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Teacher-reported instructional quality in the context of technology-enhanced teaching: The role of teachers' digital competence-related beliefs in empowering learners

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A R T I C L E I N F O

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A B S T R A C T

Teachers' competence-related beliefs are crucial in determining teachers' professional competence and instructional quality. However, in the context of technology-enhanced teaching, studies regarding competence-related beliefs, specifically competence dimensions and their relations to instructional quality, are limited. Against this backdrop, the purpose of the present study is twofold: The first is to test the factorial structure of a measure that assesses teachers' competence-related beliefs in the dimension of *empowering learners* with its subdimensions of *differentiation* and *actively engaging learners* based on the European Framework for the Digital Competence of Educators (DigCompEdu). The second is to examine the relations between competence-related beliefs and teachers' reported use of digital technologies to enhance classroom management, cognitive activation, and supportive climate. Based on data from 145 teachers (73.1% female), both the factorial structure and the relations were analyzed using various approaches of structural equation modeling. The results supported the bifactor confirmatory factor analysis model with a general factor defined as empowering learners as well as two subdimensions representing differentiation and actively engaging learners. Teachers' competence-related beliefs regarding differentiation and empowering learners are positively related to the teacher-reported use of technologies to enhance instructional quality. Understanding the structure of teachers' competence-related beliefs about empowering learners and their relations to instructional quality in technology-enhanced teaching is relevant for teacher education to address learners' diverse learning needs, as well as to promote active and creative engagement.

1. Introduction

In recent years, the usage of digital technologies for providing high-quality instruction in schools is of increasing importance for educational research and is addressed in a number of conceptual and empirical studies (e.g., Backfisch et al., 2021; Klieme, 2020; Lachner et al., 2020; Voss & Wittwer, 2020). In the discourse around what explains teachers' instructional use of digital technology,

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empirical studies have emphasized the importance of teachers' competence-related beliefs regarding their ability to use digital technology in class (Guggemos & Seufert, 2021; Hatlevik & Hatlevik, 2018; Quast et al., 2021; Rubach & Lazarides, 2021). Competence-related beliefs as an aspect of teachers' professional competence (Kunter et al., 2013) can be defined, in the context of digital technology, as a self-evaluation of the competence or ability to use digital technologies in teaching (Rubach & Lazarides, in press). The European Digital Competence Framework for Educators (DigCompEdu; Redecker & Punie, 2017) addresses the variety of teachers' digital competencies and describes the following six digital competence dimensions in the field of teachers' professional tasks: *professional engagement, digital resources, teaching and learning, assessment, empowering learners*, and *facilitating learners' digital competence*. Of these six dimensions, only digital resources, teaching and learning, assessment, and empowering learners refer to *pedagogical competencies* that define the core of the DigCompEdu framework (Redecker & Punie, 2017) and that are proposed as preconditions for a successful integration of digital technologies into teaching, whereas professional engagement and facilitating learners' digital competence refer to general digital competence dimensions. Previous studies on the DigCompEdu framework have measured teachers' behavior in these competence dimensions (e.g., Antonietti et al., 2022; Lucas et al., 2021). However, competence-related beliefs regarding specific competence dimensions as well as their factorial structure have not yet been addressed. Given the increasing heterogeneity of students, individual support for diverse learners got higher attention to deal with this heterogeneity – also in the context of digital technologies (Xie et al., 2019). A key benefit of digital technologies in education is their potential to individualize learning (Aleven, McLaughlin, Glenn, & Koedinger, 2017; Schaumburg, 2021; Schmid et al., 2022) by adapting content and teaching methods to learners' current level of understanding and progress (Rezat, 2020; Schaumburg, 2021). The DigCompEdu framework describes in its dimension of empowering learners the required pedagogic competencies of teachers to implement differentiated and actively engaged learning by using digital technologies in class. The present study addresses the reference of the DigCompEdu framework to examine the competence dimension of empowering learners through teachers' competence-related beliefs. Empowering learners includes three sub-dimensions: accessibility and inclusion, differentiation, and actively engaging learners (Redecker & Punie, 2017). The dimension accessibility and inclusion addresses students' inequalities in access to digital technologies as well as skills, especially for students with special educational needs (Redecker & Punie, 2017). Therefore, accessibility represents a precondition for participating in digital instruction, whereas differentiation and actively engaging learners relate directly to using digital technologies within pedagogical strategies for enhancing instructional quality and fostering students' learning. Hence, accessibility and inclusion may be more relevant for specific subgroups of students only and not all teachers may feel the need to have respective competencies depending on where they teach. Because the present study focuses on the required competencies in using digital technologies for enhancing instructional quality in class, it will address only the two subdimensions differentiation and actively engaging learners. Addressing the limited knowledge on the factorial structure of the constructs represented in the DigCompEdu framework, we aim to examine whether the dimension empowering learners can be assessed as one overarching dimension or rather multiple differentiated subdimensions. Moreover, we examine how teachers' competence-related beliefs regarding the dimension of empowering learners relate to instructional quality in class that was assessed through teachers' self-reports.

1.1. Instructional quality in the context of technology-enhanced learning and teaching

Due to the COVID-19 pandemic, teaching and learning processes shifted from the analog to the emergency remote teaching. Accordingly, theoretical (e.g., Klieme, 2020; Voss & Wittwer, 2020) and empirical studies (e.g., Ghateolbahra & Samimi, 2021; Rubach & Bonanati, 2022; Steinmayr et al., 2021) increasingly addressed how digital technologies can be implemented in digital environments during remote teaching in ways that foster high-quality instruction. High-quality instruction in K-12 classes has been described in terms of learning settings that are characterized by well-organized classroom management, high levels of emotional and cognitive support provided by the teacher (i.e., a supportive climate), and the use of cognitively challenging materials and tasks (i.e., cognitive activation, Klieme et al., 2009; Pianta & Hamre, 2009; Praetorius et al., 2018). While these three basic dimensions of high-quality instruction have been identified in analog teaching situations without a special focus on technology, recent studies show that instructional quality can also be supported by digital technologies in analog and digital class (i.e., socio-constructive support: Hammer et al., 2021; cognitive activation: Fütterer et al., 2022).

For example, the dimension of *classroom management* can be implemented through strategies that support the effective use of instructional time, including addressing classroom disruptions, classroom discipline, time management, clarity of rules, and monitoring different instructional phases (Evertson & Weinstein, 2006; Klieme et al., 2009; Praetorius et al., 2018; Seidel & Shavelson, 2007). In in-person classes as well as in blended learning, learning management systems can be used to provide learning materials, structure learning processes, and implement learning activities (Rubach & Bonanati, 2022; Stockless, 2018). Moreover, gamification approaches by implementing game design principles and mechanics in learning environments have been used to support classroom management (Barahona Mora, 2020; Chen et al., 2022; Kuo et al., 2017, pp. 548–551; Sanchez et al., 2017).

The dimension *supportive climate* is characterized by a respectful, appreciative teacher-student relationship and by the adaptation of learning tasks to students' prerequisites as well as individualized constructive feedback (Klieme et al., 2009; Pianta et al., 1997; Pintrich et al., 1993; Praetorius et al., 2018). Digital technology (i.e., various software) can be used to adaptively adjust content, tasks, and difficulty levels to the performance level of the students and ensure immediate and individualized formative feedback from teachers to students (Rank, 2022; Rubach & Bonanati, 2022).

The third basic dimension, *cognitive activation*, refers to instructional strategies that enhance higher-level thought processes of learners, including reactivating students' prior knowledge, integrating new knowledge into existing cognitive structures, and mastering challenging tasks appropriate for learners' cognitive capacity (Baumert et al., 2010; Klieme et al., 2009; Lipowsky et al., 2009; Praetorius et al., 2018). The use of digital technologies (i.e., cooperative digital tools, digital generative learning activities) for in-depth engagement with the lesson content can foster cognitive activation in class (Rubach & Bonanati, 2022; Voss & Wittwer, 2020; Zimmer, 2022). Moreover, computer-based simulations (Klieme, 2020) as well as digital quiz-based gamified tools (Sailer & Homner, 2020) can be cognitively activating for students.

1.2. Teachers' professional competence using digital technology

In educational research, high-quality instruction has shown to be affected by teachers' professional competence (Baumert et al., 2010; Kunter et al., 2013). Teachers' professional competence is defined as the combination of domain-specific as well as domain-generic knowledge, skills, and beliefs related to teaching (Baumert & Kunter, 2013) – the same applies to teachers' digital competence, which combines knowledge, skills, and beliefs in the context of digital technologies (Krumsvik, 2014). A series of frameworks (Brandhofer et al., 2016; Kelentrić et al., 2017; Knezek & Christensen, 2016; Krumsvik, 2014; Mishra & Koehler, 2006) and reviews (Rubach & Lazarides, in press; Skantz-Åberg et al., 2022) have attempted to conceptualize and describe the structure of teachers' digital competencies. Previous studies (Mishra & Koehler, 2006; Rubach & Lazarides, 2021) indicate that teachers need basic digital competencies as well as profession-related pedagogical competencies. The conceptualizations under which digital competencies are defined in the different frameworks differ, however; thus, there is no consistent understanding of what constitutes digital competence for teachers (Skantz-Åberg et al., 2022).

One comprehensive framework that focuses particularly on the competence dimensions that *educators* need to efficiently implement digital technologies in schools is the DigCompEdu framework (Redecker & Punie, 2017). The DigCompEdu framework defines competence dimensions of pedagogic-didactic competencies for educators that enable them to enhance and innovate teaching processes by integrating digital technologies (Cabero-Almenara et al., 2020; Redecker & Punie, 2017). In contrast to, for instance, the TPACK model (Mishra & Koehler, 2006), it details the different functions technology can play in education and provides an in-depth description of potential pedagogical competencies for implementing digital technologies in teaching and learning (Lucas et al., 2021; Rubach & Lazarides, in press). More concretely, the DigCompEdu framework defines 22 competencies assigned to six overarching competence dimensions: professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence.

The DigCompEdu framework is considered adequate for evaluating teachers' digital competence focusing on both overall digital competence as well as specific competence dimensions (Cabero-Almenara et al., 2020). Empirical studies have already validated the suggested structure of educators' digital competence and related competence dimensions proposed in the DigCompEdu framework (e.g., Cabero-Almenara et al., 2022; Ghomi & Redecker, 2019; Lucas et al., 2021), but have mostly assessed teachers' *behaviors* by asking the teachers to report to what extent they use digital technologies in teaching. While these findings give an important indication of teachers' use of digital technologies in teaching, teacher-reported behavior is not optimal for assessing teachers' professional competence (Baumert & Kunter, 2013). Antonietti et al. (2022), in contrast, measured teachers' beliefs about their competence in using digital technology in their teaching practice. In this study, we use a similar approach by assessing teachers' *beliefs* about their competencies regarding the dimension empowering learners in the DigCompEdu framework and their relations to self-reported instructional quality in class.

1.3. Competence-related beliefs and their relations to self-reported instructional quality in the context of digital technologies

Teachers' beliefs about their own professional competencies (Tschannen-Moran et al., 1998) can be classified as an individual characteristic that has proven to be relevant for teachers' instructional behavior (Holzberger et al., 2014; Kunter et al., 2013; Tschannen-Moran et al., 1998). Mixed results exist regarding the link between teachers' competence-related beliefs in using digital technology and their use of digital technology in class. Guggemos and Seufert (2021) have shown that teachers' self-assessed technological knowledge positively explains teachers' use of digital technology. Other scholars found that teachers' beliefs related to their competencies in using digital technology in pedagogical settings explain their use of digital technology in class (Hatlevik, 2017; Petko, 2012). Focusing on dimensions of self-reported instructional quality, Rubach and Lazarides (2021) did not find a link between teachers' beliefs about their own competencies using digital technologies in pedagogical settings and their use of digital technology. Quast et al. (2021), in turn, found that teachers' competence-related beliefs about their basic use of digital technology were linked to teacher-reported instructional quality using digital technology. The inconsistency in the results could be attributed to the fact that different instruments assessing teachers' competence beliefs were utilized (Rubach & Lazarides, in press). Another explanation for the inconsistent results might be that competence beliefs were assessed on a rather general level without any alignment to specific teaching task. Thus, one possibility for examining relations between competence beliefs and instructional behaviors in the context of digital technologies in class might be to focus on specific teaching-related competence dimensions that align with specific instructional behaviors.

In the present study, we thus examined how teachers' competence-related beliefs in the subdimensions differentiation and actively engaging learners based on the DigCompEdu framework (Redecker & Punie, 2017) relate to the teacher-reported use of digital technology to enhance instructional quality dimensions and to enhance the use of digital technology in class. Prior studies that dealt with the DigCompEdu framework and considered the dimension empowering learners have shown that pedagogical competence-related beliefs in this competence dimension are related to the intention to use digital technologies in teaching (Antonietti et al., 2022). To our knowledge, no study thus far has investigated how teachers' competence-related beliefs for the dimension empowering learners are linked to teachers' self-reported instructional behavior – we specifically examined the role of teachers' digital competence-related beliefs in the subdimensions of differentiation and actively engaging learners and self-reported instructional quality with respect to the implementation of digital technologies.

2. The current study

The DigCompEdu framework (Redecker & Punie, 2017) provides a differentiated and systematic representation of various competence dimensions of in-service teachers in the context of teaching with digital technologies. We extend prior initial approaches to operationalizing and empirically testing the framework (Antonietti et al., 2022; Cabero-Almenara et al., 2022; Lucas et al., 2021) by considering competence-related beliefs in the individual subdimensions of the overarching dimension empowering learners defined by the DigCompEdu framework.

In the first step, we aimed to examine the factorial structure of the measure.

Research question 1. To what extent does the factorial structure of the developed measure represent the overarching competence dimension empowering learners with two subdimensions differentiation and actively engaging learners as described in the DigCompEdu framework?

Hypothesis 1. Based on the DigCompEdu framework, it can be assumed that the factorial structure represents the subdimensions differentiation and actively engaging learners as well as a general factor of empowering learners.

We are further interested in interrelations between the digital competence-related beliefs regarding differentiation and actively engaging learners and the teacher-reported use of digital technologies to enhance instructional quality in class.

Research question 2. To what extent do teachers' digital competence-related beliefs in the competence dimension empowering learners and its subdimensions differentiation and actively engaging students relate to teacher-reported use of digital technologies to enhance instructional quality in class?

Hypothesis 2a. Based on previous research on the relation between digitally supported differentiation and teachers' use of digital technologies to enhance instructional quality (Schmid et al., 2022), we expect that teachers with higher competence-related beliefs regarding differentiating using digital technologies also report using digital technologies during teaching to enhance cognitive activation and a supportive climate in class.

Hypothesis 2b. Based on previous research on the relation between digitally supported learner engagement and teachers' use of digital technologies to enhance instructional quality (Autenrieth et al., 2018; Rawat et al., 2008; Tang et al., 2022; Wekerle et al., 2022), we assume that teachers with high levels of competence-related beliefs pertaining to actively engaging learners with digital technologies also report using digital technologies during teaching to enhance cognitive activation in class.

Although we hypothesize that the factorial structure of the measure includes the general factor empowering learners as well as the independent subdimensions differentiation and actively engaging learners, we investigate exploratively to what extent the general factor relates to teacher-reported use of digital technologies to enhance instructional quality in class.

3. Methods

3.1. Sample

Data from 145 teachers located in Germany (age: $M = 34.78$ years, $SD = 9.97$; 73.1% female, 4 missing indications of gender) were analyzed in this study. The teachers participated in an online survey that focused on the instructional use of digital tools and technologies in teaching and the development of teachers' digital competence. They were recruited via social media posts and school newsletters that included a weblink to the online survey. Teachers participated voluntarily and anonymously between November 2021 and February 2022. In the process of data cleaning, we excluded 156 responses from the sample because these participants completed less than 75% of the questionnaire. The teachers in our target sample ($n = 145$) had an average job experience of 8.29 years ($SD = 9.13$). The majority of the teachers worked in secondary schools (58.5%), one quarter (27.5%) were primary school teachers, and small proportions of the sample participants taught in other school forms (vocational schools: 8.5%; special education: 5.6%). The subjects that were most frequently taught by the participants were German language (16.6%), mathematics (14.7%), English as a foreign language (10.3%), and primary school science (7.1%) (more than one subject could be listed).

3.2. Measures

All items and reliability indices of latent constructs are listed in Table 1.

Competence-related beliefs regarding empowering learners. Based on the DigCompEdu framework (Redecker & Punie, 2017), we assessed the competence dimension of empowering learners with its two subdimensions differentiation and actively engaging learners, each with six items. Teachers evaluated their competence-related beliefs for each item on a five-point Likert scale from 1 (strongly

Table 1
Item wordings, factor loadings (λ), and the reliabilities (ω) of all included scales.

Items	Wordings	λ	λ_{GV}	ω
Digital competence-related beliefs regarding differentiation				.93
Diff01	I do not know how digital tools are supposed to help me implement personalized learning opportunities in the classroom.	.47	.45	
Diff02	I can use digital tools to promote differentiation and personalization in the classroom.	.55	.68	
Diff03	I can select and use learning activities with digital tools that allow students to progress at different paces and levels of difficulty.	.28	.80	
Diff04	I can use a variety of digital tools when planning learning processes and learning assessments in class, which I adapt to the needs, levels, paces and preferences of the students.	.12	.89	
Diff05	I can reflect on the effectiveness of digital tools to promote differentiation and personalization in the classroom and adapt my teaching strategies accordingly.	.17	.87	
Diff06	I can revise and further develop digital tools for personalizing learning activities in my classroom.	.26	.86	
Digital competence-related beliefs regarding actively engaging learners				.93
Activ01	I find it difficult to use digital tools to motivate students in the classroom.	.30	.52	
Activ02	I can use digital learning activities in class that are activating and engaging for my students (e.g., games, quizzes).	.49	.70	
Activ03	I can select appropriate digital tools to promote active engagement of my students in the classroom.	.69	.77	
Activ04	I can use a variety of digital tools to purposefully create diverse and effective lessons (e.g., to take into account different performance levels).	.20	.88	
Activ05	I can reflect on the appropriateness of digital tools to enhance students' active learning and adapt my teaching strategies accordingly.	.14	.89	
Activ06	I can revise, innovate and further develop digital tools for strategies to actively engage students (e.g., self-regulated project work with digital technologies and tools).	−.07	.88	
General factor of digital competence-related beliefs regarding empowering learners				.96
Technology-enhanced cognitive activation				.91
Cogn01	In class, I ask students to demonstrate different ways to solve a problem using digital technologies.	.88	–	
Cogn02	In class, I ask students to explain their thinking thoroughly using digital technologies.	.90	–	
Cogn03	In class, I often expect students to explain their work in detail using digital technologies.	.88	–	
Technology-enhanced supportive climate				.88
Supp01	In class, I use digital technologies to help students when they get stuck on a task.	.76	–	
Supp02	In class, I use digital technologies to inform students about their individual progress.	.77	–	
Supp03	In class, I use digital technologies to discuss difficult tasks with students.	.82	–	
Supp04	I use digital technologies to tell students what they can do to improve.	.88	–	
Technology-enhanced classroom management				.92
Class01	I use digital technologies to make it clear what I want my students to remember.	.84	–	
Class02	In class, I use digital technologies to summarize the most important things.	.88	–	
Class03	In class, we use digital technologies to review what is important.	.92	–	

Note. λ: factor loadings of the scales; λ_{GV}: factor loadings of the general factor; ω = McDonald's Omega.

disagree) to 5 (strongly agree).

Self-reported instructional quality in the context of technology-enhanced teaching. To assess teachers' use of digital technologies to enhance the instructional quality in class, we used three subscales developed by Rubach and Lazarides (2021) and Quast et al. (2021). Teachers indicated whether and how often they used digital technologies to implement cognitive activation (3 items), a supportive climate (4 items), and classroom management (3 items) in teaching. The response format was a five-point Likert scale from 1 (never) to 5 (in every lesson).

Socio-demographic characteristics. The gender of the teachers was assessed using a binary coding (1 = female, 2 = male); the third answer option "diverse" was not indicated by any of the participants. Teachers' job experience was assessed by the number of years using the open-ended question "For how many years have you been working as a teacher (including the preparatory service?)."

3.3. Data analyses

To test our hypotheses, data were analyzed with a structural equation modeling approach using Mplus 8.7 (Muthén & Muthén, 1998-2021). In the first step, we tested the factorial structure of teachers' digital competence-related beliefs, more specifically the dimension empowering learners. We conducted five different structural equation models guided by the approach described in Fadda et al. (2020) (see Fig. 1). The aim of the approach was to test the assumed factor structure (Hypothesis 1) and contrast this structure with one another. The various tested model types are all structural equation models (SEM) according to Hoyle (1995), who defines SEM as a "comprehensive statistical approach to testing hypotheses about the relations among observed and latent variables" (p. 1). In line with the theoretical framework of DigCompEdu (Redecker & Punie, 2017), we first ran a confirmatory factor analysis with a single factor representing empowering learners (Model 1, CFA) and a confirmatory factor analysis with two correlated latent factors representing the subdimensions differentiation and actively engaging learners (Model 2, CFA). In the next step, we tested an exploratory structural equation model (Model 3, ESEM) that included cross-loadings of all items on the latent factors differentiation and actively engaging learners. The ESEM combines a confirmatory factor analysis and an exploratory factor analysis (EFA) into a single structural equation model and allows cross-loadings (Gu et al., 2020). In contrast to a CFA, an ESEM is less restrictive and provides more accurate

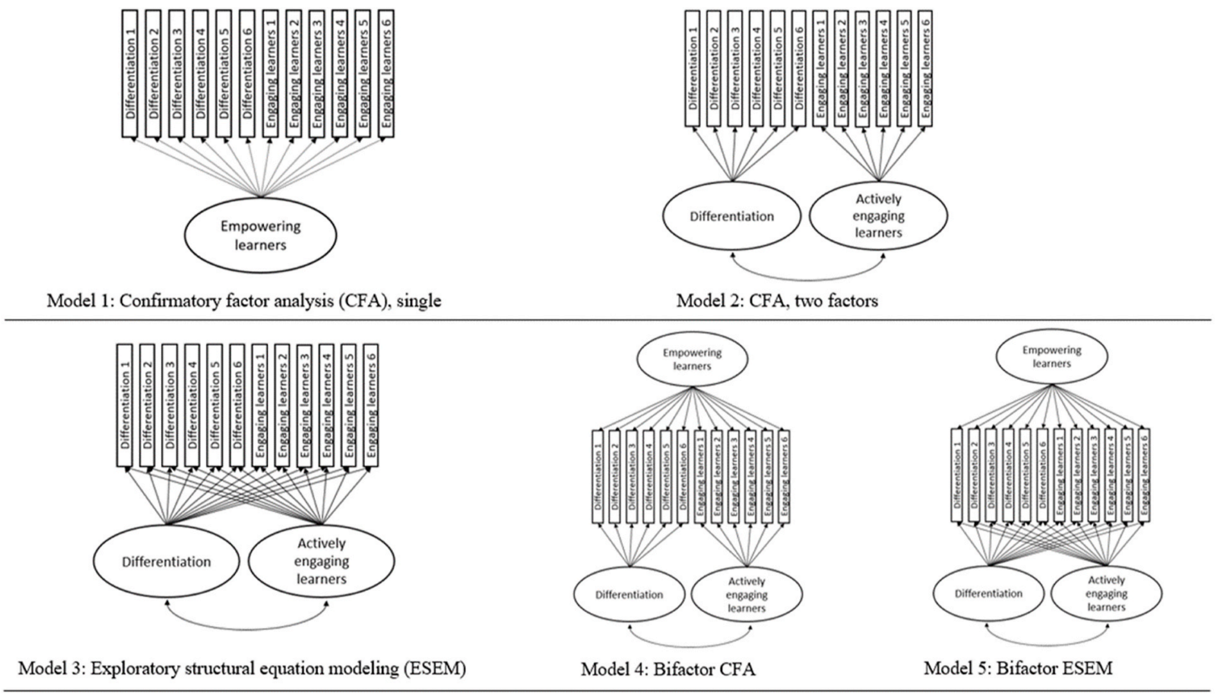

Fig. 1. Measurement models of teachers' digital competence-related beliefs for the dimension empowering learners.

estimates of factor correlations (Gu et al., 2020; Marsh et al., 2014). In the next step, we tested a bifactor confirmatory factor analysis (Model 4, bifactor CFA) to test whether the general factor empowering learners and the subdimensions differentiation and actively engaging learners define the structure. In this case, the general factor empowering learners represents the variance shared among all items, and the subdimensions differentiation and actively engaging learners include the exclusive variance of items and, thus, are unrelated to the general factor. In the last step, we tested a bifactor exploratory structural equation model (Model 5, bifactor ESEM). For the subsequent validation, we contrasted all models using the model fit indices, the χ^2 difference test, and the theoretical meaningfulness.

According to Kline (2015), we report $\chi 2$, CFI, RMSEA, and SRMR as fit indices. Values of CFI >0.90, RMSEA <0.08, and SRMR <0.08 indicate acceptable model fit (Awang, 2012). In order to compare the five tested models and select the best factor structure solution, the $\chi 2$-difference test was used (Satorra & Bentler, 2010). All tested models are depicted in Fig. 1.

The most appropriate statistical and theoretically supportive factor structure solution was then used to examine the relations between the competence-related beliefs in empowering learners, differentiation, and actively engaging learners and the teachers' reported use of digital technologies to enhance the instructional quality in class. To this end, we tested a structural equation model with latent factors. Teachers' job experience was included in the analysis as a covariate.

4. Results

4.1. Factorial structure of teachers' digital competence-related beliefs for the dimension empowering learners

To examine the factorial structure of teachers' digital competence-related beliefs for the dimension empowering learners, several structural equation models were tested following the approach of Fadda et al. (2020). The fit indices of the tested models are presented in Table 2. In Model 1, a confirmatory factor analysis (CFA) with a single factor representing the competence dimension empowering learners failed to confirm the assumed one-factor structure due to an insufficient model fit. In Model 2, the second CFA was conducted including the two subdimensions differentiation and actively engaging learners simultaneously. Just like the one-factor CFA, the two-factor CFA failed to achieve an acceptable level of fit to the data. However, Model 3 (ESEM), Model 4 (bifactor CFA), and Model 5 (bifactor ESEM) did show a sufficient fit to the data. The $\chi 2$-difference test (Satorra & Bentler, 2010) indicated the bifactor CFA (Model 4) and the bifactor ESEM model (Model 5) as the best solutions in comparison to the ESEM (Model 3). The results of the $\chi 2$-difference test are shown in Table 1. In addition to the model fit results, we further evaluated each factor solution based on its theoretical meaningfulness. Given that the DigCompEdu framework defines the subdimensions differentiation and actively engaging learners as

Table 2
Model fit results and comparison of all measurement models using the χ2-difference test (Satorra & Bentler, 2010).

Model		χ2	df	CFI	SRMR	RMSEA	χ2 difference test	TRd (△df)
1	Confirmatory factor analysis with a single factor (CFA) (H1a)	221.266	54	0.83	0.06	0.16		
2	Confirmatory factor analysis with two factors (CFA) (H1b)	202.273	53	0.89	0.05	0.15	1 vs. 2	7.52 (1)**
3	Bifactor CFA (H1c)	114.268	42	0.93	0.04	0.12	1 vs. 3	82.96 (10)***
							2 vs. 3	74.05 (11)***
							4 vs. 3	5.19 (1)*
4	Exploratory structural equation model (ESEM) (H1d)	122.862	43	0.92	0.04	0.13	1 vs. 4	78.65 (11)***
							2 vs. 4	70.19 (10)***
5	Bifactor ESEM (H1e)	96.197	33	0.94	0.03	0.13	1 vs. 5	106.86 (21)***
							2 vs. 5	93.89 (20)***
							3 vs. 5	20.79 (9)*
							4 vs. 5	27.54 (10)**

Note. CFA= Confirmatory factor analysis; ESEM = Exploratory structural equation model; χ2 = Robust chi-square test of exact fit; df = degrees of freedom; CFI = comparative fit index; SRMR = root mean square residual; RMSEA = root mean square error of approximation.

Table 3
Means, standard deviations, and bivariate Person correlations between competence-related beliefs regarding empowering learners and all variables.

Variables	M	SE	2	3	4	5	6	7	8
1 Empowering learners[a]	3.31	1.04	–	–	.48**	.55**	.43**	.10	.06
2 Differentiation[a]	3.18	1.07	–	–	.50**	.42**	.57**	.18	.12
3 Actively engaging learners[a]	3.46	1.07		–	.42**	.49**	.39**	.04	.02
4 Technology-enhanced cognitive activation	2.15	1.01			–	.70**	.67**	.30*	.12
5 Technology-enhanced supportive climate	2.32	0.98				–	.63**	.30*	.17
6 Technology-enhanced classroom management	2.97	1.23					–	.27*	.06
7 Gender[b]	1.25	0.43						–	.05
8 Job experience[c]	8.29	9.13							–

Note. N = 145 teachers; M: means; SE: standard error of the means; a: digital competence-related beliefs; b: 1 = female, 2 = male, c: in years, including the preparatory service.
*p < 0.01, **p < 0.001.

distinct, we decided to proceed with the bifactor CFA model (Model 4) as the most comprehensive model for teachers' competence-related beliefs. The standardized factor loadings as well as the omega coefficients (McDonald, 1999) of the bifactor CFA are reported in Table 1.

Bivariate Pearson correlations between all variables and descriptive statistics are reported in Table 3. Results showed that the measures that assessed digital competence-related beliefs regarding the dimension empowering learners and the subdimensions differentiation and actively engaging learners were positively and highly significantly associated with each other. The digital competence-related beliefs were also highly significantly and positively correlated with the teachers' reported use of digital technologies for cognitive activation, a supportive climate, and classroom management in class. Neither empowering learners, differentiation nor actively engaging learners was associated with teacher gender or job experience.

4.2. Structural equation model

The standardized coefficients of the structural equation model are depicted in Fig. 2. The structural equation model achieved an acceptable model fit: $\chi^2 = 365.802$, df = 201, CFI = 0.93, TLI = 0.91, RMSEA = 0.08 und SRMR = 0.05. Positive relations were observed between the general factor and all three digital instructional quality dimensions as reported by the teachers. The results showed that digital competence-related beliefs regarding the subdimension of differentiation are positively related to the teacher-reported use of digital technologies to enhance the instructional quality dimensions of cognitive activation and classroom management. However, there were no significant relations between the digital competence-related beliefs regarding the dimension of actively engaging learners and the implementation of instruction quality with digital technologies as reported by the teachers.

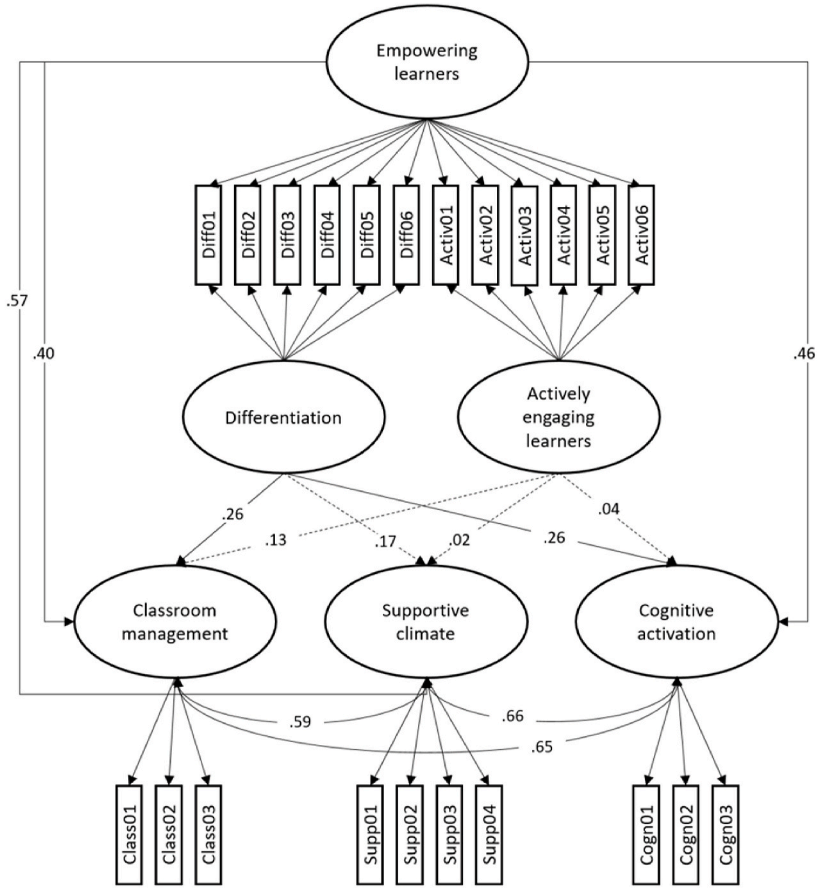

Fig. 2. : Results of the structural equation model.
Note. A solid line displays a significant path between latent variables, and a dotted line displays a non-significant path. Standardized path coefficients are provided in the figure.

5. Discussion

The objective of this study was twofold: Firstly, this study aimed to test the factorial structure of a measure that assesses teachers' digital competence-related beliefs for the dimension of empowering learners and its subdimensions of differentiation and actively engaging learners, based on the DigCompEdu framework (Redecker & Punie, 2017). Secondly, it examined the relations between these digital competence-related beliefs and teachers' reported use of digital technologies to enhance instructional quality (classroom management, cognitive activation, and a supportive climate).

5.1. Factorial structure of teachers' digital competence-related beliefs in the dimension empowering learners

Although several frameworks in the context of teachers' digital competencies highlight the importance of teachers' pedagogical competencies, the conceptualization of this competence dimension is hardly defined in detail (Skantz-Åberg et al., 2022). The DigCompEdu framework differentiates and describes various pedagogical competence dimensions that are necessary to integrate digital technologies in teaching (Redecker & Punie, 2017), but only few studies exist that empirically validated the defined competence dimensions of the framework (Antonietti et al., 2022; Ghomi & Redecker, 2019; Lucas et al., 2021).

The results of the present study revealed that two factors representing the subdimensions differentiation and actively engaging learners can be distinguished, as well as a general factor representing the overall competence-related beliefs regarding empowering learners (Hypothesis 1). It seems that the subdimensions incorporate a number of shared competencies for implementation that map to the general factors. The solution of the factor structure corresponds to the theoretical background of the DigCompEdu framework, which combines the interplay of the two subdimensions into one general dimension. However, we also showed that certain proportions cannot be combined and should be considered individually. In comparison to other competence self-assessment scales, the measurement items we developed describe specific teaching actions as differentiation and actively engaging learners using digital technologies rather than general self-efficacy items for using technologies.

5.2. Relations between teachers' digital competence-related beliefs and self-reported use of digital technologies for implementing instructional quality

Previous studies were able to demonstrate relationships between teachers' use of digital technologies for differentiation (Schmid et al., 2022) and for learner engagement and their support for instructional quality (Autenrieth et al., 2018; Tang et al., 2022; Wekerle et al., 2022). However, few studies have examined the relations between teachers' competence-related beliefs regarding these subdimensions and their use of digital technologies to enhance instructional quality (Backfisch et al., 2021). In the present study, we address this research gap and examine the extent to which teachers' digital competence-related beliefs regarding empowering learners, differentiation, and actively engaging learners are related to teacher-reported implementation of instructional quality by using digital technologies.

As expected (Hypothesis 2a), our findings demonstrated that teachers who felt highly competent using digital technologies to differentiate learning materials and tasks with respect to students' level of competence actively used digital technologies to enhance cognitive activation in class. Likewise, the results showed that competence-related beliefs regarding differentiation relate to the teacher-reported use of digital technologies to implement classroom management. However, no relation between teachers' competence-related beliefs regarding differentiation and a supportive climate could be observed. The results may indicate that differentiation is particularly important in designing and adapting learning tasks to the individual needs and competence levels of students so that they are cognitively activated and can fully utilize the learning time. In this case, students may not need additional teacher support to such an extent if the materials and tasks are already optimally adapted to their competence levels. The hypothesis can thus only be partially confirmed, since relations could only be shown between the teachers' digital competence-related beliefs regarding differentiation and the use of digital technologies for cognitive activation and classroom management.

Unexpectedly, the hypothesized positive relation between teachers' digital competence-related beliefs regarding actively engaging learners and the use of digital technologies to implement cognitive activation in class could not be confirmed (Hypothesis 2b). Although previous findings (Autenrieth et al., 2018; Tang et al., 2022; Wekerle et al., 2022) have shown that teachers' digital instructional strategies to activate students in class are positively related to indicators of cognitive activation, we were unable to confirm this with respect to teachers' digital competence-related beliefs. This result can possibly be explained by the teachers' self-assessment. It is possible that the participating teachers struggled to assess their own competence-related beliefs in this very specific subdimension of students' active engagement and learning, especially when relating it to the use of digital technologies. The results of the structural equation model suggest that when both digital competence-related beliefs are considered together in one model, differentiation has a higher relevance for the implementation of instructional quality than actively engaging learners.

Considering the general factor representing shared competence in the dimension empowering learners, the results show that higher digital competence-related beliefs regarding empowering learners are related to a higher/more frequent teacher-reported use of digital technologies to enhance all three dimensions of instructional quality. Since the competence-related beliefs about empowering learners involves perceived competence for the subdimensions differentiation and actively engaging learners, it can possibly be concluded that the overarching competence-related beliefs regarding this competence dimension are crucial for implementing instructional quality using digital technologies. Interestingly, it can be observed that the path coefficients between the dimension of empowering learners and the teacher-reported use of digital technologies to implement cognitive activation, a supportive climate, and classroom management are stronger than the path coefficients between the subdimension differentiation and cognitive activation and classroom management. It can therefore be concluded that more significant competencies for the implementation of instructional quality are measured in the dimension empowering learners, but that specific competencies of the dimension differentiation also explain instructional quality. These results support our assumption that it is not the consideration of independent subdimensions of competence-related beliefs, but the combination of various subdimensions that explains instructional behavior.

5.3. Limitations and future directions

Since the aim of this study was to develop and examine the factorial structure of a measure instrument to assess teachers' digital competence-related beliefs, the selective sampling as an influencing factor needs to be considered. The teachers were recruited via social media and online newsletters. It is possible that teachers who participated in the online survey have an affinity for digital technologies and are interested in the development of digital competencies in teaching. Moreover, the sample is quite small, with 145 participating teachers, and the majority of teachers had little teaching experience (an average job experience of 8.29 years) at the moment of participating in the survey. Future studies should include a larger and more heterogeneous group of teachers including different levels of experience and education.

In the process of examining the factorial structure of teachers' competence-related beliefs in empowering learners, the bifactor confirmatory factor analysis (bifactor CFA) model represents the most comprehensive model. However, it needs to be noted that neither the bifactor CFA model nor any of the other four tested models correspond to the proposed cutoff value of the RMSEA value $<$ .08 (Awang, 2012). Although the RMSEA value of the tested bifactor CFA ($>$0.10) can indicate poor fit (Browne & Cudeck, 1993), the literature suggests that not a single fit index but a combined analysis of various fit indices should be considered to get an overall evaluation of the model fit (Hair et al., 2017). The other fit indices of the bifactor CFA model, like the CFI value ($<$0.90), indicate a good fit of the model and Lai and Green (2016) suggest to not disregard a model that presents inconsistent results for RMSEA and CFI. Moreover, various aspects of the analytic situation can affect fit indices, for example, the RMSEA value is sensitive to sample size (Hu & Bentler, 1999). Therefore, Hu & Bentler (1999) state that the "RMSEA [is] less preferable when sample size is small (e.g., $N < 250$)", as is the case in this study. Accordingly, while replication studies with a larger sample size should be conducted to verify the model fit, we still believe that the conclusions drawn from the present study are justified.

Although the present study presents significant results for teachers' digital competence-related beliefs regarding empowering learners, differentiation, and actively engaging learners and their relations to the use of digital technologies to implement instructional quality in class, the cross-sectional design of the study needs to be considered a limitation. Because of the cross-sectional design, only significant relations can be stated, but no causal effects. A longitudinal design would allow an investigation of the causal effects of digital competence-related beliefs on instructional quality dimensions.

The factor structure of teachers' digital competence-related beliefs regarding differentiation and actively engaging learners revealed a general factor representing the overall competence-related beliefs regarding empowering learners. Hence, future research should address the question of to what extent teachers need specific and/or general competence-related beliefs to be able to implement instructional quality using digital technologies. Moreover, only competence-related beliefs regarding empowering learners were considered in this study. For future research, the development of additional measures assessing competence-related beliefs in further dimensions is planned.

Finally, it needs to be considered that the data on the digital competence-related beliefs as well as on the use of digital technologies to enhance instructional quality were collected through self-reports from the participating teachers. Self-reports can carry the risk that the participants over- or underestimate their competencies. Accordingly, digital competence-related beliefs and knowledge tend to show little correspondence (Hämäläinen et al., 2021). However, other studies using self-reports were able to achieve valid results concerning teachers' digital competence (Scherer et al., 2017). Although there are hardly any measurement instruments that assess teachers' digital competence and instructional quality based on objective tests (Rubach & Lazarides, in press; see Baier & Kunter, 2020; Lachner et al., 2019 for exceptions), external sources of information, like classroom observations or videography, should be included in future investigations to capture in-depth knowledge of effective teaching with digital technologies.

6. Conclusions

Based on the DigCompEdu framework (Redecker & Punie, 2017), we identified two specific subdimensions and one general dimension of teachers' digital competence-related beliefs: differentiation, actively engaging learners, and the overarching dimension empowering learners. The developed items allow us to assess the extent to which teachers believe they are capable of mastering learner-centered teaching actions using digital technologies. In addition, the study shows that teachers who believe they are competent in using digital technologies to differentiate learner tasks and material actively used digital technologies to implement classroom management and cognitive activation. Furthermore, the overall digital competence-related beliefs regarding empowering learners were related to teacher-reported use of digital technologies to enhance all three dimensions of instructional quality. In conclusion, we show that teachers who feel able to use digital technologies in class to empower learners, report that they use digital technologies in their teaching to enhance classroom management, cognitive activation, and supportive climate. This lends additional support to the validity of the DigCompEdu framework in that its competence dimensions are suited to predict features of high-quality teaching with digital technology. This insight is relevant for teacher education, as it suggests teaching digital pedagogical competencies in an integrative way. In addition, the results highlight the importance of teachers' competence-related beliefs, particularly in relation to instructional behavior. Accordingly, pre-service teachers should have access to learning opportunities during teacher education in which they can precisely reflect on their digital competence-related beliefs as well as the actual competencies underlying these beliefs in empowering learners in connection with instructional behavior. Moreover, given the association between these competence-related beliefs and high-quality instruction, professional development measures should be targeted towards enhancing these specific competencies that link pedagogy to technology use rather than enhancing technological knowledge, for instance. The developed measures can be used to offer professional development courses adaptively as a function of teacher's individual competence profile.

Credit author statement

Isabell Runge: Conceptualization, Investigation, Methodology, Formal analysis, Writing – original draft Rebecca Lazarides: Conceptualization, Investigation, Methodology, Formal analysis, Writing – original draft, Charlott Rubach: Conceptualization, Methodology, Resources, Writing – review & editing, Dirk Richter: Conceptualization, Methodology, Writing – review & editing, Katharina Scheiter: Conceptualization, Methodology, Writing – review & editing.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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