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Students Reading Text-Picture-Material: The Role of Teacher Competence and Instructional Quality

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Abstract

Learning material often consists of texts and instructional pictures, meaning the reader must extract and integrate information from two sources. Research shows that students' skills in integrating texts and pictures already vary in early secondary school. Teachers' professional competence and quality of instruction are important influences on the development of student's skills. Therefore, this study examines teachers' professional competence in teaching with texts, instructional pictures, and instructional quality as predictors for developing students' text-picture-integration skills. Data from 136 fourth-grade teachers were collected in Germany. A subsample of 34 teachers and 646 fourth graders participated in a video study investigating instructional quality. In a longitudinal study, we assessed teachers' competence in teaching with texts and instructional pictures via questionnaires and tested students' text-picture-integration-skills. In between, three lessons involving texts and instructional pictures were videotaped and analysed. Multilevel regression models showed a small positive direct effect of teachers' knowledge about student abilities on students' text-picture-integration-skills. Furthermore, aspects of teachers' competence were positively related to instructional quality, whereas "clarity and structure" positively predicted students' text-picture-integration-skills. The presented paper contributes to research on text-picture-integration in primary school and how teachers and instruction can facilitate it.

Keywords

Text-picture-integration, instructional quality, teacher competence, longitudinal multilevel analysis, video study

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La Lectura de Texto-Imagen en Estudiantes: El Papel de la Competencia del Maestro y la Calidad de la Instrucción

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Resumen

El material de aprendizaje consiste frecuentemente en textos e imágenes instructivas, lo que significa que el lector debe extraer e integrar información de dos fuentes. La investigación muestra que las habilidades de los estudiantes para integrar textos e imágenes ya varían en la escuela secundaria temprana. Por su parte, la competencia profesional de los maestros y la calidad de la instrucción son influencias importantes en el desarrollo de las habilidades de integración de texto e imagen de los estudiantes. Por lo tanto, este estudio examina la competencia profesional de los maestros en la enseñanza con textos, imágenes instructivas y la calidad de la instrucción como predictores para el desarrollo de las habilidades de integración de texto e imagen de los estudiantes. Se recopilaron datos de 136 profesores de cuarto grado de primaria en Alemania. Una submuestra de 34 maestros y 646 alumnos de cuarto grado participaron en un estudio de video que investigó la calidad de la instrucción. El presente estudio longitudinal, evaluó la competencia de los maestros en la enseñanza con textos e imágenes instructivas a través de cuestionarios y se probó las habilidades de integración de texto e imagen de los estudiantes. Específicamente, se grabaron y analizaron tres lecciones que involucraban textos e imágenes instructivas. Los modelos de regresión multinivel mostraron un pequeño efecto positivo directo del conocimiento de los maestros sobre las habilidades de los estudiantes en las habilidades de integración de texto e imagen de los alumnos. Además, algunos aspectos de la competencia de los maestros se relacionaron positivamente con la calidad de la instrucción, mientras que claridad y estructura predijeron positivamente las habilidades de integración de texto e imagen de los estudiantes. El presente artículo contribuye a la investigación sobre la integración de texto e imagen en la escuela primaria y cómo los maestros y la instrucción pueden facilitarla.

Palabras clave

Texto-imagen-integración, calidad instruccional, competencia docente, análisis longitudinal multinivel, estudio de vídeo

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Students' skills in reading and understanding learning materials are essential for their academic success. Often, learning materials consist not only of texts but also of instructional pictures such as graphs, charts, or maps (e.g., Hochpöchler et al., 2013), requiring the reader to integrate information from the text and picture (text-picture-integration; TPI). Although access to information from two different sources has several advantages, these materials also impose cognitive challenges on students (e.g., Ayres & Sweller, 2005)—especially on young learners in primary school, who have little experience with this kind of material. Teachers must be aware of the cognitive potential and challenges of this kind of learning material if they are to provide their students with adequate instruction and learning opportunities. Even though texts and instructional pictures (text-picture-material; TPM) are frequently used in classroom instruction, teachers often have not received any systematic training at university on how to help students process them (McElvany et al., 2012).

Studies have shown the importance of teachers' professional competence for instructional quality and students' competence development in various domains and countries (e.g., Chung et al., 2022; Darling-Hammond, 2021). However, there is little research on how these relations transfer to teaching and learning with cognitively demanding materials such as TPM. Hence, the present study addresses this research gap and aims to identify the links between teachers' competence, instruction, and students' TPI-skills. Focusing on teachers' pedagogical content knowledge, their attitudes towards the importance of working with TPM, and their motivational orientations, we first tested for a potential direct effect of teachers' TPM-related competence on their students' TPI-skills. In a second step, we analysed videos from 34 primary school classes in which teachers explicitly used TPM in their instruction, and tested a mediation effect of instructional quality between teachers' competence and students' TPI-skills. Thus, the presented study provides new evidence for the role of teachers' competence for student learning in the context of teaching and learning with TPM while also advancing instructional quality research in primary school classes.

Text-Picture-Integration in Learning Materials

School textbooks and learning materials often contain combinations of texts and instructional pictures designed to help students understand complex content, especially in natural science domains (Opfermann et al., 2017; Peterson et al., 2021). Even in primary school, information is often delivered as a written text with an associated pictorial medium such as a map, diagram, or graph. International research has produced well-established theories on teaching and learning with multiple modes of representation such as TPM. According to dual-coding theory, for example, presenting information in the form of texts and instructional pictures addresses two different symbolic systems: the verbal and nonverbal. Hence, students have to use separate subsystems when processing written language vs. nonverbal (Paivio, 1990). Based on cognitive load theory, Brunken et al. (2003) describe a dual-task approach in multimedia learning. Integrating information from two different sources is cognitively demanding for students due to the need to split cognitive resources because information is (a) presented in different modes (here, verbal and pictorial: dual-code assumption) and (b) received through different channels (here, written text and visual representation: dual-channel assumption) (Brunken et al., 2003).

The theory of multimedia learning (Mayer, 2014) states that students select relevant information from both sources and organize it into a coherent mental model. Then, the new information is integrated into already existing mental models. Based on this theory, Schnotz and Bannert (2003) proposed an integrated model of text and picture comprehension describing how students select, organize, and integrate descriptive (text) and depictive (picture) information from different sources by applying parallel cognitive processes. Readers use semantic processing to grasp the texts' verbal organization and construct a propositional representation of the written information. Simultaneously, they perceive the visual structure of the picture and construct a corresponding mental model. Accordingly, relevant information is extracted from the text through symbolic processing and from the picture through analogue processing—with a person's propositional representations and mental models assumed to interact continuously during the processes of model construction and inspection.

Theories and empirical research also indicate ways of facilitating these complex cognitive processes for students in school. Concerning the presentation of texts and pictures, the multimedia principle states that students learn better from texts and pictures than from pictures alone (Mayer & Fiorella, 2014) as long as teachers adhere to basic principles of multimedia learning such as avoiding redundant information in the text and picture and ensuring spatial and temporal contiguity (Mayer, 2014). According to the DeFT framework (Design, Functions, Tasks), teachers need to consider the design and pedagogical function of learning materials as well as the cognitive tasks students need to complete when learning with multi-representational materials (Ainsworth, 2006). Some useful instructional strategies to support students' mental integration processes include providing directive help—explicitly pointing out relevant elements and relations—or nondirective help—supporting learners in identifying relevant aspects based on their prior knowledge of content or using visual cues such as colours, labels, legends, or prompts (e.g., Shah & Hoeffner, 2002). Therefore, teachers need to be aware of potential challenges associated with TPM and teaching strategies to foster students' TPI-skills.

Role of Teachers' Professional Competence for Instruction and Students' TPM Reading

According to empirically supported models of the relations between teachers' competences and students' achievement (e.g., Darling-Hammond, 2021), teachers need both cognitive and affective competence if they are to initiate successful learning processes. One widely established model of teachers' professional competence by Baumert and Kunter (2013) includes cognitive and affective aspects. In this model, pedagogical content knowledge (PCK) is one facet of teachers' professional knowledge (Shulman, 1986). It has been identified as a relevant predictor of instructional quality and student achievement (e.g., Gess-Newsome et al., 2019). PCK is the kind of knowledge that matters for teaching and involves an understanding of how students learn a specific topic and what factors facilitate or complicate their learning processes (Shulman, 1986). Operationalisations of PCK since then are diverse, but knowledge about student understanding is a relevant component of most of them (Park & Oliver, 2008). This encompasses knowledge about student abilities, which is essential for students' understanding specific content such as texts and integrated pictures.

Teachers' beliefs are regarded as an important basis for their decisions in the classroom. Teachers' beliefs include subjective theories about student learning (e.g., beliefs about the importance of practice reading TPM) and goal orientations (Pajares, 1992). Both have been shown to influence teachers' behaviour in the classroom (e.g., Leuchter et al., 2020; Pamuk et al., 2017).

Teachers' motivational orientations are another facet of professional competence. According to the theory of self-determination (Ryan & Deci, 2020), intrinsic motivation is crucial for human actions in general. However, research has also provided strong evidence for the importance of teacher motivation for instruction and student outcomes (e.g., Han & Yin, 2016). Therefore, teachers' intrinsic motivation to use TPM in their lessons should impact their teaching. Teachers' engagement can be described as a motivational concept that reflects their voluntary allocation of personal resources to a certain task. Thus, engagement in fostering students' TPI-skills can be understood as part of teachers' cognitive engagement (Klassen et al., 2013).

Empirical evidence shows that in general, all of the aforementioned aspects of teachers' professional competence are relevant for teaching and student outcomes. However, few studies have investigated teachers' competence and its relation to instruction and learning in the context of TPI. Previous studies in the secondary school context uncovered moderate relations between teachers' beliefs about reading routines and students' self-reported engagement (Schroeder et al., 2011). Thus, the question of potential effects of teachers' TPM-related professional competence on primary school student learning and instructional quality must still be answered.

Instructional Quality in Teaching with TPM

Teachers' professional competence plays an essential role for instructional quality, which itself impacts students' learning processes (Darling-Hammond, 2021). Various studies have demonstrated relations between instructional quality and multicriterial student outcomes, such as subject-related competence and motivational and affective outcomes (e.g., Kyriakides et al., 2013). For secondary school, there is empirical evidence that students' TPI-skills benefit from frequent use of texts and instructional pictures and the explicit discussion of TPM (Oerke et al., 2019). The frequency is just one quantitative aspect of instructional quality. There are several frameworks systematizing characteristics of teaching quality (for an overview of classroom observation frameworks for instructional quality, see Praetorius & Charalambous, 2018). This research was guided by a three-dimensional framework encompassing (a) cognitive activation and deep content; (b) classroom management, clarity, and structure; and (c) supportive climate. A previous study based on this framework adapted measures of instructional quality to teaching with TPM, describing three instructional characteristics (Ohle & McElvany, 2016).

Cognitive demand (basic dimension a) includes aspects of cognitive activation and instruction on processing information from texts and instructional pictures and includes facets like "extracting information from text and picture" or "reciprocal use of text and picture".

Clarity and structure (basic dimension b) refers to the structure of learning processes in a lesson and includes facets such as "introducing the lesson's topic" and "clarity of tasks". Motivational support (basic dimension c) describes teachers' behaviour designed to motivate students and includes facets like "positive error culture" and "positive teacher-student interactions". An overview of all facets and their corresponding indicators is provided in the supplement file (Appendix A).

Based on the theoretically assumed functional chain of teacher-instruction-achievement, we investigated whether teachers' professional competence offers a suitable explanation for differences in instructional quality between classes, and whether these characteristics of instructional quality have predictive potential for students' TPI-skills.

Research Questions

To investigate the functional chain between teachers' competence, instructional quality, and students' TPI-skills, the present study addressed two main research questions (RQ) and according hypotheses (H):

RQ1: How do aspects of teachers' TPM-related competence relate to students' TPI-skills?

Assuming that teachers' professional competence is essential for successful learning processes, we expect positive direct effects of (i) teachers' knowledge about student abilities, (ii) their beliefs about the importance of practice, (iii) their intrinsic motivation to teach with TPM, and (iv) their engagement to foster all students' understanding on students' TPI-skills (Hypothesis H1).

RQ2: Are the relations between aspects of teachers' TPM-related competence and students' TPM-reading skills mediated by instructional quality?

In terms of empirical evidence for the theoretically postulated functional chain from teacher competence to instructional quality and on to student outcomes, we expect positive relations between aspects of teachers' TPI-related competence and instructional quality (Hypothesis H2a) as well as a mediating effect of instructional quality on the relation between teacher competence and students' TPI-skills (Hypothesis H2b).

Methods

Participants

Data was gathered as part of the project (blinded for review) funded by the German Research Foundation (DFG). Data from $N = 65$ primary school teachers ($M_{age} = 43.98$ years [$SD = 11.96$]; $M_{teaching\ experience} = 17.10$ years [$SD = 10.81$]; 86.2% female) and their classes ($N = 1.165$ students, $M_{age} = 10.45$ years [$SD = 0.59$], 48.3% female, mean Highest International Socio-Economic Index of Occupational Status (HISEI) $M_{HISEI} = 51.02$ [$SD = 20.17$]) was assessed. Among teachers, 34.1% were qualified to teach primary school only and 63.3% were qualified to teach both primary and lower secondary school. Participants were recruited in both rural and

urban areas. Although, the data basis was not representative, due to sample size, the sample demographics are comparable to those of a representative sample of primary school teachers in Germany from the PIRLS 2011 survey. In PIRLS 2011, 40% of all students were taught by teachers above age 50, 91.2% of teachers were female, 78.2% had studied German as one of their subjects at university (59.9% in our sample) and 90.5% held a teaching qualification for primary school or above (Tarelli et al., 2012). In our study, a subsample of n = 34 teachers (M_{age} = 43.71 years [SD = 11.56], $M_{teaching\ experience}$ = 17.85 years [SD = 11.07], 85.3% female) participated in an additional video study element along with their classes (n = 646 students, M_{age} = 10.41 years [SD = 0.58], 50.2% female, M_{HISEI} = 51.87 [SD = 20.13]). The class sizes varied between N = 15 and N = 27 students, the mean class size was $M_{class\ size}$ = 19.00. Teachers and students participated voluntarily and gave informed consent. For the video study, we asked teachers from the total sample, if they were willing to teach three lessons with TPM, provided by the research team, and to have those lessons recorded. Again, participation in the video study was voluntarily and we collected video-specific informed consent from teachers and students. At the time of data collection, it was not prescribed by law to get a protocol approval of an ethics committee.

Measures

Teacher competence. Aspects of teacher competence were operationalised for teaching with TPM and corresponding instruments were developed and evaluated on secondary school teachers in a preceding project phase (McElvany et al., 2012; for an overview, see Ohle et al., 2017). Teachers' knowledge about students' abilities was assessed with 11 statements capturing the frequency of practicing reading strategies for TPM, which varied in their relevance for fostering students' reading skills (e.g., "Please think about your everyday practice in your subject and state how often you practice the following abilities: …relate information from two different sources [text/picture]"). Teachers answered these items on a 6-point rating scale ranging from 1 (never) to 6 (very often). Teachers' responses were compared with expert ratings on the relevance of these strategies for students' TPM skills (2 points = "strategy rated same as experts", 1 point = "strategy was not rated worse than a strategy preferred by the experts", and 0 points = "rating contrary to expert rating"). Altogether, 38 comparisons of strategies were used to assess teachers' knowledge about the importance of students' abilities. In the optimised version (according to internal consistency), 28 comparisons remained; the reliability is reported in Table 1.

Aspects of teachers' motivational-affective competence were assessed with items rated on 4-point scales ranging from 1 (does not apply) to 4 (applies completely). Teachers' beliefs about the importance of explicitly practicing reading TPM in order to help students learn how to successfully obtain information from text and integrated pictures was evaluated with items such as: "Reading and understanding texts with embedded pictures has to be practiced continuously." The scale for intrinsic motivation to use TPM in lessons and to discuss it with students contained items such as: "I enjoy discussing lesson content by means of pictures that are integrated into school textbooks or other learning materials." Finally, teachers' engagement to foster all students' understanding of TPM was assessed with items such as: "I put a lot of

effort into ensuring that all students understand the text and the picture." Table 1 provides an overview of the teacher competence scales and their reliabilities.

Table 1

Teacher Competence Scales for Total Sample (N = 65) / Video Subsample (n = 34)

Scale		Cronbach's α
Knowledge about student abilities	*N* = 28 comparisons	82/.79
Beliefs about importance of practice	*N* = 4 items	.74/.68
Intrinsic motivation	*N* = 3 items	.89/.88
Engagement	*N* = 4 items	.88/.87

Confirmatory factor analyses confirmed the superiority of a three-factor model (total sample: $\chi^2 = 57.66$; *df* = 40; *CFI* = .96; *RMSEA* = .08/video subsample: $\chi^2 = 62.29$; *df* = 40; *CFI* = .90; *RMSEA* = .13) for the motivational-affective competence aspects compared to a general-factor model ($\chi^2 = 332.21$; *df* = 44; *CFI* = .31; *RMSEA* = .32/video subsample: $\chi^2 = 189.62$; *df* = 44; *CFI* = .31; *RMSEA* = .31).

Instructional Quality. We evaluated instructional quality by analysing videos of 99 lessons (three lessons per class, except for three classes with one missing lesson each). All lessons were rated in terms of three dimensions of instructional quality: (i) cognitive demand of tasks, (ii) clarity and structure, and (iii) motivational support (Ohle & McElvany, 2016); each dimension contained three to five facets, which were aggregated into a single measure for each dimension. A description of the coding manual can be found in the supplement file (Appendix A). The instructional quality measures were rated on a 4-point scale:

0 = Indicators of a facet did not occur in a lesson, facet was performed poorly

1 = Indicators of a facet only occurred seldomly in a lesson, facet was performed rather poorly

2 = Indicators of a facet occurred often in a lesson, facet was performed well

3 = Indicators of a facet occurred very often in a lesson, facet was performed very well

Two independent raters were trained according to a coding manual and double-rated 10% of the video material, achieving a satisfactory interrater reliability of .80 < g-coefficient < 1.00. Ratings for all facets were more stable within classes (.12 < *ICC* < .28) than within lessons (.01 < *ICC* .17). Therefore, the ratings for each class were aggregated and the instructional quality measures were based on the mean scores for each facet. The three missing class means were estimated using multiple imputations in SPSS 22.

Student measures. Students' skills in reading and understanding TPM were assessed with multiple-choice tests at t1 and t2. This test was also developed in a previous project phase, focusing on secondary school students. Based on data of 48 classes in grade 5 (first year of secondary school; Ohle et al., 2017), the easiest items were selected to assess TPI-skills of students at the end of primary school. Students received three texts that were linked to corresponding instructional pictures via colour coding, letters and/or symbols. For each combination of text and picture, students had to answer six items requiring TPI. An item example is provided in the supplement file (Appendix B). In the end, each test consisted of 18 items and the two tests (t1 and t2) were linked via six anchor items. The tests were analysed

with item response theory using ConQuest (Australian Council for Educational Research [ACER], 2007) and showed acceptable fit criteria (Bond & Fox, 2007) at both t1 (EAP/PV reliability = .87; 0.91 < *MNSQ* < 1.13; -4.1 < *T* < 4.1) and t2 (EAP/PV reliability = .84; 0.75 < *MNSQ* < 1.11; -6.3 < *T* < 2.6). The intraclass correlation of *ICC* = .13 revealed large heterogeneity within classes, indicating that just 13% of the variance in students' TPI-skills could be explained by classroom-level factors. Students' figural cognitive abilities served as a control variable and were assessed using Subtest 3 of the KFT 4-12R (Heller & Perleth, 2000) at t1. Students' socio-economic background was measured via Highest International Socio-Economic Index of Occupational Status (HISEI, Ganzeboom, et al., 1992).

Procedure

Students' TPI-skills were assessed a few weeks into Grade 4 (t1) and at the end of the school year (t2). Teachers completed a questionnaire on aspects of their professional competence at t1. A few weeks prior to t2, we videotaped three lessons per class. The lesson topic was "South America", which is part of the 4th-grade curriculum in Germany, but rarely taught. As a result, students' prior content knowledge, as a factor that influences students' TPM understanding (Shah & Hoeffner, 2002), should have been rather low and constant between classes. Teachers were provided with TPM for each lesson to maintain consistent content between classes. The materials consisted of one text per lesson that was linked to an instructional picture via visual cues such as colours, legends, and letters (Shah & Hoeffner, 2002). In the first lesson, students read a text about countries in South America and were given a map that was linked to the text by colour-coding. In the second lesson, students received informational texts about animals living in different regions of South America; again, the regions were linked to this second map via colours and letters. In the third lesson, students read texts about people living in different countries in South America and connected information from the texts to graphs via symbols. Teachers were allowed to plan their lessons independently in terms of the surface structure (methods) and deep structure (learning goals and processes) of instruction. They did not receive any guidelines on how to help students understand the material, in order to identify potential differences between teachers' TPM-related teaching practices.

Data Analysis

To answer the first research question – direct effects of teachers' TPM-related competence on students' TPI-skills – we specified distinct multilevel regression models for each aspect of teachers' competence using Mplus 7 (Muthén & Muthén, 1998-2012). On the between level, aspects of teachers' TPM-related competence were specified as predictors. On the within level, students TPI-skills at t1, age, gender, socio-economic background (HISEI) and cognitive abilities were used as predictor variables for students' TPI-skills at t2. To answer the second research question – relations between teachers' competence and instructional quality and a potential mediation effect – we specified a multilevel path model using teachers' TPM competence aspects as predictors of instructional quality, which was itself specified as a predictor variable for students' TPI-skills at t2 on the between level. We also specified indirect

paths between the aspects of teachers' competence, instruction, and students' skills. On the within level, the same predictors were specified as in Research Question 1. We used the full information maximum likelihood estimator (MLR algorithm) in the analyses in Mplus to handle missing values. Due to the small sample size, we report results with a significance level of $p < .10$. Descriptive analyses were conducted with SPSS 22 (IBM Corp., 2013).

Results

Descriptive Results

Table 2 displays the means and standard deviations of teachers' TPM-related competence.

Table 2

Descriptive Results for Teachers' TPRM-related Competence for Total Sample (N = 65) / Video Subsample (n = 34)

Scale	*M* (*SD*)
Knowledge about student abilities	1.28 (0.26) /1.25 (0.24)
Beliefs about importance of practice	3.64 (0.39) /3.68 (0.38)
Intrinsic motivation	3.22 (0.51) /3.22 (0.52)
Engagement	3.17 (0.49) /3.09 (0.50)

Descriptive results from the video analysis showed that relevant activities for reading TPRM (cognitive demand) occurred only rarely in the lessons ($M_{\text{Cognitive demand}} = 0.96$ [$SD = 0.16$]). Clarity and structure were occurred slightly more frequently in the videotaped lessons ($M_{\text{Clarity and structure}} = 1.77$ [$SD = 0.19$]), indicating that teachers ensured that the tasks and lesson topic were transparent for the students. Motivational support was also positively rated ($M_{\text{Motivational support}} = 1.65$ [$SD = 0.17$]), indicating a positive learning climate.

Table 3 provides an overview of students' TPI-skills at both measurement points, their cognitive abilities and the corresponding bivariate correlations.

Table 3

Students' TPI-skill at t1 and t2, their Cognitive Abilities, and Bivariate Correlations for Total Sample (N = 1.165) / Video Subsample (N = 646)

		M	*SD*	1	2	3
1	TPI-skill *t1*	0.03/-0.02	1.04/1.03	--		
2	TPI-skill *t2*	0.31/0.29	1.07/1.06	.72**/.71**	--	
3	Cognitive abilities	47.20/47.01	10.96/10.78	.42**/.43**	.39**/.37**	--

Note. ** $p < .01$

The low correlations between students' TPI-skills and their cognitive abilities indicate the discriminant validity of the TPI-test.

Direct Effects of Teachers' Competence on Students' TPI-skills

Multilevel regression models revealed no statistically significant relations between teacher competences and students' TPI-skills (Hypothesis 1) on the between-level. In the video sample, we found medium-sized relations, which failed to reach statistical significance, possibly due to the small sample size. So, on a descriptive level, there was a positive relation between teachers' knowledge about student abilities and students' TPI-skills at t2 and negative relations between teachers' a) beliefs about importance to practice reading TPM and b) teachers' engagement to foster all students' TPI-skills and students' TPI-skills the end of the school year. On the within level, students' TPI-skills at the beginning of the school year, age, socio-economic background and cognitive abilities were positive predictors for their TPI-skills at the end of Grade 4. Detailed results are displayed in Table 4.

Table 4

Direct Effects of Teachers' TPM-related Competence on Students' TPI-skill at t2 for Total Sample and Video Sample

	Model 1		Model 2		Model 3		Model 4	
	total sample	video sample	total sample	video sample	total sample	video sample	total sample	video sample
Within level								
TPI-skill (t1)	.64*	.61*	.64*	.61*	.64*	.61*	.64*	.61*
Age	-.06*	-.07*	-.06*	-.07*	-.06*	-.07*	-.06*	-.07*
Gender	-.02	-.05	-.02	-.04	-.02	-.05	-.02	-.05
HISEI	.08*	.10*	.08*	.10*	.08*	.10*	.08*	.09*
Cognitive abilities	.09*	.09*	.09*	.09*	.09*	.08*	.09*	.08*
R^2	.52	.49	.52	.49	.52	.49	.52	.49
Between level								
Knowledge about student abilities	.05	.47	--	--	--	--	--	--
Beliefs about importance of practice	--	--	-.06	-.31	--	--	--	--
Intrinsic motivation	--	--	--	--	-.12	-.05	--	--
Engagement	--	--	--	--	--	--	-.27	-.43
R^2	.00	.22	.00	.10	.01	.00	.08	.18

Note. * $p < .05$; standardized coefficients are reported in this table.

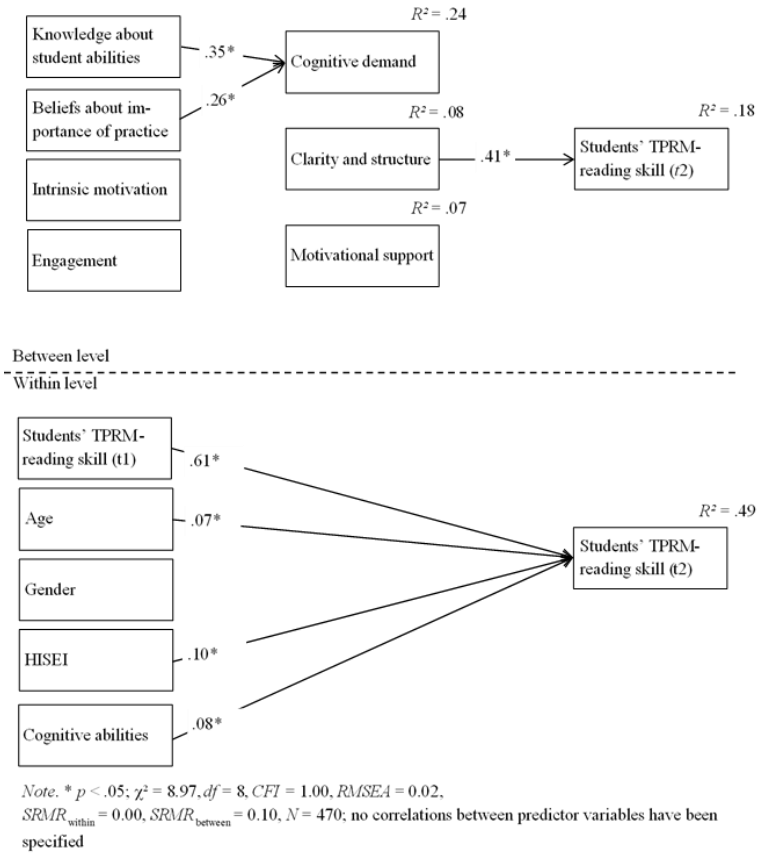
On the individual level, around half of the variance in students' TPI-skills at t2 was explained by their age, gender, socio-economic background, and cognitive abilities. In the video subsample, 22% of the variance in students' TPI-skills between classes could be explained by teachers' knowledge.

Relations between Teachers' Competence, Instructional Quality, and Students' TPI-skills

On the between level, relations between aspects of teachers' TPM-related competence and cognitive demand were found (Hypothesis 2a). The better teachers were in differentiating between strategies to foster students' TPI-skills and the more they believed that practicing reading TPM is essential for students' TPI-skills, the more cognitively demanding their lessons were. Higher cognitive demand meant that teachers explicitly thematised the information provided by the text and picture and how to integrate information from both sources. Clarity and structure was not related to teachers' competence; instead, it exhibited a medium positive relation to students' TPI-skills. This means that students were better in integrating texts and pictures when the tasks and lesson topic were clear and previous knowledge was activated at the beginning of a lesson. Motivational support was not related to teachers' competence nor to students' TPI-skills. In this model, there were no indirect effects of teachers' TPM-related competence on students' TPI-skills (Hypothesis 2b). The full model is displayed in Figure 1.

Figure 1

Multilevel Mediation Model of Teachers' TPM-related Competence, Instructional Quality and Students' TPI-skills



Note. * $p < .05$; $\chi^2 = 8.97$, $df = 8$, $CFI = 1.00$, $RMSEA = 0.02$, $SRMR_{within} = 0.00$, $SRMR_{between} = 0.10$, $N = 470$; no correlations between predictor variables have been specified

Altogether, 49% of the variance in students' TPI-skills at t2 on the individual level could be explained by their individual predictors. Furthermore, 18% of the variance in students' TPI-skills at t2 between classes was explained by the clarity of tasks and topics in the lesson.

Discussion

This study aimed to investigate the role of teachers' competence and instructional quality for the development of students' TPI-skills during Grade 4 in primary school. TPM plays an essential role in learning materials, especially in science classes (Opfermann et al., 2017). Hence, students' TPI-skills should already be fostered before they enter secondary school. Multilevel regression models no statistically significant direct effects of teachers' competences on students' TPI-skills at the end of primary school. In the video sub-sample, teachers' knowledge about student strategies is the strongest predictor on the between level, but – probably due to the small sample size – this effect is not statistically significant. Anyway, this result is in line with research results from other domains highlighting the relevance of teachers' PCK for student outcomes and instruction (e.g., Kunter et al., 2013). Teachers should be familiar with strategies to foster students' TPI-skills and be able to compare the relevance of the strategies they use in the classroom. Teachers' TPM-related competences also predicted the amount of cognitive demand in their lessons. Because the measures of teachers' competence specifically focused on teaching with TPM, it seems reasonable that they explained the largest amount of variance in the TPM-specific measure of instructional quality. This finding underpins the importance of teachers' knowledge and beliefs for instruction. Regarding the initial question, whether findings on relations between teacher competences and student's outcomes from other domains are transferable to the context of teaching and learning with TPM, the presented results precautiously suggest that functional chains are similar between domains.

Concerning the relations between instructional quality and student outcomes, clarity and structure was a positive predictor of students' TPI-skills on the classroom level. This aspect of instructional quality has also been identified as relevant for student learning in several other studies (Titsworth et al., 2015). We unexpectedly found no significant effect of cognitive demand, which explicitly includes TPM instruction, on students' TPI-skills. One possible explanation is the rather low level of cognitive demand found in the videotaped lessons overall. This can be problematic, especially for learners with low domain-specific prior knowledge, because it is these students in particular who benefit from teachers explicitly pointing out text–picture relations (Richter et al., 2018). On individual level, similar to findings in other studies, students' skills at the beginning of the school year were the strongest predictor for their skills at the end of grade 4. Since the variables on class level, used in this study, only explained 18% of variance in students' TPI-skills at t2, other (individual) factors contribute more to students' TPI-skills. Regarding the growing importance of digital media in school and students' private lives, playing educational games and using different channels for learning might bear potential to foster students' TPI-skills.

Limitations

Although the present study provides new empirical evidence on teaching and learning with TPM in primary school classes, it also has its limitations. One strength of the study was asking external observers to assess instructional quality during lessons involving the use of TPM and

linking these measures with students' skills, but the rather small sample size is a common limitation of video studies. Altogether, 34 teachers and their classes participated in the video study, which limits the number of predictors of students' outcomes that can be included on the classroom level. Furthermore, only large effects can be identified with an acceptable level of statistical significance.

Further Perspectives and Conclusion

Regarding the assessment of teachers' pedagogical content knowledge, future studies could improve the PCK test by focusing on teachers' evaluations of students' abilities and their relevance for successfully working with TPM. Furthermore, qualitative studies analysing individual teacher–student interactions could provide useful information on how to foster students' TPI-skills. Moreover, the collected video material could also be used to investigate the fit between teachers' learning offers and students' uptake of these offers or to investigate differentiated and personalised instruction.

Reading TPM is relevant for students' outcomes throughout their school careers, since TPM is used in various domains and contexts. Analysing the functional chain between teacher competence, instruction, and student outcomes in this specific context extends the empirical evidence on the importance of teacher competence for instructional quality. Furthermore, this is—to the best of our knowledge—the first investigation of instructional quality specifically focusing on teaching and learning with TPM in primary school that applies video analysis. The results showed that teachers' knowledge about students' abilities in reading TPM and their belief in the need to practice the use of TPM relate positively to TPI-related quality aspects in their instruction. In accordance with the competence approach that professional knowledge can be promoted at university, teaching with TPM should be addressed in teacher education, possibly in courses on teaching methods. This would be a promising possibility to promote teachers' professional knowledge in a context that is relevant for multiple school subjects and school types. It would also raise awareness for the challenges TPM poses for students and could encourage (future) teachers to address reading TPM explicitly in their classes.

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