Information and communication technologies in physical education: Exploring the association between role modeling and digital literacy

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Abstract
Teacher educators should serve as role models in terms of information and communication technologies (ICTs) use to promote digital literacy of future teachers. To analyze the association between role modeling by teacher educators and preservice teachers' digital literacy and ICT integration intention in their classrooms, 185 physical education (PE) preservice teachers in the German federal state of Baden-Württemberg completed an online questionnaire of self-assessed technological, pedagogical, and content knowledge (TPACK) and ICT integration. The results of regression models revealed a positive association between content knowledge and pedagogical knowledge (PK) and overall intent to integrate ICT into teaching. The results further indicated that the impact of role modeling on preservice teachers varies depending on the chosen ICT. In this paper, we discuss the implications of these findings for higher education in general and for PE in particular.

Keywords
Information and communication technologies, physical education, teacher, TPACK, integration intent

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Introduction

The role of teachers in the digitalization of education is recognized as a complex holistic phenomenon (Ertmer and Ottenbreit-Leftwich, 2010). Research has shown that organizational infrastructure and education policy are key components in the digitalization of education (Wohlfart et al., 2021) and that teachers' digital literacy is more important than access to digital technologies to ensure their integration (Pettersson, 2018). This seems especially relevant for practical subjects, such as physical education (PE), which teachers must teach under quite specific conditions in which instruction takes place in a non-classroom environment. Much PE teaching takes place in gymnasiums, stadiums, and swimming pools, which are generally not technology-friendly environments (Koh et al., 2022; Kretschmann, 2017). Although the specific types of information and communication technologies (ICTs) used in these environments remain unclear, PE teachers need to incorporate technology in their teaching practices to enhance student learning and to prepare students for a world that is increasingly reliant on technology (European Commission, 2010; Ferrari, 2012). Incorporating digital tools in PE has a number of benefits, including providing innovative ways to track student progress, facilitating virtual and remote learning, enhancing student motivation and engagement through gamification, and encouraging physical activity through the use of activity trackers and virtual reality simulations (Jastrow et al., 2022; Van Hilvoorde and Koekoek, 2018).

Previous research on the role of teachers in the digitalization of education has typically focused on their (perceived) digital literacy or on their willingness and ability to integrate ICT into their teaching (e.g. Granić and Marangunić, 2019; McKnight et al., 2016; Wohlfart and Wagner, 2023). Several studies have highlighted the positive transfer effect of role modeling on ICT integration in the classroom (Rokenes and Krumsvik, 2014; Spiteri and Chang Rundgren, 2020; Starkey, 2020; Tondeur et al., 2012; Voogt et al., 2013) and PE more specifically (Koh et al., 2022; Krause, 2017; Krause and Lynch, 2018). However, in previous research, only 41% of teachers internationally reported having learned how to integrate ICT into their teaching (Drossel et al., 2019; IEA, 2019). Similarly, findings indicate a lack of adequate experience, training, and exposure to quality ICT integration within PE teacher education (Baek et al., 2018; Krause et al., 2020).

Various models have been used to assess digital literacy among teacher educators and among preservice and in-service teachers. The most prominent of these is the technological, pedagogical, and content knowledge (TPACK) model (Koehler and Mishra, 2008; Mishra and Koehler, 2006), which acknowledges the complexity of teaching by differentiating seven knowledge domains in the interplay of technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK). Although many studies have captured students' and preservice teachers' TPACK based on self-assessment data (Chai et al., 2016; Voogt et al., 2013), little is known about the implementation of ICT in teaching practice after graduation (Wohlfart and Wagner, 2023). In addition, there is a lack of empirical evidence on the influence of teachers' perceived digital literacy and teacher educators' role modeling on ICT use in teaching PE. Our aim in the present study was to take a first step toward exploring the association of role modeling by teacher educators with PE preservice teachers' digital literacy and ICT integration intention in future teaching practice.

Conceptual framework: Digital literacy and role modeling

In policy papers and scientific studies, the construct of digital literacy has been defined and explored in various ways. Ferrari (2012: 3) describes digital literacy as a:

> set of knowledge, skills, attitudes (thus including abilities, strategies, values and awareness) that are required when using ICT and digital media to perform tasks; solve problems; communicate; manage information; collaborate; create and share content; and build knowledge effectively, efficiently, appro priately, critically, creatively, autonomously, flexibly, ethically, reflectively for work, leisure, participa tion, learning, socialising, consuming, and empowerment.

For the purpose of our study, we define digital literacy broadly as ICT-related skills, knowledge, creativity, and attitudes. To capture the complexities of ICT use in subject-specific teaching, we operationalized digital literacy in terms of the TPACK model. The model is based on Shulman's (1986) assumption that teaching succeeds when teachers combine subject-specific CK and PK as pedagogical CK (PCK). In a series of learning-by-design seminars, Mishra and Koehler (2006) added TK to this complex interplay, encompassing the skills required to operate, learn, and adapt to new and existing technologies. Their analyses revealed the interplay of three types of knowledge: PCK, technological-PK (TPK), and technological-CK (TCK). PCK incorporates pedagogical practices and learning goals, TPK incorporates technologies and pedagogical practices, and TCK incorporates technologies and learning goals. There is a complex web of relationships among these distinct knowledge domains, as shown in the TPACK model in Figure 1. The intersection of TPK, PCK, and TCK captures the complexity of the knowledge domains that constitute teaching practice (Koehler and Mishra, 2008; Rosenberg and Koehler, 2015).

Since the TPACK model first emerged, over 380 related peer-reviewed studies and at least seven systematic reviews have been published, making it the most widely used conceptual framework in studies of digitalization and digital literacy in education (Wohlfart and Wagner, 2023). However, these studies differ in their operationalization of the knowledge domains.

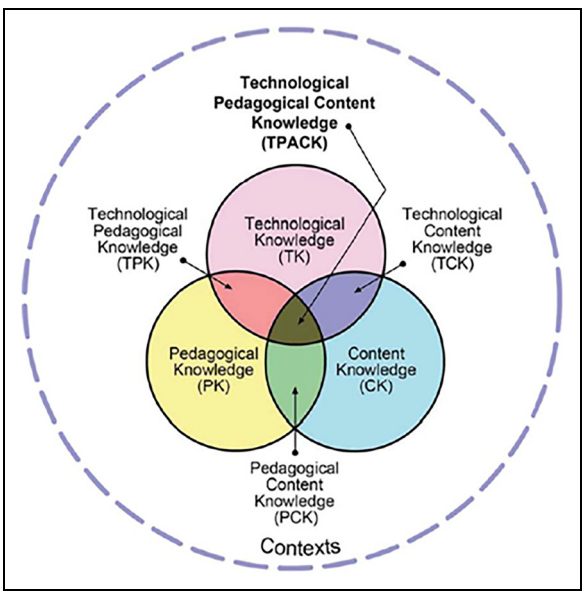

Figure 1. The technological, pedagogical, and content knowledge (TPACK) model (reproduced with permission from http://tpack.org).

Although some maintain a more or less clear distinction between the domains (Chai et al., 2013; Deng et al., 2017; Mishra and Koehler, 2006), others highlight the difficulty of doing so (Archambault and Barnett, 2010; Kopcha et al., 2014; Voogt et al., 2013; Willermark, 2018). Subject-specific versions of the model have partly resolved this issue (Deng et al., 2017; Von Kotzebue, 2022). However, it is also important to specify ICT type (Tondeur et al., 2012) and changes in teachers' perceptions of specific ICT over time (Voogt et al., 2013). Rapid technological advances mean that TK needs to be updated more often than PK or CK (Voogt et al., 2013; Wang et al., 2018).

Existing research also suggests that teachers' previous experience of technology affects digital literacy and is positively correlated with the integration of ICT into teaching practice (Scherer and Teo, 2019; Voogt et al., 2013). The availability of technical support and facilitation, access to resources, professional development paths, appropriate pedagogy, and opportunities for collaboration and leadership are also associated with teachers' integration of ICT in their own practice (Chai et al., 2013; Kay, 2006; Pettersson, 2018; Tondeur et al., 2012). In the context of PE, previous research has highlighted various benefits of specific ICT integration for learning outcomes (Koekoek et al., 2018; Trabelsi et al., 2021), as well as the necessity of favorable environmental conditions (Koh et al., 2022).

Successful integration of existing or new technologies depends on knowledge of and access to these technologies, as well as time to become familiar with their use (Tondeur et al., 2012). Teachers' attitudes or fears influence their willingness and ability to integrate technology (Njiku, 2022; Wilson et al., 2020). Exposure to a student-centered constructivist pedagogical approach during teacher education can have a positive influence on digital literacy development and integration of ICT in teaching practice (Chai et al., 2013; Harper, 2018). In their scoping review, Østerlie et al. (2022) highlighted the possible benefits of flipped learning as a student-centered pedagogical approach specifically for PE. Among existing theoretical frameworks, role modeling seems to offer the most promising approach to digital literacy development (Kay, 2006; Rokenes and Krumsvik, 2014; Starkey, 2020; Tondeur et al., 2012; Voogt et al., 2013; Wang et al., 2018). According to Rokenes and Krumsvik (2014: 262), role modeling involves "teacher educators, in-service teachers, mentors, and peers promoting particular practices and views of learning through intentionally displaying certain teaching behavior, which could play an important role in shaping student teachers' professional learning." One significant advantage of the role modeling approach for preservice teachers is its transferability to authentic classroom situations (Kay, 2006).

Building upon this theoretical framework and previous research, we formulated three hypotheses to explore the association of role modeling by teacher educators with preservice PE teachers' digital literacy and their intent to integrate ICT into their teaching practice. Previous studies have commonly linked digital literacy development with ICT integration in teaching (Kohler et al., 2022; Scherer and Teo, 2019; Voogt et al., 2013). Consequently, it is reasonable to posit that focusing on digital literacy in PE teacher education may help to promote and enhance ICT integration in teaching practice, potentially ensuring higher levels of student digital competence. Based on this understanding, we propose the following hypothesis:

H_1. There is a positive association between preservice PE teachers' self-assessed CK, PK, TK, and associated intersectional knowledge (PCK, TPK, TCK, and TPACK) and their intent to integrate ICT into teaching practice.

In acknowledgment of the pivotal role that role modeling can play in fostering digital literacy development (Kay, 2006; Rokenes and Krumsvik, 2014; Starkey, 2020; Wang et al., 2018), we propose two additional hypotheses:

H_2. The integration of ICT by university lecturers in PE is positively associated with preservice teachers' self-assessed CK, PK, TK, and associated intersectional knowledge (PCK, TPK, TCK, and TPACK).

H_3. The integration of ICT by university lecturers in PE is positively associated with preservice teachers' intent to integrate ICT into teaching practice.

Methods and sample

To test these hypotheses, we conducted an online quantitative survey of preservice PE teachers in the German federal state of Baden-Württemberg. For the purpose of this study, we adapted Schmidt et al.'s (2009) validated TPACK questionnaire (translated and revalidated in German by Endberg (2019)). We adapted the wording of the content-specific items to focus on subject-specific PE content according to the requirements of the federal state's education curriculum (Ministry of Culture, Youth and Sports, 2016a, 2016b). We also included questions on ICT integration by university lecturers and intended ICT integration in respondents' own teaching practice.

In line with previous TPACK studies (Schmid et al., 2020; Valtonen et al., 2015) and calls for more consistent semantics (Redecker, 2017; Starkey, 2020), ICT was defined as all technological and digital tools and technologies used "to communicate, create, disseminate, store, and manage information" (Blurton, 1999: 1). The final 50-item questionnaire captured sociodemographic and education-specific information and relevant content- and context-related information associated with the TPACK model, in addition to information about ICT integration by teacher educators and intended integration by the preservice teachers in classroom practice in the future.[1]

The questionnaire was created using SoSci Survey. In April 2021, it was made available through an online link to the entire cohort of preservice teachers who commenced the second stage of formal PE teacher education in the German federal state of Baden-Wuerttemberg in January 2021 (N = 416).[2] The final sample included data from 185 preservice teachers (44.4% of the cohort).[3] The data were analyzed using SPSS version 25. The internal validity of the TPACK dimensions was established through accreditation, as evidenced by Cronbach's α values for TK (0.90), CK (0.86), PK (0.83), TPK (0.76), and TPACK (0.87), as well as the Spearman Brown coefficient values for TCK (0.72) and PCK (0.51). As the focus of the study was on the TK dimensions rather than PCK, we accepted this low reliability and suggest increasing the number of items in future studies (Eisinga et al., 2013). After further item-proofing steps (correlations), we performed a descriptive analysis of the data. In the next step, we performed regression analyses to test our hypotheses.

The respondents (female: 50%; male: 49%; diverse: 1%; average age: 28 years; standard deviation (SD) = 4.4) had completed an average of 12 semesters in higher education (SD = 2.23) at 14 different educational institutions (79% of the sample reported finishing their Master of Education at one of the eight state universities in the federal state of Baden-Württemberg, 13% at universities of education in Baden-Wuerttemberg (*Pädagogische Hochschulen*), and 7% at institutions of teacher education in other federal states). At the time of completing the online questionnaire, they had just begun the second stage of their formal teacher education at secondary schools across the federal state.

In Germany, student teachers are required to choose a minimum of two subjects, and in our sample, the most frequent combinations with PE were mathematics (22%) and English (17%).

Results

We organized our results to address the hypotheses regarding digital literacy and its association with ICT integration intent (H_1), as well as the associations between role modeling and self-assessed digital literacy (H_2) and ICT integration intent (H_3).

Digital literacy

Table 1 summarizes the respondents' self-assessments of their competencies and knowledge and their intention to integrate ICT into their own teaching.

Across the knowledge domains, CK and TPK had the highest and lowest mean values (4.25 and 3.30, respectively). There were no significant differences in self-assessment related to gender and age. The respondents were asked about their intention to integrate ICT into their own lessons on a scale from one to five (1 = never; 5 = always). In terms of the tools used in ICT integration, the respondents referred most frequently to personal computers (PCs) and laptops and least frequently to tablets and content communication software.

We performed a regression analysis to investigate the association between self-assessed TPACK domains and the respondents' intention to integrate ICT into their own lessons. In the linear model, the dependent variable was the aggregated index for ICT integration intent (mean (M) = 2.82;

Table 1. Descriptive statistics for preservice PE teachers' self assessments of proficiency in TPACK domains (1 = strongly disagree, 5 = strongly agree; n = 132) and intended ICT integration (1 = never; 5 = always; n = 113).

Knowledge domains and ICT items	*M*	SD	Number of items	Cronbach's α
Content knowledge	4.25	0.53	3	0.86
Pedagogical content knowledge	3.96	0.59	1	—
Pedagogical knowledge	3.81	0.55	7	0.83
Technological content knowledge	3.57	0.76	1	—
Technological knowledge	3.44	0.75	6	0.90
TPACK	3.32	0.63	4	0.87
Technological pedagogical knowledge	3.30	0.63	6	0.76
Intended ICT integration	2.82	0.57	9	0.74
Aggregated index	2.82	0.57	9	0.74
Smartphone	2.68	0.90	1	—
Tablet	3.49	0.81	1	—
Laptop	2.50	1.17	1	—
PC	1.50	0.80	1	—
Software for content creation	2.76	1.20	1	—
Software for content storage	2.81	1.20	1	—
Software for content management	3.31	1.07	1	—
Software for content processing	3.10	1.01	1	—
Software for content communication	3.40	0.92	1	—

M: mean; SD: standard deviation; PE: physical education; TPACK: technological, pedagogical, and content knowledge; ICT: information and communication technology; PC: personal computer.

SD = 0.57), and the seven TPACK domains were included as possible predictor variables. As indicated by the results, only two predictors were significantly associated with ICT integration intent: CK ($t(109) = 2.16$, $p < .05$) and PK ($t(109) = 3.65$, $p < .01$). According to the model, there was a positive association between CK ($b = 0.21$; standard error (*SE*): $b = 0.10$; 95% bias-corrected accelerated confidence interval 0.02 0.39; $p < .05$) and PK ($b = .33$; *SE*: $b = .09$; 95% bias-corrected accelerated confidence interval 0.15 0.51; $p < .01$) and preservice teachers' ICT integration intent ($R^2 = 0.178$, adjusted $R^2 = 0.163$, $p < .05$). Contrary to our theoretical assumptions, there was no significant association between preservice teachers' self-assessed knowledge and ICT integration intent. Accordingly, H_1 was supported for CK and PK but not for the other knowledge dimensions.

Role modeling

The respondents were asked about university lecturers' integration of specific forms of ICT during their PE teaching studies on a scale ranging from one (never) to five (always). The most frequently mentioned item was software for content communication ($M = 3.81$; SD = 1.05), followed by laptops ($M = 3.16$; SD = 1.05). Smartphones ($M = 1.74$; SD = 0.94) and tablets ($M = 2.19$; SD = 1.02) were the least frequently mentioned. An aggregate index for all nine types of ICT returned a moderate mean value for teacher educators' ICT integration ($M = 2.58$; SD = 0.68).

To analyze the association between teacher educators' integration of ICT and preservice teachers' self-assessed skills and intention to integrate ICT into their own teaching, we conducted a number of regression analyses. Table 2 summarizes the dependent and independent variables used in these analyses, and Table 3 lists the significant results.

In relation to role modeling, only TK and PK were significantly associated with preservice teachers' intention to integrate ICT into their classrooms. Specifically, the results demonstrated that the integration of software for content creation was positively associated with self-assessed TK and TPK, whereas the use of laptops was negatively associated with self-assessed TK. Based on these findings, there was no overall support for H_2 (positive association of lecturers' ICT integration with preservice teachers' self-assessed knowledge) across the seven dimensions. However, the results support the conclusion that teacher educators' integration of some types of ICT in preservice training promotes TK and TPK.

In relation to the respondents' intention to integrate ICT into their classrooms, the results of the regression analyses revealed a diverse picture with several predictor variables. The regression models indicated that the software for content creation and content processing was positively associated with ICT integration intent, whereas the content communication software was negatively associated with ICT integration intent. ICT integration intent was most strongly associated with teacher educators' integration of software for content creation, followed by laptops, PCs, and software for content storage. Four of the nine types of ICT (smartphones, laptops, software for content creation, and software for content storage) were negatively associated with the intent to integrate ICT into future classrooms. Based on these results, role modeling by teacher educators was strongly associated with preservice teachers' ICT integration intent, but this association was not always positive. Accordingly, H_3 was not supported.

Discussion

The main purpose of this study was to explore the association between role modeling by teacher educators on digital literacy and ICT integration intent among preservice teachers. Overall, our findings

Table 2. Operationalizing the association between university lecturers' ICT integration and preservice teachers' ICT integration intent (dependent and independent variables).

University lecturers' ICT integration			Scale
Dependent variables	TPACK (one regression model per knowledge domain)		Quasi-metric: 1 = strongly disagree; 5 = strongly agree
	Intended integration of ICT in preservice teachers' teaching (aggregated mean value and by ICT resource)		Quasi-metric: 1 = never; 5 = always
Independent variables	Integration of ICT by university lecturers	Smartphone	Quasi-metric: 1 = never; 5 = always
		Tablet	
		Laptop	
		PC	
		Software for content creation	
		Software for content storage	
		Software for content management	
		Software for content processing	
		Software for content communication	

ICT: information and communication technology; TPACK: technological, pedagogical, and content knowledge; PC: personal computer.

Table 3. Assoc at on between un vers ty ecturers' ICT ntegrat on and preserv ce teachers' se f-assessments and ICT ntegrat on ntent.

	Mode s: se f-assessment of know edge doma ns		Mode s: ntended ntegrat on of ICT					
	TK	TPK	Aggregated ndex of a n ne ICT	Smartphone	Laptop	PC	Software for content creat on	Software for content storage
Constant	3.313**	3.078**	2.324**	2.535*	1.506**	1.276	1.895**	2.706**
	(0.302)	(0.232)	(0.228)	(0.372)	(0.048)	(0.317)	(0.440)	(0.479)
Smartphone	—	—	—	—	—	0.281**	—	—
						(0.092)		
Tab et	—	—	—	—	—	—	—	—
Laptop	−0.101^{+}	—	—	—	0.348**	—	0.197*	—
	(0.061)				(0.090)		(0.089)	
PC	—	—	—	—	0.203*	0.208**	−0.157^{+}	—
					(0.080)	(0.057)	(0.079)	
Software for content creat on	0.155*	0.135**	0.133**	—	—	—	0.512**	—
	(0.066)	(0.051)	(0.050)				(0.097)	
Software for content storage	—	—	—	0.171*	—	—	—	0.316**
				(0.086)				(0.113)
Software for content management	—	—	—	—	—	−0.139^{+}	—	—
						(0.079)		
Software for content process ng	—	—	0.127*	—	—	—	—	—
			(0.063)					
Software for content commun cat on	—	—	−0.108^{+}	−0.233*	−0.207^{+}	—	−0.203^{+}	−0.265*
			(0.061)	(0.100)	(0.119)		(0.119)	(0.130)
N	112	112	112	111	112	110	111	111
R^2	0.149*	0.164*	0.165*	0.150*	0.263**	0.208**	0.316**	0.170*
Corrected R^2	0.075	0.091	0.092	0.075	0.198	0.138	0.256	0.097

CT: information and communication techno ogy; TK: techno ogica know edge; TPK: techno ogica –pedagogica know edge; PC: persona computer.

Note. Standard errors are in parentheses. On y significant mode s and resu ts are reported. $^{+}$Significant at the 0% eve . *Significant at the 5% eve . **Significant at the % eve .

present a positive picture of preservice teachers' readiness for their future roles. They also support our contention that teacher education must ensure that future teachers are digitally literate to ensure they can integrate ICT into their classroom practice. To integrate ICT into their classrooms, teachers must identify as digitally literate. To explore this issue, we formulated and tested three hypotheses. The implications of our findings are discussed below.

PK and CK as predictors of ICT integration

Unsurprisingly, the respondents assessed their knowledge as highest in the more traditional domains of content and pedagogy (CK, PK, and PCK). The results for the technological dimension (TK) deviated to some extent, indicating greater respondent heterogeneity in relation to this knowledge domain (Table 1). The dynamic nature of TK makes it more difficult to grasp than other knowledge domains, which may explain the lower scores for the TK domain. This finding aligns with that of other studies of TK (Deng et al., 2017; Von Kotzebue, 2022). Although national and international policy papers emphasize the need for preservice teachers to be digitally literate (KMK, 2016; European Commission, 2010), our findings suggest that higher education curricula may not have fully adapted to address this need. In combination with the freedom of research and teaching at institutions of higher education, standardizing curriculum development is difficult (Misco and Patterson, 2007).

Although previous studies have reported a positive link between teachers' digital literacy and integration of ICT in teaching practice (Kohler et al., 2022; Scherer and Teo, 2019; Voogt et al., 2013), our results fail to support this view. Instead, our findings indicate that there is a positive association between PK and CK development and preservice teachers' intentions to integrate ICT into their teaching practice. These findings align with Shulman's (1986) assertion of the need for teachers to *understand* before they can apply knowledge in practice. Assuming that greater confidence in the areas of PK and CK encourages preservice teachers to try new approaches to ICT integration in the classroom, building preservice teachers' confidence in these vital competencies should be a goal for teacher education.

Role modeling and ICT: Associations and intentions

In this study, we explored the association of role modeling by teacher educators with preservice teachers' intention to integrate ICT into their classroom practice. Specifically, we examined whether there was an association between ICT-related role modeling by university lecturers and the promotion of digital literacy (H_2) and preservice teachers' intent to integrate ICT into future teaching practice (H_3). We were unable to confirm either hypothesis. However, several interesting findings emerged that warrant further research. First, teacher educators' use of software for content creation was positively associated with preservice teachers' self-assessments of TK and TPK. As TK and TPK were among the lowest-scoring domains, it seems important to promote the use of software for content creation in teacher education. The strong correlations observed between TK and more complex domains of TCK ($r = .46$; $p < .01$), TPK ($r = 0.57$; $p < .01$), and TPACK ($r = .41$, $p < .01$) align with recent evidence (Von Kotzebue, 2022). Surprisingly, we did not find any correlations between any other ICT items and the knowledge domains, which raises further questions about the influence of these factors. This aspect needs to be addressed in future research to gain a deeper understanding of their potential relationships. Second, we identified several significant predictors of intent to integrate ICT into preservice teachers' practice that

confirmed the role of teacher educators as models and their importance in ICT integration in the classroom, as previously reported by Tondeur et al. (2012). Our results indicate that the use of specific types of ICT, such as software for content creation, by teacher educators was positively associated with preservice teachers' intentions to integrate ICT into their classrooms. In contrast, we observed a negative association between the use of software for content communication in teacher education and preservice teachers' intent to integrate ICT into their classrooms. This negative association of integration intent may be attributed to inadequate modeling, which has been shown to have a detrimental impact on TPACK (Wang et al., 2018). This finding is particularly surprising because software for content communication was reported to be used more frequently than any other type of ICT by the respondents in this study.

The low levels of ICT integration in higher education reported in this study are noteworthy. On average, the respondents reported below-average ($M < 3.0$) integration of ICT in teacher education ($M = 2.5$; SD = 0.67) for all types of ICT other than software for content communication and laptops ($M = 3.81$ and 3.16, respectively). Thus, it seems essential to critically evaluate the quality of PE training of student teachers and the assumed function of teacher educators as role models in preparing preservice teachers for integrating ICT into their PE classes.

Implications of the findings for PE

The present analysis of self-assessed TPACK data confirmed the subject-specific advantages of CK and PK. These findings, which are based on Schmidt et al.'s (2009) questionnaire, are in accordance with those of surveys of TPACK among preservice PE teachers (Baert, 2014; Cengiz, 2015; Semiz and Ince, 2012). In all these surveys, the lowest scores were obtained for self-assessed TK. One possible explanation is that TK and associated technologies (e.g. digital applications, instant video feedback, and audiovisual media) emerged relatively recently. Another possibility is that the way that ICT is used currently may deter the application of other types of knowledge in the classroom (Krause and Lynch, 2018). In line with previous studies, we highlight the need for TK transfer from teacher educators to preservice teachers (e.g. Trabelsi et al., 2021).

The practical nature of PE means that PE teachers must teach under specific conditions, with much of their teaching conducted in gymnasiums, stadiums, and swimming pools, which are generally not technology-friendly environments (Koh et al., 2022; Kretschmann, 2017). For this reason, ICT use in PE may be limited, and fewer modeling opportunities may have a negative impact on subsequent intended use. Although the respondents reported that teacher educators seldom used tablets in learning settings ($M = 2.19$; SD = 0.64), they identified the tablet as their medium of choice for ICT integration in their classrooms in the future ($M = 3.49$; SD = 0.81). This finding aligns with previous evidence on the perceived teaching advantages of laptops, in combination with digital applications, such as video analysis (Hung et al., 2018; Kok et al., 2020; Mödinger et al., 2022; Palao et al., 2015). PE teacher education should harness these opportunities and explore the use of these ICT tools in teaching (Jastrow et al., 2022). Student-centered teaching approaches, such as flipped learning environments, could also offer valuable opportunities for PE teachers to integrate ICT into their teaching (Østerlie et al., 2022).

Limitations and future research

Our study has shed light on several limitations, and we outline potential areas for future research to enhance the understanding of digital literacy and ICT integration in the context of teacher education.

Firstly, the findings were based on a self-assessment questionnaire, which raises questions about the validity of such instruments in educational research (Schmid et al., 2020; Wohlfart and Wagner, 2023). To address this concern, future studies should adopt alternative methods to assess the genuine digital literacy of aspiring teachers more accurately.

Additionally, the internal validity of the TPACK items may be questionable. Rather than evaluating them as separate knowledge domains, it may be more appropriate to explore the intricate interrelationships between these domains in classroom settings (Mishra and Koehler, 2006). We urge a critical evaluation of Schmidt et al.'s (2009) TPACK instrument, widely adapted and utilized, to assess the validity of its knowledge domains. Additionally, the self-assessment questionnaire items, especially those relating to PCK and TCK, should be reviewed and potentially expanded.

Furthermore, regarding self-assessed digital literacy and its association with ICT integration intent, our study did not find a significant relationship. Future research should further examine, test, and critically reflect on the link between digital literacy and ICT integration (as defined). Njiku's (2022) analysis of the relationship between attitudes to ICT and TPACK dimensions is a promising step, revealing a strong positive correlation between the two constructs. A more evidence-based understanding of these constructs and their interdependencies is essential to develop effective guidelines for standardizing ICT integration in teacher education institutions. Another limitation pertains to the selected sample, and the survey results might differ for different samples (Koh et al., 2022). To ensure greater generalizability, future research should consider diverse samples to understand potential variations in the findings. In line with this, we urge caution in generalizing our results to in-service teachers, as there may be a disconnect between preservice teachers' ICT integration intent and classroom practice (Koehler et al., 2014; Von Kotzebue, 2022).

Moreover, the items used to operationalize university lecturers' and preservice teachers' ICT integration and intent have not been previously validated. As ICT resources continuously evolve, the included questionnaire items should be carefully reviewed and possibly revised or removed to reflect current practices more accurately. In our study, respondents had the opportunity to name subject-specific ICT options not listed on the questionnaire. However, only a few respondents ($n = 7$) utilized this option. To gain a comprehensive understanding of the field, we strongly recommend that future studies incorporate and examine PE-specific ICT options, such as heart rate monitors, pedometers, and PE-specific software.

Finally, the corrected R^2 values ranged from 0.075 to 0.256, indicating that only a modest percentage of the variance in the dependent variables was explained by the independent predictor variables. This finding emphasizes the need for caution when generalizing the findings, as additional factors may have contributed to the results of our study.

Conclusions

The present study explored the association between university lecturer role modeling and PE preservice teachers' digital literacy and ICT integration intent. Drawing on the existing literature, we formulated and tested three hypotheses through a survey of preservice PE teachers in Germany. In accordance with the literature, our results revealed a positive association between general PK and subject-specific CK and ICT integration intent among preservice PE teachers. They also revealed a positive association between teacher educators' role modeling and digital literacy (TK and TPK), as well as general ICT integration intent, including specific types of ICT. Our findings do not support previous reports suggesting a positive association between self-assessed TK knowledge and ICT

integration intent. We discussed the potential implications of inadequate role modeling and its association with preservice teachers and PE teaching. Inadequate role modeling in teacher education in the area of ICT has implications for the digital literacy of preservice teachers and PE teaching. Our findings represent a first step toward clarifying the association between digital literacy and ICT integration in PE and confirm the need for further research in this area.

Compliance with ethical standards

The authors declare that all principles of ethical and professional conduct have been followed.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publica tion of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The writing of this article and the underlying study were supported, in part, by the Vector Foundation as well as through the funding of the project "digiMINT," which is a part of the Qualitätsoffensive Lehrerbildung, a joint initiative of the Federal Government and the Länder that aims to improve the quality of teacher training. The program is funded by the Federal Ministry of Education and Research. The authors are responsible for the content of this publication.

Notes

1. Some examples of responses to the questions, together with the response scales used, are provided below: (1) TPACK items (rated on a scale of 1 5, where 1 = strongly disagree and 5 = strongly agree): TK: I can independently solve technical issues related to ICT. PCK: I can select appropriate teaching methods to guide students' thinking and learning processes in sports. TPK: I can choose ICT that enhance students' learning in a lesson. TPACK: I can select ICT to use in my classroom to enhance what I teach, how I teach, and what students learn. (2) ICT role modeling items (rated on a scale of 1 5, where 1 = never and 5 = always): How often were the following ICT implemented by your university lecturers in your sports studies? (3) ICT integration intent items (rated on a scale of 1 5, where 1 = never and 5 = always): How frequently do you plan to incorporate the following ICT tools in your sports lessons?
2. In Germany, teachers undertake a minimum of five years (equivalent to 10 semesters) higher education training, consisting of a Bachelor's and Master's degree in Education, during the initial stage of their formal teacher education. This is followed by the "Referendariat," which is a traineeship in a school. The Referendariat includes seminars and is completed within one to two years (duration varies by federal state), with the assessment based on theoretical and practical exams. Upon successful completion of this stage, teachers become eligible to assume teaching positions.
3. The total sample size in this study was 185 participants. However, the number of responses varies, as some participants chose not to answer certain questions or skipped some items in the questionnaire.

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