Education and Information Technologies (2023) 28:2845–2867
https://doi.org/10.1007/s10639-022-11274-3

Does teacher's data literacy and digital teaching competence influence empowering students in the classroom? Evidence from China

Ruyi Lin[1] · Junfeng Yang[1] · Feng Jiang[1] · Jiaping Li[1]

Received: 20 June 2022 / Accepted: 2 August 2022 / Published online: 2 September 2022

Abstract

With the digital transformation of education, data and digital technologies are regarded as the driving forces for teaching innovation. Teachers' data literacy and digital teaching competence are becoming increasingly important for empowering students' digital capacity, ethically technology usage, and collaboration or communication skills in the classroom. Therefore, whether teachers' data literacy and digital teaching competence can empower students in the classroom needs to be explored. This study aims to reveal the relationship between teacher's information communication technology (ICT) attitude, ICT skills, data literacy, digital teaching competence and empowering students. The data were collected from an online self-assessment scale which included a total of 629 K-9 teachers who participated in this study. Using SPSS and AMOS, a model was built by using Structural Equation Models to explain and predict the relationships. The results indicated that: (a) ICT attitude had no significant impact on digital teaching competence, and ICT skills significantly predicted digital teaching competence, but neither ICT attitude nor skills had a significant direct impact on empowering students; (b) data literacy significantly predicted digital teaching competence and had a significant direct impact on empowering students; (c) digital teaching competence, as dominant mediator in ICT attitude, ICT skills and data literacy, strongly predicted empowering students. The findings provided valuable evidence for teachers, policymakers, administrators, teacher educators, and teachers to better reimagine the teachers' digital teaching competence. In the future, the teachers' digital teaching competence should become the top priority in teacher ICT training, which was the most direct influencing factor for empowering students.

Keywords Digital teaching competence · Data literacy · Empowering students · ICT attitude · ICT skills

✉ Junfeng Yang
yjf@hznu.edu.cn

[1] Jing Hengyi School of Education, Hangzhou Normal University, Hangzhou, China

1 Introduction

Under COVID-19 pandemic, the digital transformation of education is accelerated and became the most important challenge and global trend (UNESCO IITE, 2022). As society going digital, digital technologies and data had the potential to transforming education to cultivate student's new skills required by the changing and uncertain world (OECD, 2019). Facing the challenges of digital transformation, teachers need to integrate digital technologies and data into their practice in the classroom. Digital teaching competence implies the acquisition of a set of skills, knowledge and attitude that the teacher must possess for the technical, pedagogical and didactic incorporation of information and communication technologies (ICT) in educational contexts (Cabero-Almenara et al., 2021a). However, what factors will affect teacher's digital competence remains a topic of debate (Engen, 2019; Scherer et al., 2017). Under the digital transformation of education, teachers' digital competence building is highly concerned by policy makers, international organizations and researchers, which has proposed some conceptual framework, such as the ICT competence framework for teachers (UNESCO IITE, 2018), the European Digital Competence Framework (DigCompEdu) (Redecker, 2017), ISTE standards for educators (ISTE, 2017), Technological Pedagogical Content Knowledge Framework (TPACK) (Koehler & Mishra, 2009) and etc. Current research mainly focused on developing frameworks for teachers and assessing teachers' digital competence (Lucas et al., 2021; Lachner et al., 2019).

Existing studies indicated that data use could improve teachers' teaching practices (Miller-Bains et al., 2022; Mandinach & Jackson, 2012) and lead to promote students learning and achievements (Schildkamp, 2019; Lai & McNaughton, 2016; Marsh, 2012). More and more educators are expected to use data to support their teaching (Miller-Bains et al., 2022). The competence, to transform information into actionable instructional knowledge and practices by collecting, analyzing, and interpreting all types of data (assessment, school climate, behavioral, snapshot, longitudinal, moment-to-moment, and so on), was called data literacy for teaching (Gummer & Mandinach, 2015). Therefore, data literacy was an essential skill for educators when making decisions about student progress (Trantham et al., 2021; Mandinach & Gummer, 2016a). However, there were only few research on data literacy for teaching that mainly focused on the following two main categories, the first of which were studies dedicated to assessing teachers' data literacy by developing scales (Trantham et al., 2021; Shreiner & Dykes, 2021), and other studies explored the teaching effects on student learning achievement by using data in teaching (Van Geel et al., 2016).

The digital transformation of education has put forward higher requirements and expectations for teachers. Not only should teachers use digital technologies in teaching practice, but they should also empower students to use technology for learning and improve their learning capacity (Lucas et al., 2021). However, few research could be found on exploring the influencing factors for teachers' empowering students' digital competence, ethically use technology, collaboration or communication skills in classroom. In addition, fewer studies examined

the relationship among teachers' digital teaching competence, data literacy, and empowering students. Therefore, this study aimed at developing a scale to discuss the relationship among teachers' ICT attitude, ICT skills, data literacy, digital teaching competence and empowering students. Another purpose of our study was to understand the underlying mechanism of how digital competence as the mediators impacted teacher to empower students. The findings have the potential to reveal the in-service teachers' status quo of ICT attitude, ICT skills, data literacy, digital teaching competence and empowering students.

2 Literature and hypotheses

2.1 ICT attitude

Teachers' digital competence are generally regarded as intertwining with their attitude towards technology (Spiteri & Rundgren, 2020). Teachers' attitude about ICT will influence an individual's behaviour and play an important role in their learning, so ICT attitude is considered important (Funkhouser & Mouza, 2013; Sang et al., 2012; Prestridge, 2012; Van Dinther et al., 2011; Van Braak et al., 2004). ICT attitude is defined as general feelings of support or opposition to the use of ICT (Yuen & Ma, 2008). Based on previous research, teachers had a generally positive attitude towards the use of digital technologies in teaching who were confident in their ICT skills (Fraillon et al., 2020) and more likely to apply ICT to their teaching (Admiraal et al., 2017). However, teachers who have a negative attitude towards the use of ICT in the classroom are simply unlikely to use ICT (Mahat et al., 2012). In addition, some studies found that teachers' ICT attitude may affect their ICT skills (Wang & Zhao, 2021), change teachers' teaching methods (Wu et al., 2019), and influence the competence to effectively use ICT in teaching (Hernández-Ramos et al., 2014; Wen & Shih, 2008). Therefore, ICT attitude is a determinant of the integration of digital technologies and their effective and innovative use in the teaching process (Eickelmann & Vennemann, 2017), which further promotes teachers' digital teaching competence. For example, Hernández-Ramos et al. (2014) highlighted the role of teachers' ICT attitude in the use of ICTs and found that teachers' digital teaching competence were relatively strong with positive ICT attitude. However, Hämäläinen et al. (2019) found that despite this positive attitude among teachers, there were still significant differences in teachers' digital competence. Wang & Zhao (2021) and Ndibalema (2014) also confirmed this conclusion. Since literature studies show that the impact of ICT attitude on digital teaching competence is inconsistent, it is necessary to explore the relationship between ICT attitude and digital teaching competence.

2.2 ICT skills

The potential of digital technologies in learning and teaching needs to be unleashed, everyone needs to develop digital skills, and basic digital skills should be part of

the core transferable skills that any citizen should be able to develop (European Union, 2020). Research on the digital skills of teachers always paid attention to ICT skills, which refered to the use of ICT (Fernández-Batanero et al., 2020; Tondeur et al., 2018; Van Laar et al., 2017). In this study, ICT skills include the use of hardware devices (e.g., computers, projectors or visualizers) and software application (e.g., social media, web platforms or discipline-specific teaching tools). Previous research found that the utilization of hardware devices, such as projectors (Aslan & Zhu, 2017) and interactive whiteboards (Aldhafiri, 2020), and applications, such as social media (Robles Moral & Fernández Díaz, 2021), MOOCs (Castaño-Muñoz et al., 2018) and virtual environments (Yeung et al., 2012), would change the traditional teaching methods of teachers, which would have an impact on teachers' digital teaching competence, thereby improving student learning. Thus, ICT skills could be seen as a requisite for taking advantage of technology-enhanced teaching practices (Hämäläinen et al., 2021; Knezek & Christensen, 2016). For example, Hatlevik (2017) found that assessing teachers' self-efficacy in basic ICT skills could predict changes in teachers' digital competence. In addition, we also concern about whether the improvement of ICT skills will improve teachers' data literacy.

2.3 Data literacy

With the increasing development of educational analytics technology (Ndukwe & Daniel, 2020) and the digitization of education (Perrotta & Williamson, 2018), educational data literacy seems to have spread among many educators in the K-12 education field (Raffaghelli & Stewart, 2020). Regarding the debate over digital competence, the EU COM incorporated data literacy into its DigComp framework (Carretero et al., 2017). However, the framework mainly focused on the search, retrieval, and interpretation of data, but less on creative analysis and use of data (Raffaghelli & Stewart, 2020). Moreover, scholars from all over the world committed to building a series of frameworks to assess teachers' educational data literacy (Papamitsiou et al., 2021; Kennedy-Clark et al., 2021; Kippers et al., 2018; Mandinach & Gummer, 2016b). Most dimensions of teachers' data literacy in frameworks included the following three dimensions: data collection, data analysis, data evaluation, and data application. In addition, more and more researchers tried to explore how to use data to support teachers' teaching decisions to personalize the teaching process (Fuchs et al., 2021; Powell et al., 2021).

Existing studies showed that data use in classroom had a positive impact on student learning (Marsh, 2012). However, there was less research on whether teachers' data literacy improved students' digital competence. Abrams et al. (2021) argued that this disconnect between data use practices and student learning improvement was partly attributable to limit teacher preparation and professional development. Some studies showed that teachers' use of data in the classroom benefited teachers to improve their classroom teaching (Coburn & Turner, 2011). More studies, under the context of digital competence, only assessed the level of data literacy (Reisoğlu & Çebi, 2020; Zhao et al., 2021). Past studies showed that teachers generally lacked adequate data literacy (Sun et al., 2016). In recent years, educators' data literacy

had improved significantly (Kippers et al., 2018). However, little research investigated the relationship between data literacy and digital teaching competence, which is necessary to discuss. In short, teachers' data literacy may be an important factor affecting teachers' digital teaching competence and empowering students.

2.4 Digital teaching competence

As ICT tools became a core part of teachers' daily work, teachers must rethink and change their previous education methods through technology (Zhao et al., 2021). The use of technology did not indicate high-quality teaching, but rather depended on how teachers integrated technology into their teaching (González et al., 2020). Teachers' digital teaching competence were key factors in enhancing their professional development and improving students' learning processes (Fernández-Batanero et al., 2020). Research also showed that teachers' digital teaching competence was key to integrating digital technologies into educational practice (Lázaro-Cantabrana et al., 2019), which would affect students. In today's classroom, teachers often needed to use digital technology to carry out teaching activities. However, in the process of teaching, teachers with poor digital teaching competence might not be able to take full advantage of ICT to promote students' knowledge (Guillén-Gámez et al., 2019). Disappointing students' learning outcomes were often associated with teachers' lack of ICT integration (Wu et al., 2019; Eteokleous, 2008). Previous studies showed that empowering students' digital competence could be enhanced by improving teachers' digital teaching competence, such as reusing instructional media and digital resources (Robles Moral & Fernández Díaz, 2021), developing teaching models with digital technologies (del Arco et al., 2021), and providing personalized learning support (Zhang et al., 2021). Therefore, this study argues that digital teaching competence may play an important role in empowering students.

2.5 Empowering students

Students' digital competence increasingly became a common concern of international education researchers (He et al., 2021; Mehrvarz et al., 2021). What's more, communication and collaboration skills were essential for survival in the twenty-first century (Silber-Varod et al., 2019), and students as a digital citizen, the responsible and ethical use of technology was increasingly valued (ISTE, 2016). How to promote these capacities in the classroom was the key for students to become responsible and capable people in the twenty-first century. In this study, empowering students refers to promoting students' digital capacity, ethics of technology utilization, students' collaboration and communication skills in classroom. Teachers should be able to access, create and use digital resources and media for teaching, moreover they should be able to utilize appropriate technologies to promote the development of students' digital competence (Alarcón et al., 2020). In recent years, the improvement of students' digital competence was considered as a positive impact on student engagement and academic burnout

(Wang et al., 2021; Heidari et al., 2021). However, some studies found that teachers were generally less competence of empowering students' digital competence (Istenic Starcic et al., 2018), ethically technology usage (Ribble & Miller, 2013), collaboration and communication (Llorent-Vaquero et al., 2020). For example, Hatlevik and Hatlevik (2018) found that only about half of teachers valued developing students' digital competence from the survey of 1158 teachers. Therefore, improving students' digital competence, ethically technology usage, collaboration and communication in classroom should become the key concern of teachers, that is, to empower students.

Existing research showed that teachers' ICT attitude and skills had an impact on students' digital competence (Eickelmann & Schulz-Zander, 2008). Lorenz et al. (2019) found that teacher attitude, Frequency of ICT use, ICT equipment, and ICT-related collaboration all had an impact on students' digital competence. Hatlevik and Hatlevik (2018) found that facilitating the use of ICT in teaching by teachers could indirectly facilitate teachers to improve students' digital competence. Kaarakainen et al. (2018) advocated ensuring that every student in Finnish schools had the best opportunity to learn digital skills by improving teachers' ICT skills. As professionals who dedicated to teaching, in addition to use digital technologies, teachers also needed to improve students' learning through well-founded pedagogy to improve their digital competence (Krumsvik, 2014; Redecker, 2017). Rubach and Lazarides (2021) mentioned that teachers, who believed themselves could use digital tools to communicate effectively with students and use such tools to solve complex problems, were more likely to be close to students and use digital technology to support students' learning effectively and directly.

2.6 The research hypothesis

Based on a literature review, this study aimed to explore the mediating role of digital teaching competence and their relationship with ICT attitude, ICT skills, data literacy, digital teaching competence, and empowering students. The following hypotheses and hypothesis research models were proposed (as shown in Fig. 1):

Hypothesis 1: teachers' ICT attitude positively predicted digital teaching competence.
Hypothesis 2: teachers' ICT skills positively predicted digital teaching competence.
Hypothesis 3: teachers' data literacy positively predicted digital teaching competence.
Hypothesis 4: teachers' digital teaching competence positively predicted empowering students.
Hypothesis 5: teachers' ICT attitude positively predicted empowering students.
Hypothesis 6: teachers' ICT skills positively predicted empowering students.
Hypothesis 7: teachers' data literacy positively predicted empowering students.
Hypothesis 8: teachers' ICT attitude positively predicted ICT skills.
Hypothesis 9: teachers' ICT skills positively predicted data literacy.

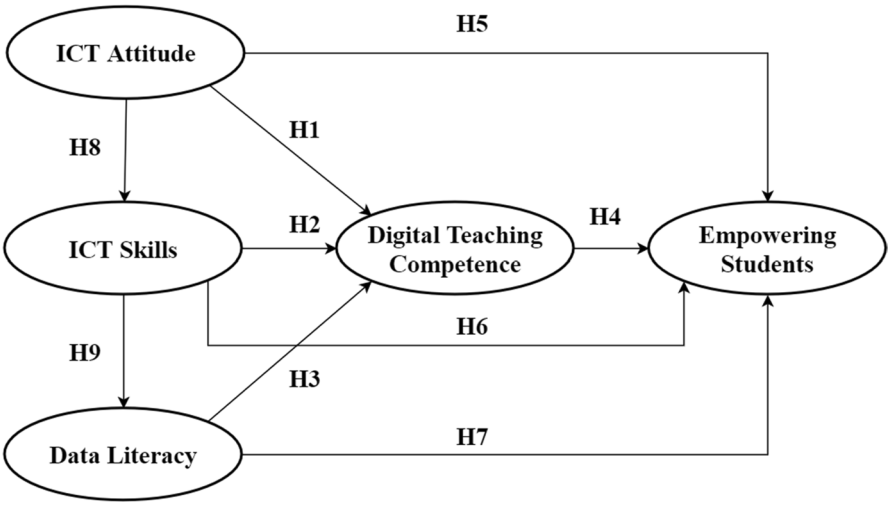

Fig. 1 Research model

3 Method

3.1 Participants

Participants in this study were teachers from 19 schools working in kindergartens, primary schools, secondary schools (K-9) in Binjiang District, Hangzhou, Zhejiang, China. These teachers were teaching in different subjects, but these teachers had all participated in training on the Implementation of the Information Technology Application Competence Improvement Project 2.0, which was a policy on large-scale training for improving teachers digital teaching competence in China. Data was collected through the online questionnaire platform Wenjuanxing (https://www.wjx.cn/), from 5 to 8 November 2021. The completion of the online questionnaire was voluntary and anonymous. A total of 629 valid questionnaires were compiled. Detailed demographic information about the participants was listed in Table 1.

3.2 Instrument development

The instrument used in this study consist of two parts. The first section contained demographic information of the participants, including gender, years of teaching experience, school level and educational background. The second section consisted of five subscales, including ICT attitude, ICT skills, data literacy, digital teaching competence and empowering students. These subscales encompassed validated and widely adopted measurements, containing 20 items: ICT attitude (3 items), ICT skills (4 items), data literacy (4 items), digital teaching competence (5 items) and empowering students (4 items). All items were designed with a 5-point Likert scale, ranging from 1 to 5 on a scale of strongly disagree to agree strongly. Table 2 showed the scale and references.

Table 1 Participants' demographic information

Characteristics	Categories	Frequency	Percentage (%)
Gender	Female	575	91.4
	Male	54	8.6
Years of teaching experience	1 - 5 years	213	33.9
	6 – 15 years	237	37.7
	16 - 25 years	129	20.5
	26 – 35 years	50	7.9
School level	Kindergarten	440	70.0
	Primary school	66	10.5
	Secondary school	123	19.6
Educational background	Vocational college	39	6.2
	Undergraduate	513	81.6
	Graduate	77	12.2

3.3 Data analysis

The data were analyzed using SPSS 26.0 and AMOS 24.0. First, a confirmatory factor analysis (CFA) was performed to assess the validity of latent variables, and Cronbach's alpha (α) was calculated to determine the internal consistency of all subscales in the instrument. Second, this study presented the descriptive statistics and correlations among the variables. Third, structural equation modeling (SEM) was performed to explore the relationship to test the hypotheses and calculate the mediator effect among the five latent variables, including ICT attitude, ICT skills, data literacy, digital teaching competence, empowering students.

4 Results

4.1 Instrument validation`

During the CFA, according to Lomax & Schumacker (2004), the factor loads for 20 items ranged from 0.712 to 0.950. Cronbach's alpha coefficients of subscale, including ICT attitude, ICT skills, data literacy, digital teaching competence and empowering students, were 0.864, 0.843, 0.929, 0.969 and 0.944, which indicated good internal consistency. The factor loads for each item, Cronbach's alpha and the detail for each subscale were shown in Table 3.

4.2 Descriptive statistics and correlations among the variables

The averages of ICT attitude, ICT skills, data literacy, digital teaching competence and empowering students were 4.556, 3.789, 3.691, 3.932, and 3.790 (Table 4). The high level of teachers' ICT attitude indicated that teachers had

Table 2 Survey instrument

Item	Description	References
IA1	I recognize the importance of the application of information technology (IT) in modern education.	Guillén-Gámez & Mayorga-Fernández (2020), Cabero-Almenara et al. (2021b)
IA2	I actively pay attention to the application and development of IT in education.	
IA3	I am willing to share with colleagues the experience and new discoveries about the application of IT.	
IS1	I solve common problems in multimedia teaching equipment applications.	Zhao et al. (2021), Sánchez-Cruzado et al. (2021)
IS2	I expertly use the information-based teaching equipment in the classroom (e.g., computers, projectors, visualizers).	
IS3	I expertly use at least one discipline-specific teaching tools (e.g., geometer's sketchpad, online maps, realistic experiments).	
IS4	I expertly use at least one social media and web platform to support students learning (e.g., e-mail, WeChat, MOOCs).	
DL1	I efficiently retrieve and access raw data from the teaching process (e.g., access to data, databases).	Papamitsiou et al. (2021), Carey et al. (2018)
DL2	I reasonably use statistical analysis software to process and analyze the obtained data (e.g., SPSS, Excel).	
DL3	I judge the source, the collection method, and the quality of data to ensure accuracy.	
DL4	I analyze data to support teaching decisions and improve teaching strategies.	
DTC1	I select digital medias and resources based on different teaching sessions.	Papamitsiou et al. (2021), Carey et al. (2018)
DTC2	I use digital media based on different teaching sessions to enhance my teaching practice.	
DTC3	I provide targeted study recommendations based on the student level.	
DTC4	I choose the appropriate information-based teaching mode (e.g., project-based learning, resource-based learning, blended learning).	
DTC5	I provide effective digital technologies to support communication, collaboration, and exploration for students (e.g., learning guidance, learning process).	
ES1	I foster students' understanding of legal and ethical implications in information social in the classroom.	Redecker (2017), Alarcón et al. (2020)
ES2	I provide the learning chance for students in using digital technologies to facilitating students' digital capacity.	
ES3	I provide the collaborative chance for students in using digital technologies.	
ES4	I encourage students to communicate in using digital technologies based on their learning needs (e.g., using online meetings, discussion forums).	

IA, ICT attitude; *IS*, ICT skills; *DL* Data literacy, *DTC* Digital teaching competence, *ES* Empowering students

a positive attitude and belief in the integration of information technology into teaching. The Pearson product-moment correlation coefficient between these variables ranged from 0.367 to 0.750, indicating a significant correlation among all variables.

We calculated descriptive statistics, including gender, years of teaching experience, school level, and educational background in five variables (Table 5). Then, the level of significant differences was also presented. The data showed that no significant differences were found between sex and educational background across five variables ($p > 0.05$). However, both the years of teaching experience and the school level found significant differences in five dimensions ($p < 0.05$). The data showed that no significant differences were found between gender and educational background across five variables ($p > 0.05$). However, both the years of teaching experience and the school level were found significant differences in five variables ($p < 0.05$).

4.3 Assessment of the model fit

The fitness of the measurement and study models was assessed (Table 6) and the results showed that the fitness of both models was acceptable compared to the criteria proposed by Hu and Bentler (1999).

4.4 Hypotheses testing

Significant correlations among ICT attitude, ICT skills, data literacy, digital teaching competence, and empowering students indicated that these variables were highly correlated. To find the structural relationship between all variables, SEM was adopted to test the significance of each path. The non-normalized coefficient (B), normalized coefficient (β), standard error (SE), t-value, and R^2 (explanatory power of the independent variables) were analyzed to test the hypothesis. The results showed that seven of the nine hypotheses were supported (Table 7 and Fig. 2). It was found that ICT skills ($\beta = 0.39$, $p = 0.000$) and data literacy ($\beta = 0.47$, $p = 0.000$) had a significant positive impact on digital teaching competence, supporting hypothesis 2 and hypothesis 3. Digital teaching competence ($\beta = 0.56$, $p = 0.000$) and data literacy ($\beta = 0.26$, $p = 0.000$) were found to have significant positive effects on empowering students, supporting hypothesis 4 and hypothesis 7. ICT attitude had significant positive effects on ICT skills ($\beta = 0.57$, $p = 0.000$), supporting hypothesis 8. ICT skills had significant positive effects on data literacy ($\beta = 0.74$, $p = 0.000$), supporting hypothesis 9. However, there were no significant direct impact of ICT attitude on digital teaching competence ($\beta = 0.00$, $p = 0.915$) and empowering students ($\beta = 0.02$, $p = 0.508$), rejecting hypothesis 1 and hypothesis 5. In addition, it was not found that ICT skills had a significant direct impact on empowering students ($\beta = 0.04$, $p = 0.482$), rejecting hypothesis 6.

Table 3 Results of CFA

Latent variable	Item	Mean	SD	Factor Loadings	α
IA	IA1	4.71	0.574	0.713	0.864
	IA2	4.43	0.814	0.900	
	IA3	4.53	0.749	0.880	
IS	IS1	3.69	0.902	0.816	0.843
	IS2	3.93	0.839	0.819	
	IS3	3.43	1.053	0.711	
	IS4	4.11	0.931	0.720	
DL	DL1	3.85	0.899	0.778	0.929
	DL2	3.63	0.936	0.866	
	DL3	3.59	0.963	0.936	
	DL4	3.70	0.923	0.925	
DTC	DTC1	3.98	0.819	0.925	0.969
	DTC2	3.95	0.829	0.920	
	DTC3	3.97	0.814	0.929	
	DTC4	3.87	0.880	0.941	
	DTC5	3.89	0.848	0.924	
ES	ES1	3.90	0.951	0.834	0.944
	ES2	3.77	0.987	0.913	
	ES3	3.79	0.966	0.945	
	ES4	3.70	1.015	0.898	

IA, ICT attitude; *IS*, ICT skills; *DL* Data literacy, *DTC* Digital teaching competence, *ES* Empowering students. $N = 629$

Table 4 Correlation coefficient

Latent variable	M	SD	Correlation coefficient			
			IA	IS	DL	DTC
IA	4.556	0.638				
IS	3.789	0.770	0.467**			
DL	3.691	0.845	0.435**	0.677**		
DTC	3.932	0.790	0.402**	0.675**	0.732**	
ES	3.790	0.907	0.367**	0.586**	0.679**	0.750**

IA, ICT attitude; *IS*, ICT skills; *DL* Data literacy, *DTC* Digital teaching competence, *ES* Empowering students. $N = 629$; $^{**}p < 0.01$

4.5 Indirect and total effects among the variables

After removing insignificant pathways, indirect effect and 95% confidence intervals among teachers' ICT attitude, ICT skills, data literacy, digital teaching competence and empowering students were recalculated (Table 8). The results showed that the indirect effect of ICT attitude on empowering students was weighted at 0.699, which

Table 5 Descriptive statistics of IA, IS, DL, DTC and ES

	Categories	N	AT	TE	DL	TC	ES
Gender	Female	575	4.555 (0.645)	3.903 (0.850)	3.713 (0.796)	3.945 (0.788)	3.792 (0.908)
	Male	54	4.562 (0.564)	3.778 (0.762)	3.689 (0.850)	3.793 (0.805)	3.769 (0.901)
	Sig.		0.612	0.141	0.433	0.352	0.562
Years of teaching experience	1 - 5 years	213	4.4523 (0.709)	3.9390 (0.680)	3.9249 (0.756)	4.0178 (0.711)	3.9296 (0.780)
	6 – 15 years	237	4.6695 (0.553)	3.8608 (0.789)	3.7236 (0.860)	4.0262 (0.827)	3.8228 (0.966)
	16 - 25 years	129	4.5323 (0.610)	3.5426 (0.808)	3.3857 (0.881)	3.7209 (0.822)	3.5562 (0.975)
	26 – 35 years	50	4.5200 (0.697)	3.4400 (0.701)	3.3300 (0.682)	3.6640 (0.703)	3.6400 (0.821)
	Sig.		0.004**	0.000***	0.000***	0.000***	0.001**
School level	Kindergarten	440	4.627 (0.592)	3.840 (0.713)	3.743 (0.802)	3.991 (0.756)	3.821 (0.905)
	Primary school	66	4.556 (0.559)	3.985 (0.757)	3.879 (0.807)	4.088 (0.700)	3.985 (0.810)
	Secondary school	123	4.304 (0.767)	3.498 (0.895)	3.407 (0.949)	3.636 (0.883)	3.575 (0.932)
	Sig.		0.000***	0.000***	0.000***	0.000***	0.005**
Educational background	Vocational	39	4.581 (0.523)	3.821 (0.588)	3.660 (0.648)	3.923 (0.756)	3.827 (0.839)
	Undergraduate	513	4.568 (0.635)	3.784 (0.797)	3.665 (0.872)	3.937 (0.801)	3.788 (0.932)
	Graduate	77	4.463 (0.709)	3.805 (0.670)	3.883 (0.723)	3.904 (0.737)	3.783 (0.773)
	Sig.		0.394	0.94	0.104	0.941	0.965

IA, ICT attitude; *IS*, ICT skills; *DL* Data literacy, *DTC* Digital teaching competence, *ES* Empowering students. $N=629$; ***$p<0.001$; **$p<0.01$; *$p<0.05$

was co-mediated by ICT skills, data literacy and Digital teaching competence. The indirect effect of ICT skills on empowering students was weighted at 0.742, mediated by digital teaching competence. In addition, the direct effect of data literacy on empowering students was 0.26, and the indirect effect was 0.239, which was also mediated by digital teaching competence.

5 Discussion

5.1 Effects of teachers' ICT attitude and ICT skill on digital teaching competence and empowering students

While this study found that teachers had a high level of ICT attitude, we didn't find that teachers' ICT attitude had a significant impact on digital teaching competence (hypothesis 1). This was consistent with previous research (Wang & Zhao, 2021; Ndibalema, 2014). Hämäläinen et al. (2019) showed that a positive attitude towards ICT cannot necessarily led to effective technology integration. In addition, this study did not find that teachers' ICT attitude had a significant impact on empowering students (hypothesis 5). As a new generation of teachers become more adaptable to and benefit more from technology, it might be easier than ever to recognize the usefulness of ICT in education (Wang & Zhao, 2021). Based on the above two rejected hypotheses, we can explain that teachers still had a long way to translate ICT attitude into digital teaching competencies. Teachers needed to invest more time and effort in integrating technology into teaching. However, the burden of teachers was heavy, teachers were tired of all kinds of work, and they did not have enough time to integrate technology and teaching. Therefore, the teachers' burden needed to be released and teachers needed to be given enough time and opportunities to improve their digital teaching competence. In addition, there is also a need to strengthen teachers' awareness of empowering students. Teachers should advocate that technology as part of the teaching process will help increase students' digital capacity and collaborative learning (Alfalah, 2018).

The hypothesis 2 was supported that teachers' ICT skills significantly positively impacted with digital teaching competence. As noted in previous studies, ICT skills were considered to play an important role in predicting teachers' digital teaching competence (Hämäläinen et al., 2021). However, this study did not find that ICT skills had a significant direct impact on empowering students (hypothesis 6). This finding means that the high ICT skills, such as using hardware and software,

Table 6 The goodness of fit indices for the measurement model and research model

Model	$\chi 2$	CMIN/df	TLI	CFI	RMR	RMSEA
Measurement model	633.394 (0.000)	3.959	0.956	0.963	0.0343	0.069
Research model	640.850 (0.000)	3.980	0.956	0.962	0.0357	0.069
Recommended criteria	$p > 0.05$	< 5.0	> 0.90	> 0.90	< 0.05	< 0.08

Table 7 The results of the direct effects hypotheses

Hypotheses	Hypothesized path	B	β	SE	Critical ratio	Result
Hypothesis 1	IA → DTC	−0.01	0.00	0.066	−0.106	Rejected
Hypothesis 2	IS → DTC	0.44	0.39	0.061	7.133***	Supported
Hypothesis 3	DL → DTC	0.40	0.47	0.040	9.933***	Supported
Hypothesis 4	DTC → ES	0.59	0.56	0.051	11.441***	Supported
Hypothesis 5	IA → ES	0.04	0.02	0.066	0.663	Rejected
Hypothesis 6	IS → ES	0.04	0.04	0.063	0.703	Rejected
Hypothesis 7	DL → ES	0.22	0.26	0.043	5.288***	Supported
Hypothesis 8	IA → IS	0.94	0.57	0.079	11.889***	Supported
Hypothesis 9	IS → DL	0.98	0.74	0.054	18.303***	Supported

IA, ICT attitude; *IS*, ICT skills; *DL* Data literacy, *DTC* Digital teaching competence, *ES* Empowering students. $N = 629$; ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

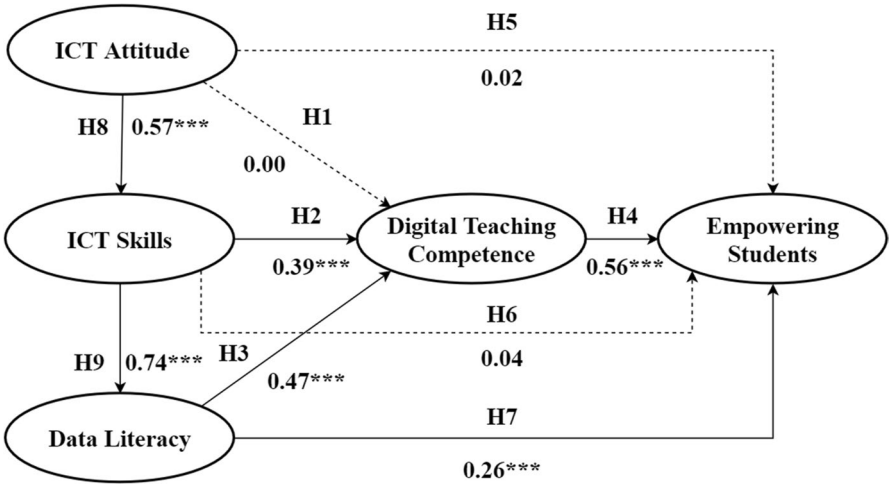

Fig. 2 Research model with its standardized coefficients. Dashed lines indicated no significant effects

can improve teachers' digital teaching competence, but it can't equal to empower student.

Although studies showed that hypotheses 1, 5, and 6 were rejected, it didn't mean that the role of ICT attitude and ICT skills in the digital teaching competence could be ignored. Because the study found that teachers' ICT attitude had a significant impact on ICT skills (hypothesis 8) and ICT skills had a significant impact on data literacy (hypothesis 9). Meanwhile, teachers' ICT attitude had an indirect impact on digital teaching competence, mediated by ICT skills and data literacy, ultimately influencing and empowering students. Similar to Hatlevik and Hatlevik (2018), the use of ICT in teaching by teachers could indirectly facilitate teachers to improve students' digital competence. Therefore, the fact that digital teaching competence was a

Table 8 The results of the indirect effects hypotheses

Dependent variable	Independent variable	Indirect effect	95% confidence interval		R^2
			Lower	Upper	
DL	IA	0.927***	0.338	0.497	0.558
DTC	IA	0.775***	0.337	0.492	0.641
	IS	0.388***	0.273	0.429	
ES	IA	0.699***	0.290	0.432	0.666
	IS	0.742***	0.582	0.697	
	DL	0.239***	0.201	0.359	

IA, ICT attitude; *IS*, ICT skills; *DL* Data literacy, *DTC* Digital teaching competence, *ES* Empowering students. $N = 629$; ***$p < 0.001$

combination with ICT attitude, ICT skills and data literacy, rather than ICT attitude, ICT skills or data literacy alone, which revealed the improvement of digital teaching competence was a complex process.

5.2 Effects of teachers' data literacy on digital teaching competency and empowering students

The results demonstrated the strong positive impact of teachers' data literacy on the development of digital teaching competencies (hypothesis 3), which was overlooked in previous studies. Existing studies found that data use can improve teachers' teaching practices (Miller-Bains et al., 2022; Mandinach & Jackson, 2012), but there was less research on whether data literacy can improve teachers' digital teaching competence. The overall digital transformation of education became an inevitable trend, and international organizations and countries emphasized the importance of data (UNESCO, 2022; UNICEF, 2021; World Bank, 2020; Scottish Government, 2021). Data-driven teaching would impact long-term pedagogical change (Boesdorfer et al., 2022). However, we found that teachers' data literacy was the worst in these five factors. This study examined the data literacy from four perspectives: data collection, data analysis, data evaluation and data application. Teachers currently was good at collect data and apply data. Teachers can effectively and smoothly obtain students' data in the teaching process and use the data. However, teachers' competence for data analysis and data evaluation was relatively weak. It can be seen that the teachers only use data as a daily practice to judge students subjectively by their years of teaching experience, while ignoring the major difficulty of using it to make more accurate decisions to improve teaching (Mandinach & Gummer, 2013; Means et al., 2010). Teachers needed to shift from experience to accurate decision in their teaching practice, using data analysis tools to enhance teaching effectiveness.

This study also found that teachers' data literacy had a direct impact weight of 0.26 on empowering students (hypothesis 7). Data literacy also had an indirect impact on empowering students, mediated by digital teaching competence. Previous studies ignored the relationship between data literacy, digital teaching competence and empowering students, so this was one of the contributions in this paper. This

evidence suggested that teachers' data literacy played a role in both digital teaching competence and empowering students. Specifically, improved data literacy can enhance teacher to empower students. In general, good data literacy can provide students with a more adequate data basis and provide students with more personalized learning support. Some studies showed that specialized training for teachers, which would help teachers enhance their data literacy, was critical to meeting the challenges of the post-pandemic era (Sánchez-Cruzado et al., 2021). Thus, improving data literacy is imminent (Papamitsiou et al., 2021).

5.3 Digital teaching competence as a dominant mediator

The results showed that digital teaching competence played a mediated role in empowering students. Digital teaching competence had a strong impact on empowering students, and hypothesis 4 was accepted. The results of this study showed that digital teaching competence were not only direct predictors of empowering students, but also as a dominant mediator for ICT attitude, skills, and data literacy. This suggested that improving teachers' digital teaching competence would boost teachers to empower students. If so, the question became "How can we effectively improve teachers' digital teaching competence?" Teacher training was an effective way to improve teachers' digital teaching competence (Cabero-Almenara et al., 2021a; Fernández-Batanero et al., 2020). Gudmundsdottir and Hatlevik (2018) pointed out that the basic use of ICT in current training did not guarantee professional practice. Problems arise when the technical training was based primarily on technology rather than teaching aspects (Miguel-Revilla et al., 2020). Therefore, there were problems with the focus of teacher training, and the content of training needed to be innovated. Simply learning how to use ICT was no longer enough for teachers to teach digitally and empower students. Teacher training needed to focus on the specific context of teachers' digital teaching by combing content, technology and pedagogy. Therefore, the teachers' digital teaching competence should become the top priority in teacher ICT training, which was the most direct influencing factor for empowering students. However, teacher training programs had long ignored the need for teachers' digital teaching competence. It was now necessary for researchers or institutions to assess the reality of teachers so that policy makers could develop the required measures (Napal Fraile et al., 2018). Otherwise, the efforts invested in training may be largely ineffective without considering what teachers really needed in the classroom (Miguel-Revilla et al., 2020). Meanwhile, technology developers should pay attention to minimalist technology, which should be convenient to use in teaching and lesson preparation (Kafyulilo et al., 2016). Technology using purpose was to make digital technology more convenient for teachers, truly solve teachers' problems, and reduce the burden on teachers.

In addition to the above findings, this study also found that the years of teaching experience and school level also affected teachers' digital teaching competence and empowering students. For years of teaching experience, it was found that teachers with 6-15 years of teaching experience had the strongest digital

teaching competence, while teachers aged 26-35 had the weakest digital teaching competence. Similar to the previous study, Cabero-Almenara et al. (2021a) found that teachers who had 4-14 years of teaching experience had higher digital teaching competence than younger and experienced teachers. The younger teachers seemed to have higher ICT skills, but the use of technology was superficial. Therefore, it was necessary for younger teachers to develop the teaching competence to integrate technology in teaching. Compared with the younger teachers, the experienced teachers tended to have weaker ICT attitude, ICT skills, and data literacy, resulting in experienced teachers having relatively weak digital teaching competence. However, we found that teachers with 1-5 years of teaching experience had the strongest competence to empower students. From the perspective of school level, primary school teachers had the highest digital teaching competence and empower students, secondary school teachers had the lowest digital teaching competence and empowering students, and kindergarten teachers were in between. This can be explained by the fact that secondary school teachers, under the pressure of students' high-stakes tests, have to train students ability to achieve high marks in these tests, with no time or energy to consider empowering students.

6 Conclusion, limitation and future research

This study explored the impact of ICT attitude, ICT skills and data literacy on empowering students, mediating teachers' digital teaching competence. Participants included 629 K-9 teachers. The findings showed that data literacy significantly predicted teachers' digital teaching competence and had a significant direct impact on empowering students. In addition, digital teaching competence, as dominant mediator in ICT attitude, ICT skills, and data literacy, strongly predicted empowering students in classroom. By revealing the relationship among ICT attitude, ICT skills, data literacy, digital teaching competence and empowering students, this study put forward new ideas and directions for teachers' continuing education. It is suggested that teachers' data literacy should be integrated in continuing education to enhance their digital teaching competence and to empower students in the future.

There are some limitations in this study. First, the sample in this study were from China. Therefore, the results could not simply be generalized to other countries. In addition, there were fewer male teachers in the sample. Second, this study was investigated by self-reporting. While this way was the most used measurement tools, it can be easy to overestimate or underestimate a teacher's competence. Nonetheless, some self-reported studies, which appear to be increasingly reliable by giving the large sample, provided important information about teachers' digital competence (Lucas et al., 2021; Scherer et al., 2017; Siddiq et al., 2016). Finally, there may be other factors that influence teachers' digital teaching competence to empower students. Future study can integrate more factors (such as communication and collaboration, information responsibility, etc.) and consider other qualitative research methods to analyze the reasons in teachers' digital teaching competence under different

factors. In addition, future research should explore about how to promote teachers' digital teaching competence for empowering students from different aspects, for example, digital capacity, digital learning competency, collaborative skills, etc.

Funding This research was funded by the 2022 China National Social Science Key Project: Research on the Ethics and Limits of AI in Education Scenarios (No: ACA220027)

Data availability Datasets generated during the survey and analyzed during the current study may be obtained from the first author upon reasonable request.

Declarations

Ethics approval Hangzhou Normal University Human Ethics Approval Number: 2022023.

Conflict of interest The authors declare that there is no conflict of interest.

References

Abrams, L. M., Varier, D., & Mehdi, T. (2021). The intersection of school context and teachers' data use practice: Implications for an integrated approach to capacity building. *Studies in Educational Evaluation, 69*, 100868. https://doi.org/10.1016/j.stueduc.2020.100868

Admiraal, W., Louws, M., Lockhorst, D., Paas, T., Buynsters, M., Cviko, A., Janssen, C., de Jonge, M., Nouwens, S., Post, L., van der Ven, F., & Kester, L. (2017). Teachers in school-based technology innovations: A typology of their beliefs on teaching and technology. *Computers & Education, 114*, 57–68. https://doi.org/10.1016/j.compedu.2017.06.013

Alarcón, R., del Pilar Jiménez, E., & de Vicente-Yagüe, M. I. (2020). Development and validation of the DIGIGLO, a tool for assessing the digital competence of educators. *British Journal of Educational Technology, 51*(6), 2407–2421. https://doi.org/10.1111/bjet.12919

Aldhafiri, M. D. (2020). The effectiveness of using interactive white boards in improving the Arabic listening skills of undergraduates majoring in Arabic language at Kuwaiti universities. *Education and Information Technologies, 25*(5), 3577–3591. https://doi.org/10.1007/s10639-020-10107-5

Alfalah, S. F. M. (2018). Perceptions toward adopting virtual reality as a teaching aid in information technology. *Education and Information Technologies, 23*(6), 2633–2653. https://doi.org/10.1007/s10639-018-9734-2

Aslan, A., & Zhu, C. (2017). Investigating variables predicting Turkish pre-service teachers' integration of ICT into teaching practices. *British Journal of Educational Technology, 48*(2), 552–570. https://doi.org/10.1111/bjet.12437

Boesdorfer, S. B., Del Carlo, D. I., & Wayson, J. (2022). Secondary science teachers' definition and use of data in their teaching practice. *Research in Science Education, 52*(1), 159–171. https://doi.org/10.1007/s11165-020-09936-8

Cabero-Almenara, J., Barroso-Osuna, J., Gutiérrez-Castillo, J.-J., & Palacios-Rodríguez, A. (2021a). The teaching digital competence of health sciences teachers. A study at Andalusian universities (Spain). *International Journal of Environmental Research and Public Health, 18*(5), 2552. https://doi.org/10.3390/ijerph18052552

Cabero-Almenara, J., Guillén-Gámez, F. D., Ruiz-Palmero, J., & Palacios-Rodríguez, A. (2021b). Digital competence of higher education professor according to DigCompEdu. Statistical research methods with ANOVA between fields of knowledge in different age ranges. *Education and Information Technologies, 26*(4), 4691–4708. https://doi.org/10.1007/s10639-021-10476-5

Carey, M., Grainger, P., & Christie, M. (2018). Preparing preservice teachers to be data literate: A Queensland case study. *Asia-Pacific Journal of Teacher Education, 46*(3), 267–278. https://doi.org/10.1080/1359866X.2017.1402860

Carretero, S., Vuorikari, R., & Punie, Y. (2017). *The digital competence framework for citizens*. Publications Office of the European Union.

Castaño-Muñoz, J., Kalz, M., Kreijns, K., & Punie, Y. (2018). Who is taking MOOCs for teachers' professional development on the use of ICT? A cross-sectional study from Spain. *Technology, Pedagogy and Education, 27*(5), 607–624. https://doi.org/10.1080/1475939X.2018.1528997

Coburn, C. E., & Turner, E. O. (2011). Research on data use: A framework and analysis. *Measurement: Interdisciplinary Research and Perspectives, 9*(4), 173–206. https://doi.org/10.1080/15366367.2011.626729

del Arco, I., Flores, Ò., & Ramos-Pla, A. (2021). Structural model to determine the factors that affect the quality of emergency teaching, according to the perception of the student of the first university courses. *Sustainability, 13*(5), 2945. https://doi.org/10.3390/su13052945

Eickelmann, B., & Schulz-Zander, R. (2008). School effectiveness, school development and digital media. *Yearbook of School Development, 15*, 157–193.

Eickelmann, B., & Vennemann, M. (2017). Teachers' attitudes and beliefs regarding ICT in teaching and learning in European countries. *European Educational Research Journal, 16*(6), 733–761. https://doi.org/10.1177/1474904117725899

Engen, B. K. (2019). Understanding social and cultural aspects of teachers' digital competencies. *Comunicar, 61*(XXVII), 9–18. https://doi.org/10.3916/C61-2019-01

Eteokleous, N. (2008). Evaluating computer technology integration in a centralized school system. *Computers & Education, 51*(2), 669–686. https://doi.org/10.1016/j.compedu.2007.07.004

European Union (2020). Digital Education Action Plan (2021-2027). https://education.ec.europa.eu/sites/default/files/document-library-docs/deap-communication-sept2020_en.pdf

Fernández-Batanero, J. M., Montenegro-Rueda, M., Fernández-Cerero, J., & García-Martínez, I. (2020). Digital competences for teacher professional development. Systematic review. *European Journal of Teacher Education*, 1–19. https://doi.org/10.1080/02619768.2020.1827389

Fraillon, J., Ainley, J., Schulz, W., Friedman, T., & Duckworth, D. (2020). *Preparing for life in a digital world: IEA international computer and information literacy study 2018 international report* (p. 297). Springer Nature.

Fuchs, L. S., Fuchs, D., Hamlett, C. L., & Stecker, P. M. (2021). Bringing data-based individualization to scale: A call for the next-generation technology of teacher supports. *Journal of Learning Disabilities, 54*(5), 319–333. https://doi.org/10.1177/0022219420950654

Funkhouser, B. J., & Mouza, C. (2013). Drawing on technology: An investigation of preservice teacher beliefs in the context of an introductory educational technology course. *Computers & Education, 62*, 271–285. https://doi.org/10.1016/j.compedu.2012.11.005

González, F., Castaño-Calle, R., & De Castro, R. (2020). Environmental education mediated by ICT. Towards the goals of sustainable development. *Actas VirtualUSATIC, 2020*, 157–158.

Gudmundsdottir, G. B., & Hatlevik, O. E. (2018). Newly qualified teachers' professional digital competence: Implications for teacher education. *European Journal of Teacher Education, 41*(2), 214–231. https://doi.org/10.1080/02619768.2017.1416085

Guillén-Gámez, F. D., & Mayorga-Fernández, M. J. (2020). Quantitative-comparative research on digital competence in students, graduates and professors of faculty education: An analysis with ANOVA. *Education and Information Technologies, 25*(5), 4157–4174. https://doi.org/10.1007/s10639-020-10160-0

Guillén-Gámez, F. D., Lugones, A., & Mayorga-Fernández, M. J. (2019). ICT use by pre-service foreign languages teachers according to gender, age and motivation. *Cogent Education, 1–17*. https://doi.org/10.1080/2331186X.2019.1574693

Gummer, E., & Mandinach, E. (2015). Building a conceptual framework for data literacy. *Teachers College Record, 117*(4), 1–22. https://doi.org/10.1177/016146811511700401

Hämäläinen, R., De Wever, B., Nissinen, K., & Cincinnato, S. (2019). What makes the difference–PIAAC as a resource for understanding the problem-solving skills of Europe's higher-education adults. *Computers & Education, 129*, 27–36. https://doi.org/10.1016/j.compedu.2018.10.013

Hämäläinen, R., Nissinen, K., Mannonen, J., Lämsä, J., Leino, K., & Taajamo, M. (2021). Understanding teaching professionals' digital competence: What do PIAAC and TALIS reveal about technology-related skills, attitudes, and knowledge? *Computers in Human Behavior, 117*, 106672. https://doi.org/10.1016/j.chb.2020.106672

Hatlevik, O. E. (2017). Examining the relationship between teachers' self-efficacy, their digital competence, strategies to evaluate information, and use of ICT at school. *Scandinavian Journal of Educational Research, 61*(5), 555–567. https://doi.org/10.1080/00313831.2016.1172501

Hatlevik, I. K. R., & Hatlevik, O. E. (2018). Students' evaluation of digital information: The role teachers play and factors that influence variability in teacher behaviour. *Computers in Human Behavior, 83*, 56–63. https://doi.org/10.1016/j.chb.2018.01.022

He, T., Huang, Q., Yu, X., & Li, S. (2021). Exploring students' digital informal learning: The roles of digital competence and DTPB factors. *Behaviour & Information Technology, 40*(13), 1406–1416. https://doi.org/10.1080/0144929X.2020.1752800

Heidari, E., Mehrvarz, M., Marzooghi, R., & Stoyanov, S. (2021). The role of digital informal learning in the relationship between students' digital competence and academic engagement during the COVID-19 pandemic. *Journal of Computer Assisted Learning, 37*(4), 1154–1166. https://doi.org/10.1111/jcal.12553

Hernández-Ramos, J. P., Martínez-Abad, F., García Peñalvo, F. J., García, M. E. H., & Rodríguez-Conde, M. J. (2014). Teachers' attitude regarding the use of ICT. A factor reliability and validity study. *Computers in Human Behavior, 31*, 509–516. https://doi.org/10.1016/j.chb.2013.04.039

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1–55. https://doi.org/10.1080/10705519909540118

ISTE. (2016). ISTE standards: students. https://www.iste.org/standards/iste-standards-for-students. Accessed 7 May 2022

ISTE. (2017). ISTE Standards for educators. https://www.iste.org/standards/continue-to-download. Accessed 20 Apr 2022

Istenic Starcic, A., Terlevic, M., Lin, L., & Lebenicnik, M. (2018). Designing learning for sustainable development: Digital practices as boundary crossers and predictors of sustainable lifestyles. *Sustainability, 10*(6), 2030. https://doi.org/10.3390/su10062030

Kaarakainen, M.-T., Kivinen, O., & Vainio, T. (2018). Performance-based testing for ICT skills assessing: A case study of students and teachers' ICT skills in Finnish schools. *Universal Access in the Information Society, 17*(2), 349–360. https://doi.org/10.1007/s10209-017-0553-9

Kafyulilo, A., Fisser, P., & Voogt, J. (2016). Factors affecting teachers' continuation of technology use in teaching. *Education and Information Technologies, 21*(6), 1535–1554. https://doi.org/10.1007/s10639-015-9398-0

Kennedy-Clark, S., Galstaun, V., & Reimann, P. (2021). Preparing pre-service teachers for teaching performance assessments using the OTTO model. *Teachers and Teaching, 27*(1–4), 164–180. https://doi.org/10.1080/13540602.2021.1933420

Kippers, W. B., Poortman, C. L., Schildkamp, K., & Visscher, A. J. (2018). Data literacy: What do educators learn and struggle with during a data use intervention? *Studies in Educational Evaluation, 56*, 21–31. https://doi.org/10.1016/j.stueduc.2017.11.001

Knezek, G., & Christensen, R. (2016). Extending the will, skill, tool model of technology integration: Adding pedagogy as a new model construct. *Journal of Computing in Higher Education, 28*(3), 307–325. https://doi.org/10.1007/s12528-016-9120-2

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education*, *9*(1), 60–70. https://www.learntechlib.org/primary/p/29544/. Accessed 20 Apr 2022

Krumsvik, R. J. (2014). Teacher educators' digital competence. *Scandinavian Journal of Educational Research, 58*(3), 269–280. https://doi.org/10.1080/00313831.2012.726273

Lachner, A., Backfisch, I., & Stürmer, K. (2019). A test-based approach of modeling and measuring technological pedagogical knowledge. *Computers & Education, 142*, 103645. https://doi.org/10.1016/j.compedu.2019.103645

Lai, M. K., & McNaughton, S. (2016). The impact of data use professional development on student achievement. *Teaching and Teacher Education, 60*, 434e443. https://doi.org/10.1109/10.1016/j.tate.2016.07.005

Lázaro-Cantabrana, J., Usart-Rodríguez, M., & Gisbert-Cervera, M. (2019). Assessing teacher digital competence: The construction of an instrument for measuring the knowledge of pre-service teachers. *Journal of New Approaches in Educational Research, 8*(1), 73–78. https://doi.org/10.7821/naer.2019.1.370

Llorent-Vaquero, M., Tallón-Rosales, S., & de las Heras Monastero, B. (2020). Use of information and communication technologies (ICTs) in communication and collaboration: A comparative study between university students from Spain and Italy. *Sustainability, 12*(10), 3969. https://doi.org/10.3390/su12103969

Lomax, R. G., & Schumacker, R. E. (2004). *A beginner's guide to structural equation modeling*. Psychology Press.

Lorenz, R., Endberg, M., & Bos, W. (2019). Predictors of fostering students' computer and information literacy – Analysis based on a representative sample of secondary school teachers in Germany. *Education and Information Technologies, 24*(1), 911–928. https://doi.org/10.1007/s10639-018-9809-0

Lucas, M., Bem-Haja, P., Siddiq, F., Moreira, A., & Redecker, C. (2021). The relation between in-service teachers' digital competence and personal and contextual factors: What matters most? *Computers & Education, 160*, 104052. https://doi.org/10.1016/j.compedu.2020.104052

Mahat, S., Jamsandekar, P. P., & Nalavade, K. M. (2012). A study of teachers' attitudes towards ICT teaching process. *International Journal of Information Technology and Knowledge Management, 6*(1), 93–97.

Mandinach, E. B., & Gummer, E. S. (2013). Defining data literacy: A report on a convening of experts. *Journal of Educational Research and Policy Studies, 13*(2), 6–28.

Mandinach, E. B., & Gummer, E. S. (2016a). *Data literacy for educators: Making it count in teacher preparation and practice*. Teachers College Press.

Mandinach, E. B., & Gummer, E. S. (2016b). What does it mean for teachers to be data literate: Laying out the skills, knowledge, and dispositions. *Teaching and Teacher Education, 60*, 366–376. https://doi.org/10.1016/j.tate.2016.07.011

Mandinach, E. B., & Jackson, S. (2012). *Transforming teaching and learning through datadriven decision making*. Corwin Press.

Marsh, J. A. (2012). Interventions promoting educators' use of data: Research insights and gaps. *Teachers College Record, 114*(1), 1–15. https://doi.org/10.1177/016146811211401106

Means, B., Padilla, C., & Gallagher, L. (2010). *Use of education data at the local level: From accountability to instructional improvement*. US Department of Education.

Mehrvarz, M., Heidari, E., Farrokhnia, M., & Noroozi, O. (2021). The mediating role of digital informal learning in the relationship between students' digital competence and their academic performance. *Computers & Education, 167*, 104184. https://doi.org/10.1016/j.compedu.2021.104184

Miguel-Revilla, D., Martínez-Ferreira, J. M., & Sánchez-Agustí, M. (2020). Assessing the digital competence of educators in social studies: An analysis in initial teacher training using the TPACK-21 model. *Australasian Journal of Educational Technology, 36*(2), 1–12. https://doi.org/10.14742/ajet.5281

Miller-Bains, K. L., Cohen, J., & Wong, V. C. (2022). Developing data literacy: Investigating the effects of a pre-service data use intervention. *Teaching and Teacher Education, 109*, 103569. https://doi.org/10.1016/j.tate.2021.103569

Napal Fraile, M., Peñalva-Vélez, A., & Mendióroz Lacambra, A. M. (2018). Development of digital competence in secondary education teachers' training. *Education Sciences, 8*(3), 104. https://doi.org/10.3390/educsci8030104

Ndibalema, P. (2014). Teachers' attitudes towards the use of information communication technology (ICT) as a pedagogical tool in secondary schools in Tanzania: The case of Kondoa district. *International Journal of Education and Research*, 2(2), 1–16. http://hdl.handle.net/20.500.12661/2384. Accessed 20 Apr 2022

Ndukwe, I. G., & Daniel, B. K. (2020). Teaching analytics, value and tools for teacher data literacy: A systematic and tripartite approach. *International Journal of Educational Technology in Higher Education, 17*(1), 22. https://doi.org/10.1186/s41239-020-00201-6

OECD. (2019). Going Digital: Shaping Policies, Improving Lives – Summary, OECD, Paris. https://www.oecd.org/going-digital/going-digital-synthesis-summary.pdf. Accessed 16 Apr 2022

Papamitsiou, Z., Filippakis, M. E., Poulou, M., Sampson, D., Ifenthaler, D., & Giannakos, M. (2021). Towards an educational data literacy framework: Enhancing the profiles of instructional designers and e-tutors of online and blended courses with new competences. *Smart Learning Environments, 8*(1), 18. https://doi.org/10.1186/s40561-021-00163-w

Perrotta, C., & Williamson, B. (2018). The social life of learning analytics: Cluster analysis and the "performance" of algorithmic education. *Learning, Media and Technology, 43*(1), 3–16. https://doi.org/10.1080/17439884.2016.1182927

Powell, S. R., Lembke, E. S., Ketterlin-Geller, L. R., Petscher, Y., Hwang, J., Bos, S. E., et al. (2021). Data-based individualization in mathematics to support middle school teachers and their students

with mathematics learning difficulty. *Studies in Educational Evaluation, 69*, 100897. https://doi.org/10.1016/j.stueduc.2020.100897

Prestridge, S. (2012). The beliefs behind the teacher that influences their ICT practices. *Computers & Education, 58*(1), 449–458. https://doi.org/10.1016/j.compedu.2011.08.028

Raffaghelli, J. E., & Stewart, B. (2020). Centering complexity in "educators' data literacy" to support future practices in faculty development: A systematic review of the literature. *Teaching in Higher Education, 25*(4), 435–455. https://doi.org/10.1080/13562517.2019.1696301

Redecker, C. (2017). *European framework for the digital competence of educators: DigCompEdu (JRC107466)*. Publications Office of the European Union. https://doi.org/10.2760/159770

Reisoğlu, İ., & Çebi, A. (2020). How can the digital competences of pre-service teachers be developed? Examining a case study through the lens of DigComp and DigCompEdu. *Computers & Education, 156*, 103940. https://doi.org/10.1016/j.compedu.2020.103940

Ribble, M., & Miller, T. N. (2013). Educational leadership in an online world: Connecting students to technology responsibly, safely, and ethically. *Journal of Asynchronous Learning Networks, 17*(1), 137–145.

Robles Moral, F. J., & Fernández Díaz, M. (2021). Future primary school teachers' digital competence in teaching science through the use of social media. *Sustainability, 13*(5), 2816. https://doi.org/10.3390/su13052816

Rubach, C., & Lazarides, R. (2021). Addressing 21st-century digital skills in schools – Development and validation of an instrument to measure teachers' basic ICT competence beliefs. *Computers in Human Behavior, 118*, 106636. https://doi.org/10.1016/j.chb.2020.106636

Sánchez-Cruzado, C., Santiago Campión, R., & Sánchez-Compaña, M. T. (2021). Teacher digital literacy: The indisputable challenge after COVID-19. *Sustainability, 13*(4), 1858. https://doi.org/10.3390/su13041858

Sang, G., Valcke, M., Tondeur, J., Zhu, C., & van Braak, J. (2012). Exploring the educational beliefs of primary education student teachers in the Chinese context. *Asia Pacific Education Review, 13*(3), 417–425. https://doi.org/10.1007/s12564-012-9206-0

Scherer, R., Siddiq, F., & Tondeur, J. (2017). On the quest for validity: Testing the factor structure and measurement invariance of the technology-dimensions in the technological, pedagogical, and content knowledge (TPACK) model. *Computers & Education, 112*, 1–17. https://doi.org/10.1016/j.compedu.2017.04.012

Schildkamp, K. (2019). Data-based decision-making for school improvement: Research insights and gaps. *Educational Research, 61*(3), 257–273. https://doi.org/10.1080/00131881.2019.1625716

Scottish Government. (2021). A changing nation: how Scotland will thrive in a digital world. https://www.gov.scot/publications/a-changing-nation-how-scotland-will-thrive-in-a-digital-world/. Accessed 7 May 2022

Shreiner, T. L., & Dykes, B. M. (2021). Visualizing the teaching of data visualizations in social studies: A study of teachers' data literacy practices, beliefs, and knowledge. *Theory & Research in Social Education, 49*(2), 262–306. https://doi.org/10.1080/00933104.2020.1850382

Siddiq, F., Scherer, R., & Tondeur, J. (2016). Teachers' emphasis on developing students' digital information and communication skills (teddics): A new construct in 21st century education. *Computers & Education, 92–93*(12), 1–14. https://doi.org/10.1016/j.compedu.2015.10.006

Silber-Varod, V., Eshet-Alkalai, Y., & Geri, N. (2019). Tracing research trends of 21st-century learning skills. *British Journal of Educational Technology, 50*(6), 3099–3118. https://doi.org/10.1111/bjet.12753

Spiteri, M., & Rundgren, S. N. C. (2020). Literature review on the factors affecting primary teachers' use of digital technology. *Technology, Knowledge and Learning, 25*(1), 115–128. https://doi.org/10.1007/s10758-018-9376-x

Sun, J., Przybylski, R., & Johnson, B. J. (2016). A review of research on teachers' use of student data: From the perspective of school leadership. *Educational Assessment, Evaluation and Accountability, 28*(1), 5–33. https://doi.org/10.1007/s11092-016-9238-9

Tondeur, J., Aesaert, K., Prestridge, S., & Consuegra, E. (2018). A multilevel analysis of what matters in the training of pre-service teacher's ICT competencies. *Computers & Education, 122*, 32–42. https://doi.org/10.1016/j.compedu.2018.03.002

Trantham, P. S., Sikorski, J., de Ayala, R. J., & Doll, B. (2021). An item response theory and Rasch analysis of the NUDKS: A data literacy scale. *Educational Assessment, Evaluation and Accountability*,1–23. https://doi.org/10.1007/s11092-021-09372-w

UNESCO. (2018). ICT Competency framework for teachers. Retrieved April 15, 2022, https://unesdoc.unesco.org/ark:/48223/pf0000265721

UNESCO IITE. (2022). UNESCO IITE releases its new Medium-Term Strategy for 2022-2025. https://iite.unesco.org/wp-content/uploads/2022/03/UNESCO-IITE-Medium-Term-Strategy-2022-2025.pdf. Accessed 16 Apr 2022

UNICEF. (2021). Digital Learning for Every Child. https://www.unicef.org/reports/digital-learning-every-child. Accessed 7 May 2022

Van Braak, J., Tondeur, J., & Valcke, M. (2004). Explaining different types of computer use among primary school teachers. *European Journal of Psychology of Education, 19*(4), 407. https://doi.org/10.1007/BF03173218

Van Dinther, M., Dochy, F., & Segers, M. (2011). Factors affecting students' self-efficacy in higher education. *Educational Research Review, 6*(2), 95–108. https://doi.org/10.1016/j.edurev.2010.10.003

Van Geel, M., Keuning, T., Visscher, A. J., & Fox, J. P. (2016). Assessing the effects of a school-wide data-based decision-making intervention on student achievement growth in primary schools. *American Educational Research Journal, 53*(2), 360e394. https://doi.org/10.3102/0002831216637346

Van Laar, E., Van Deursen, A. J., Van Dijk, J. A., & De Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. *Computers in Human Behavior, 72*, 577–588. https://doi.org/10.1016/j.chb.2017.03.010

Wang, Q., & Zhao, G. (2021). ICT self-efficacy mediates most effects of university ICT support on pre-service teachers' TPACK: Evidence from three normal universities in China. *British Journal of Educational Technology, 52*(6), 2319–2339. https://doi.org/10.1111/bjet.13141

Wang, X., Zhang, R., Wang, Z., & Li, T. (2021). How does digital competence preserve university students' psychological well-being during the pandemic? An investigation from self-determined theory. *Frontiers in Psychology, 12*. https://doi.org/10.3389/fpsyg.2021.652594

Wen, J. R., & Shih, W. L. (2008). Exploring the information literacy competence standards for elementary and high school teachers. *Computers & Education, 50*(3), 787–806. https://doi.org/10.1016/j.compedu.2006.08.011

World Bank. (2020). Reimagining Human Connections: Technology and Innovation in Education at the World Bank. https://www.worldbank.org/en/topic/edutech/publication/reimagining-human-connections-technology-and-innovation-in-education-at-world-bank. Accessed 7 May 2022

Wu, B., Yu, X., & Hu, Y. (2019). How does principal e-leadership affect ICT transformation across different school stages in K-12 education: Perspectives from teachers in Shanghai. *British Journal of Educational Technology, 50*(3), 1210–1225. https://doi.org/10.1111/bjet.12766

Yeung, A. S., Lim, K. M., Tay, E. G., Lam-Chiang, A. C., & Hui, C. (2012). Relating use of digital technology by pre-service teachers to confidence: A Singapore survey. *Australasian Journal of Educational Technology, 28*(8). https://doi.org/10.14742/ajet.774

Yuen, A. H., & Ma, W. W. (2008). Exploring teacher acceptance of e-learning technology. *Asia-Pacific Journal of Teacher Education, 36*(3), 229–243. https://doi.org/10.1080/13598660802232779

Zhang, Y., Yun, Y., An, R., Cui, J., Dai, H., & Shang, X. (2021). Educational data mining techniques for student performance prediction: Method review and comparison analysis. Frontiers in *Psychology, 12*. https://doi.org/10.3389/fpsyg.2021.698490

Zhao, Y., Pinto Llorente, A. M., Sánchez Gómez, M. C., & Zhao, L. (2021). The impact of gender and years of teaching experience on college teachers' digital competence: An empirical study on teachers in Gansu Agricultural University. *Sustainability, 13*(8), 4163. https://doi.org/10.3390/su13084163