom interactions (Michaels & O'Conner, 2012). Thus, this to our knowledge is the first study focussing explicitly on teachers' changed practices and students' motivation to learn mathematics and science. It furthermore takes both a situational and longitudinal stance on students' self-determined learning motivation and brings together state of the art research on productive classroom discourse (Walshaw & Anthony, 2008; Wells & Arauz, 2006) and the role of teachers and TPD in supporting students' self-determined learning motivation (Turner et al., 2011). After describing the successful implementation of a TPD programme focussing on productive classroom discourse (Gröschner, Seidel, Kiemer, et al., 2014), we showed that the reported decrease in students' self-determined learning motivation and interest (Eccles et al., 1993; Maulana et al., under review) can be countered to a certain extent by teachers' facilitation of productive classroom discourse. Hereby, the DVC took the components of effective TPD into account (Gröschner, Seidel, Kiemer, et al., 2014; Desimone, 2009; van Veen et al., 2012; Wilson, 2013) and included the use of video in the cycle of *planning*, *teaching* and reflecting (Santagata, 2009). The intervention was compared to a traditional TPD programme including a coherent set of workshops on the same content, with the same duration, and an additional opportunity for social exchange among participants.

The video analysis of teachers' discourse behaviour at pre- and post-test of the study indicated that the IG teachers changed their questioning and feedback behaviour positively (Hypothesis 1a and 1b confirmed). While the CG teachers showed increasingly more closed questions and simple feedback, indicating a more teacher-centred and less productive discourse behaviour, participants in the video-based, reflection-oriented treatment condition (DVC) exhibited a positive trend and significant positive changes in the course of the study. The significant increase in constructive feedback shows that this aspect of productive classroom discourse is apparently more likely to be demonstrated in observed practices than a more open questioning style (van den Bergh, Ros, & Beijaard, 2013a, 2013b). Thus, questioning seems to be a more-difficult-to-adapt teacher practice as teachers' style of asking questions is very much a routine (Oliveira, 2010) and teachers sometimes struggle with asking open questions because they require different situational interactions with students, whereas feedback is more of an instruction matter (Mercer, 2010). Furthermore, even though the CG received a form of TPD, the lack of opportunities for video-based reflection, using examples from their own practice and a strong community of learners (McLaughlin & Burnaford, 2007) may have hindered their transfer of new practices into their classrooms and thus accounts for their decrease in productive classroom discourse practices.

With regard to the second research question, this study showed that compared with a CG, the DVC resulted in more positive linear growth of students' interest in the subject. These kinds of decreases are also observed in the CG, but not for teachers participating in the DVC (Hypothesis 2 confirmed). Thus, teacher participation in the DVC intervention on re-defining classroom discourse is an appropriate means to improve student interest in STEM subjects. A β-weight of 5.87 on this motivational student characteristic underscores the effectiveness of the DVC as a relevant, practice-oriented TPD programme (Gröschner, Seidel, Kiemer, et al., 2014). Furthermore, the positive comparison of the DVC with the CG suggests that the TPD programme may be a more powerful and effective form of professional development (Borko et al., 2008; Sherin & Han, 2004) than traditional workshops.

Furthermore, this finding adds to the body of literature that conceptualises interest as a state-trait-like variable that can be developed through repeated positive interactions between person and object, as well as by the specific characteristics of the environment (Frenzel, Pekrun, Dicke, & Goetz, 2012; Sansone & Smith, 2000). The findings support those theories of interest development that propose situational interest as an antecedent of sustained individual interest and thus as a prerequisite for interest

Table 3
Changes from pre-to post-test in motivational constructs: bivariate correlations.

	Interest in the subject Δpre–post	Intrinsic learning motivation Δpre–post	Autonomy Δpre–post	Competence Δpre–post	Social relatedness Δpre–post
1	1	.28**	.25**	.36**	.17+
2		1	.47**	.38**	.25**
3			1	.52**	.46**
4				1	.48**
5					1

Note. $n = 108$ Students; +<.10, *<.05, **<.01.

development (Hidi & Renninger, 2006; Krapp & Prenzel, 2011). Also, we present further evidence that productive classroom discourse positively affects motivational student variables (Jurik et al., 2014).

The DVC, by focussing on teachers' use of strategies for productive classroom discourse (Walshaw & Anthony, 2008), was conceptualised in a way that students' need for autonomy, competence and social relatedness was scaffolded. In line with the literature on both self-determination theory (Ryan & Deci, 2000) and productive classroom discourse, we assumed that these kind of changed experiences are connected to an increase in self-determined-learning motivation. The study results support these conjectures and accord with previous findings of the effects of productive classroom discourse on student learning outcomes (Kovolainen & Kumpulainen, 2005; Walshaw & Anthony, 2008). Hypothesis 3a was therefore confirmed. The curvilinear trajectories of the IG teachers for autonomy and competence support are in line with the literature on teacher learning. Existing research often warrants fluctuation in such learning because of teachers grappling with new practices and the time needed to consolidate changes in routine practices (Bakkenes, Vermunt, & Wubbels, 2010), and it supports the often cited argument in TPD research for continuous, long-term teacher learning (Borko et al., 2008). In the case of social relatedness, fluctuations were less strong, resulting in a significant initial increase, which then levels out throughout the school year. A possible explanation for this different trend could be that the classes had not been newly formed at the beginning of the school year, but as is the norm in Germany, had been a group (with few changes) since 5th grade. Most classes had the same teacher in previous school years; hence, it can be assumed that a feeling of connectedness had already been established and was only improved slightly through the intervention (Mainhard, Brekelmans, & Wubbels, 2011). Future research should focus on this issue by inquiring into the specific mechanisms of productive classroom discourse that promote basic psychological need perception, and in turn, self-determined-learning motivation by taking class transition processes or peer group-specific learning processes into account.

Regarding our fourth research question, the bivariate correlations in changed student perceptions of basic psychological need support, intrinsic learning motivation and interest in the subject, indicate that the positive differences in these variables are significantly related. The path analyses support that continuous changes in situational perceptions of autonomy and competence are predictive of students' changed perceptions of intrinsic learning motivation. Beyond that, perceptions of autonomy and competence are also indirectly predictive of students' experiences of interest in STEM subjects, as is their perception of their situational intrinsic learning motivation. These findings are in line with reported effects of productive classroom discourse on student motivation (Jurik et al., 2014) and research on the development of interest in the subject (Frenzel et al., 2012; Renninger & Hidi, 2011). Hypothesis 4 could thus be confirmed. These instances of perceived autonomy and competence can be enhanced through teaching practices that focus on productive classroom discourse, or more specifically, on student activation and scaffolding of student ideas (Walshaw & Anthony, 2008). The next steps are to further investigate the relation between perceived autonomy/competence and classroom discourse, as well as the specific role of the teachers' support for basic need fulfilment in the context of classroom discourse. Furthermore, aspects of teachers' attitudes and beliefs as prerequisites for changed practice should be considered.

In interpreting the study results, the small and non-randomised sample has to be taken into account. A year-long intervention study, especially one using classroom videos is an invasive method that a small number of teachers are willing to undergo (van Eekelen, Vermunt, & Boshuizen, 2006). Yet this holds both for the DVC intervention teachers as well as the CG since all teachers had to engage with the same effort with respect to time and content. To guarantee the participants' acceptance and minimise reactance, they were given a free choice between the two TPD programmes, not randomly assigned. As this was the first study exploring the effects of the DVC, we focussed on not compromising the quality of the data by reactive behaviours during the school year (Gröschner, Seidel, Kiemer, et al., 2014). Future studies should increase the teacher sample to avoid a selection bias and allow more generalisable inductions from the data, as well as apply hierarchical latent growth curve models to consider the nested data-structure at the teacher level. Another limitation of this study is its reliance on students' self-reports to establish their perceptions of basic psychological need fulfilment and their motivational orientations. Further investigations should attempt to diversify data on students' perceptions, e.g. through the use of teacher reports, behavioural indicators or techniques like experience sampling.

Future research should more specifically investigate which teacher practices foster students' perceptions of teachers' basic need support and the role of students' basic need experiences. Given the importance of both perceived autonomy and competence as predictor for changes in students' interest in the subject, investigations into ways of fostering perceptions of autonomy/competence, as well as teachers' autonomy-support/competence-support through productive classroom discourse appear especially fruitful (Reeve & Jang, 2006). More fine-grained analyses of the micro-processes of teacher–student interactions could shed light on differential effects of teacher discourse behaviour (feedback and questioning) on students' basic need perceptions. Mixed-method approaches that combine student self-report and observational data appear especially meaningful in this context.

5. Conclusions

This study shows that after successful implementation (Gröschner, Seidel, Kiemer, et al., 2014), the video-based TPD approach of the DVC was effective in changing teachers' behaviour towards more productive classroom discourse. This finding is especially noteworthy because the comparison with the CG shows that without such effective measures, teachers tend to narrow their discourse practices (in the form of closed questions and simple feedback) towards more teacher-centred forms of discourse over the course of a school year. The results of this study further show positive changes in students' experiences of autonomy, competence and social relatedness as well as intrinsic learning motivation, when their teachers participated in the DVC intervention. This is the first study to integrate student motivation research with research on productive classroom discourse supporting the theoretically derived assumptions about changes in students' motivation to learn mathematics and science because of specific TPD activities of their teachers. The results demonstrate the importance of productive classroom discourse in promoting positive learning outcomes for students' motivational orientations and its role in fostering student interest in STEM subjects.

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