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Will, skills, or conscientiousness: What predicts teachers' intentions to participate in technology-related professional development?

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ABSTRACT

To unfold the potential of learning with technology in classrooms, teachers must be prepared to integrate it meaningfully and with high instructional quality. Professional development (PD) is an important avenue for preparing in-service teachers to integrate technology into their teaching. Whereas existing research indicates that teachers' motivation predicts classroom technology use and participation in PD, knowledge about other predictors (e.g., technology-related knowledge and personality) is scarce. This scarcity is surprising because technology-related prior knowledge and, for example, conscientiousness are especially important in systems in which teachers choose PD voluntarily. In this study, we analyzed unique data from 321 in-service teachers whose schools were randomized to receive one-to-one technology. Using sequential linear and nonlinear regression, we examined the extent to which teachers' will, skills, and conscientiousness simultaneously (rather than separately) predicted their intentions to participate in technology-related PD. Controlling for important personal and contextual characteristics, we found robust evidence that the perceived utility of technology in classrooms was a stronger predictor of participation intentions than technology-related knowledge and conscientiousness. Contrary to existing assumptions, our findings illustrate that teachers should still be made aware of the utility of technology for instruction to strengthen their intentions to participate in technology-related PD.

1. Introduction

The use of technology to create effective classroom learning environments promises to support student learning (Chauhan, 2017; Cheung & Slavin, 2013; Hillmayr, Ziernwald, Reinhold, Hofer, & Reiss, 2020). Whereas schools are becoming increasingly equipped with technology (Fraillon, Ainley, Schulz, Friedman, & Gebhardt, 2014, 2020), the scientific view is that it is not the frequency or quantity but the quality of technology integration that is important for promoting successful learning (Fütterer, Scheiter, Cheng, & Stürmer, 2022; Lawless & Pellegrino, 2007; Petko, Cantieni, & Prasse, 2017). To ensure that teachers are capable of integrating

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technology into classrooms with high instructional quality, they must be well-trained (Harris, Mishra, & Koehler, 2009). In fact, teachers are life-long learners who must adapt to and adopt new teaching practices and tools over time (OECD, 2019). However, teachers do not necessarily have the motivational prerequisites or the technological pedagogical knowledge needed to actualize technology's potential in classrooms (Fraillon et al., 2020; Lucas, Bem-Haja, Siddiq, Moreira, & Redecker, 2021). This became particularly evident during the COVID-19 pandemic when digital instruction during the school closures became the norm—a form of instruction many teachers did not feel prepared for (Fütterer et al., 2021; Howard et al., 2020). Against this backdrop, technology-related professional development (PD) is critical for preparing in-service teachers for high-quality digital teaching (Eickelmann, Drossel, & Heldt, 2021; Hillmayr, Ziernwald, Reinhold, Hofer, & Reiss, 2020; Lawless & Pellegrino, 2007).

However, in several countries, including Germany, very few teachers have participated in technology-related PD (Fraillon, Ainley, Schulz, Friedman, & Gebhardt, 2014, 2020; for Germany, see Eickelmann et al., 2019). The reasons for this lack of participation are largely unclear. To help teachers develop high-quality digital instruction, it is important to know which aspects are related to their intentions to enroll in PD. As in many countries (including Germany) the PD system is organized in such a way that teachers mainly organize their PD participation on their own, it is important to understand which personal characteristics are important for self-initiated participation in technology-related PD. Whereas motivation (e.g., perceived utility value of technology for teaching), skills (e.g., technological pedagogical knowledge), and personality (e.g., conscientiousness) are assumed to predict whether adults take learning opportunities (e.g., Cookson, 1986), teachers' motivation and self-reported knowledge in particular have been investigated extensively and identified as key predictors across different PD formats (e.g., workshops, summer institutes, coaching; Krille, 2020). Such drivers of teachers' PD participation are important to consider, as they have the potential to explain why teachers differ widely in their PD behavior (e.g., time invested in PD participation; OECD, 2014, 2019). Specifically, objectively measured (i.e., test-based) professional knowledge and personality traits have rarely been examined as predictors of teachers' PD intentions and behavior, and knowledge about the relative importance of motivational, cognitive, and personality factors is scarce.

In this study, we addressed these research gaps by systematically investigating teachers' will (i.e., their motivation or perceived utility value of technology for teaching), skills (i.e., technology-related knowledge), and conscientiousness in predicting their intentions to participate in technology-related PD. Generating such new knowledge will extend the extant research on PD in technology contexts and inform educational practice about the possible foci that may enhance PD participation.

2. Theoretical background

2.1. Teachers' intentions to participate in technology-related PD

Whereas future generations of teachers are likely to benefit from the increasing integration of technology-related learning opportunities in preservice university teacher training programs (see Lipowsky & Rzejak, 2015), PD plays an important role for teachers who are already in the profession. Following Richter, Kunter, Klusmann, Lüdtke, & Baumert, 2011, we define PD as teachers' participation in formal and informal learning opportunities to enhance and broaden teachers' competence, including, for instance, knowledge and motivation. In particular, technology-related PD is highlighted as an important step in preparing in-service teachers for high-quality technology-enhanced teaching (Eickelmann, Drossel, & Heldt, 2021; Fernández-Batanero, Montenegro-Rueda, Fernández-Cerero, & García-Martínez, 2020; Hillmayr, Ziernwald, Reinhold, Hofer, & Reiss, 2020; Konstantinidou & Scherer, 2022; Kopcha, 2012; Lawless & Pellegrino, 2007; Tondeur et al., 2016). For instance, Konstantinidou & Scherer, 2022 showed that teachers' technology-related PD participation is related to their teaching practices—teachers who enrolled in PD adopted high-quality teaching practices more frequently and emphasized digital skills to a greater extent than others. Furthermore, PD can enhance teachers' self-efficacy to use technology in classrooms (Drossel & Eickelmann, 2017; Hall & Trespalacios, 2019), self-reported technology-related skills (Lawless & Pellegrino, 2007), and the effectiveness of technology for learning outcomes (Hillmayr, Ziernwald, Reinhold, Hofer, & Reiss, 2020).

Here, we examined teachers' intentions to participate in technology-related PD on the basis of social psychological theories (Sheeran, 2002; e.g., Theory of Planned Behavior [TPB]: Ajzen, 1987), which postulate that intentions are key predictors of behavior. In fact, many empirical studies have supported the intention-behavior relationship (Sheeran, 2002; Webb & Sheeran, 2006). Furthermore, TPB has been shown, for example, to be suitable for research on people's (Grotelueschen & Caulley, 1977; Yang, Blunt, & Butler, 1994) and especially teachers' intentions to participate in PD (e.g., Dunn, Hattie, & Bowles, 2018; Gorozidis & Papaioannou, 2014; Hwang, Hong, & Hao, 2018).

2.2. Predictors of teachers' intentions to participate in PD

For adults' use of learning opportunities (e.g., PD), motivation (will), cognition (skills), and personality traits are key categories of predictors (e.g., see Cookson, 1986; see also the model of teacher learning introduced by Fishman, Marx, Best, & Tal, 2003). For instance, teachers with low motivation to use technology will be less likely to engage in technology-related PD. In our study, we investigated all three aspects. Variables related to these person characteristics are also included in well-known models used to explain the use of technology for teaching (e.g., the "will, skill, tool" model: Petko, 2012).

2.2.1. Will and skills: teachers' motivation and technology-related knowledge as predictors

Previous findings have illustrated that both teachers' *motivation* (Gorozidis & Papaioannou, 2014; Krille, 2020; McMillan, McConnell, & O'Sullivan, 2016; D. Richter, Kleinknecht, & Gröschner, 2019; especially in technology-related PD: Drossel &

Eickelmann, 2017) and *knowledge* (Desimone, Smith, & Ueno, 2006; D. Richter, Engelbert, Weirich, & Anand Pant, 2013; especially in technology-related PD: Drossel & Eickelmann, 2017; Kao, Wu, & Tsai, 2011; Krille, 2020) can explain their participation in PD. For instance, Drossel & Eickelmann, 2017 and Kao, Wu, & Tsai, 2011 found that teachers who participated in technology-related PD showed higher self-reported technology-related skills. Furthermore, in her systematic literature review, Krille (2020) explained that technology-related knowledge in particular varies between teachers, and the mismatch of prior knowledge with the levels of knowledge PD offers were important barriers to PD participation.

In educational systems where teachers can choose to participate in PD (e.g., in Germany) and PD is not mandatory due to external circumstances (e.g., distance learning during COVID-19-related school closures), there is evidence of a *catalytic* rather than an *educative function* of PD (D. Richter, Kunter, Klusmann, Lüdtke, & Baumert, 2011, Richter, Engelbert, Weirich, & Anand Pant, 2013; E. Richter, Kunter, Marx, & Richter, 2021). A catalytic function of PD assumes that teachers are more likely to attend PD courses on topics that interest them or in which they already have a good base of knowledge and skills (Desimone, Smith, & Ueno, 2006). Therefore, it seems reasonable to assume that variables related to classroom technology use (e.g., motivation, knowledge) are also suitable for predicting PD behavior (e.g., perceiving the need for PD, attending PD courses). Again, both teacher motivation (e.g., utility beliefs and attitudes regarding technology for teaching: Backfisch, Lachner, Hische, Loose, & Scheiter, 2020; Konstantinidou & Scherer, 2022; Scherer & Teo, 2019; van Braak, Tondeur, & Valcke, 2004) and technology-related knowledge (e.g., technological or technological pedagogical knowledge: Backfisch, Lachner, Hische, Loose, & Scheiter, 2020, Backfisch, Scherer, Siddiq, Lachner, & Scheiter, 2021; Joo et al., 2018; Lachner, Backfisch, & Stürmer, 2019; Scherer & Teo, 2019) are related to using technology for teaching. For instance, Scherer & Teo (2019) showed in their meta-analysis that the perceived usefulness of technology was an important predictor of teachers' intentions to use technology in the classroom. Lai, Wang, & Huang, 2022 provided evidence that technology-related knowledge—based on the Technological Pedagogical Content Knowledge (TPACK; Mishra & Koehler, 2006) framework—determined teachers' use of technology for teaching. Moreover, Petko (2012) showed that teachers' technology-related knowledge explained the frequency of teachers' technology use for teaching.

The importance of motivation and knowledge for the use of technology in teaching is in line with the will, skill, tool model (Knezek & Christensen, 2016) in which *positive attitudes* (e.g., utility value) toward classroom technology use and sufficient *technology-related skills* (e.g., knowledge) are the most important predictors of teachers' implementation of technology in classrooms, besides the *sufficient access* to technology (Petko, 2012). Moreover, teachers who use more technology in the classroom are more likely to participate in technology-related PD (e.g., Drossel & Eickelmann, 2017), which is in line with assumptions of a *catalytic function* of PD.

2.2.2. Teachers' conscientiousness

Besides motivational and cognitive aspects, conscientiousness—a key personality trait—could also be important for predicting teachers' PD participation, especially in systems in which teachers choose PD voluntarily. Conscientiousness describes, for example, people's tendencies to follow norms and rules and to be highly responsible (Kim, Jörg, & Klassen, 2019; Roberts, Lejuez, Krueger, Richards, & Hill, 2014), and it predicts many important life outcomes (e.g., occupational success, academic achievement: Dudley, Orvis, Lebiecki, & Cortina, 2006; Roberts, Lejuez, Krueger, Richards, & Hill, 2014; especially on teachers' effectiveness: Kell, 2019; Kim, Jörg, & Klassen, 2019; Klassen & Tze, 2014). Thus, in comparison with other personality traits (e.g., openness to experience), conscientiousness has been discussed as the most important factor for academic and work-related contexts (e.g., He, Donnellan, & Mendoza, 2019; Poropat, 2009; Zell & Lesick, 2022). The assumption that conscientiousness is also relevant for predicting teachers' PD behavior is plausible because of positive associations between conscientiousness and effort-related job outcomes and between teachers' work engagement and PD participation (Fütterer, Hübner, Fischer, & Stürmer, 2023; D. Richter, Kunter, Klusmann, Lüdtke, & Baumert, 2011).

2.2.3. Further personal and contextual predictors

Drawing from models of adults' intentions to participate in educational opportunities (e.g., Cookson, 1986), we focused on examining the relative importance of teachers' will, skills, and conscientiousness for predicting their intentions to participate in technology-related PD. However, previous studies have shown that teachers' PD participation is related to further personal and contextual variables (Darling-Hammond et al., 2009; Krille, 2020; Kwakman, 2003). For example, there is evidence that teachers' PD participation is related to teaching experience (Hauk et al., 2022; D. Richter, Engelbert, Weirich, & Anand Pant, 2013; Zhang, Admiraal, & Saab, 2021) and teachers' gender (see Siddiq, Scherer, & Tondeur, 2016). However, the findings have been mixed regarding the direction of the relationships. For instance, Yang, Blunt, & Butler, 1994 and the authors of the recent report from the Teaching and Learning International Survey (TALIS; OECD, 2019) found no associations between PD participation and these demographic variables.

Furthermore, it is well-documented that previous behavior influences later behavior (Ajzen, 2001, 2002b; Sheeran, 2002). Indeed, some existing findings indicate that previous PD participation is an important predictor of later intentions to participate in PD (Fütterer, Hübner, Fischer, & Stürmer, 2023; Yang, Blunt, & Butler, 1994), and past experience with PD has been shown to be important for teachers' later PD activity (Masuda et al., 2013; Zhang, Admiraal, & Saab, 2021). For instance, teachers who experienced the quality of PD as negative (e.g., less coherence; Darling-Hammond et al., 2017; Desimone, 2009) may show reduced intentions to participate in future PD (Hill, 2009).

Finally, PD availability was revealed to be important for teachers' PD activity. For instance, Hill (2009) argued that the availability of PD varies considerably across regions in the US, and not everyone has access to suitable and high-quality PD. Especially regarding technology-related PD, an insufficiently availability of PD offers explains why few teachers participate (Eickelmann et al., 2019).

2.3. Research questions and hypotheses

We argue that technology-related PD is crucial for preparing in-service teachers to teach in a digitalized world and that the intention to participate is an important prerequisite for actually participating in technology-related PD. However, a lack of empirical studies have considered a broader spectrum of teacher characteristics for predicting teachers' PD participation (e.g., objective measures of technology-related skills or personality traits relevant to career success). Regarding the knowledge facets, it appears, for instance, that using self-reports to predict PD behavior for technology-related skills is questionable, as the accuracy of self-assessment is often biased (Aesaert, Voogt, Kuiper, & van Braak, 2017). That is, beliefs and self-reports of knowledge are oftentimes interpreted as measures of actual knowledge. However, the representation of teacher knowledge by their self-efficacy, as measured by self-reports, is problematic. Therefore, it has not yet been possible to assess how important knowledge facets really are for teachers' decisions to participate in PD. Moreover, different person characteristics have rarely been studied simultaneously. However, the simultaneous investigation of different variables of influence is necessary for assessing the relative importance of personal characteristics for teachers' PD participation. We thus tested the role of teachers' characteristics in their intentions to participate in technology-related PD activities by addressing the following preregistered research questions (RQs).

(RQ1). To what extent is teachers' motivation associated with teachers' intentions to participate in technology-related PD?

(RQ2). How much additional variation (i.e., in addition to motivation) does teachers' technology-related knowledge explain in teachers' intentions to participate in technology-related PD?

(RQ3). How much additional (i.e., in addition to motivation and knowledge) predictive power does teachers' conscientiousness have for teachers' intentions to participate in technology-related PD?

It can be assumed that stronger intentions to participate in PD are formed by teachers who are motivated to use technology for teaching (will), already have prior knowledge (skills), or are generally committed to strongly engaging in their profession and to participating in PD (conscientiousness). In this study, we analyzed the relative predictive power of these aspects for teachers' intentions to participate in technology-related PD. Further analyses of possible quadratic associations and further research questions on the possible differential effects (RQ4-RQ6) were not preregistered and thus formed the exploratory part of our study.

Gender differences for the constructs we examine have been studied extensively in previous research (for teachers' motivation to use technology [e.g., perceived utility] see e.g., Teo, Fan, & Du, 2015; for teachers' technology-related knowledge see e.g., Scherer & Siddiq, 2015; for conscientiousness see e.g., Lehmann, Denissen, Allemand, & Penke, 2013). Although scattered findings on, for instance, teachers' computer self-efficacy suggest that there are gender differences with respect to the relationship to PD behavior (Scherer & Siddiq, 2015), the analyses of the relationships between our constructs and teachers' intention to participate in technology-related PD are exploratory.

(RQ4). How do teachers' motivation, technology-related knowledge, and conscientiousness interact with teachers' gender in predicting teachers' intentions to participate in technology-related PD?

Furthermore, we explored whether teachers' motivation and technology-related knowledge are compensatory related.

(RQ5). How do teachers' motivation and technology-related knowledge interact in predicting teachers' intentions to participate in technology-related PD?

Because we also had the unique opportunity to use data in which the teachers' schools were randomly assigned to either a reform initiative (i.e., equipping teachers and students with tablet computers) or a control group (see detailed description in the Sample and Procedure section), we additionally explored the following research question.

(RQ6). How do teachers' motivation, technology-related knowledge, and conscientiousness interact with reform initiatives (i.e., basic equipping of teachers and students with one-to-one technology) in predicting teachers' intentions to participate in technology-related PD?

3. Method

3.1. Sample and Procedure

In this study, we used data from the school trial *tabletBW meets science* (Fütterer, Scheiter, Cheng, & Stürmer, 2022). This school trial was a ministerially funded initiative in which seventh-grade students and teachers were equipped with tablet computers in one-to-one classrooms. The aim of the school trial was to promote technology-based teaching and learning in classrooms in academic track schools in the federal state of Baden-Württemberg in Germany. Twenty-eight urban and rural schools with an equal representation of schools across the four districts of the state were selected from the Ministry of Education, Youth, and Sports Baden-Württemberg. Fourteen schools were randomly assigned to a *tablet condition* (i.e., every student and teachers in two seventh-grade classes received tablet computers), and 14 schools to a *non-tablet condition* (i.e., students and teachers in two seventh-grade classes did not get tablet computers). In Germany, at the time the study was conducted digital devices like tablet computers were hardly available in classrooms. Some schools did have tablet computers that students and teachers could borrow from the school for individual lessons. This means that the two groups differed in that they were randomly equipped with tablet computers on a 1:1 basis (tablet condition) or not (non-tablet condition). We used the data from teachers in both conditions. The tablet-condition teachers were asked to integrate tablet computers into their daily classroom practices. However, they were neither obliged to integrate tablet computers nor instructed in how to use tablet computers in their classes. Teachers from the tablet condition were offered (a one-day) in-service PD as an introduction to the use of tablet computers in the classroom. The participation in these PD offers were not mandatory. In this study, we analyzed data from teachers from the measurement point at which they first participated from 2018 to 2019, regardless of the subjects they taught (for more detailed information, please see Fütterer, Scheiter, Cheng, & Stürmer, 2022; Hammer, Göllner, Scheiter, Fauth, & Stürmer, 2021) if they gave informed consent.

Teachers were asked to complete online questionnaires, for instance, about their technology-based teaching (e.g., motivation to use technology) and personality (e.g., conscientiousness). Furthermore, we used (online and paper-and-pencil) tests to assess teachers' knowledge and skills (e.g., technological knowledge). We also assessed demographic variables. The first time of measurement took about 90 min (60-min online survey including a technological pedagogical knowledge test and a pedagogical knowledge test; 30-min paper-and-pencil technological knowledge [i.e., computer literacy] test).

We used data from 321 in-service teachers (53% women). On average, the teachers were 39.76 years old ($SD = 8.88$; Range: 24–64). The teachers' average teaching experience was 11.13 years ($SD = 8.03$). Teachers primarily taught mathematics, history, and English most frequently (each taught by 21% of teachers) followed by German and biology (each taught by 11% of teachers).

3.2. Measures

3.2.1. Dependent variable

Following Ajzen's (2002a) recommendations to construct an item to assess a person's behavioral intentions, we assessed teachers' intentions to participate in technology-related PD in the future (i.e., specific to the context of PD regarding tablet computers) with one item ("I intend to educate myself regarding tablet computers in the future"). Although the item wording does not explicitly refer to PD, we assume that teachers were reasonably aware that the item refers to the tablet computer use in teaching practice (i.e., 1:1 equipment within the school trial). Teachers rated the item using a 4-point rating scale ranging from 1 (*I do not agree at all*) to 4 (*I totally agree*). Single-item measures are appropriate when a construct is unambiguous or narrow in scope (Allen, Iliescu, & Greiff, 2022) and have also been used in previous studies on teachers' intentions to participate in PD (e.g., Dunn, Hattie, & Bowles, 2018).

3.2.2. Independent variables

To be able to address the question of which teachers intend to participate in technology-related PD and which do not consider their motivational and cognitive prerequisites regarding the use of technology in classrooms, we, first, included teachers' motivation to use technology (perceived utility) as an independent variable. Second, we included their professional knowledge, which was measured as their knowledge about technology (technological knowledge; TK) and their knowledge about the pedagogical use of technology for teaching (situational and conceptual technological-pedagogical knowledge; TPK). Third, we included conscientiousness.

3.2.2.1. Utility value of technology in classrooms. As our measure of motivation, we assessed the perceived social and personal utility of technology in the classroom with four items (e.g., "I think tablet computers are useful for my teaching"). The wording of all items measuring utility of technology in the classroom is given in Table A1 in the appendix. Teachers rated each item on a 4-point rating scale ranging from 1 (*I do not agree at all*) to 4 (*I totally agree*). We used an adapted version of the *Technological Innovativeness Scale* (TIS; van Braak, Tondeur, & Valcke, 2004) that Backfisch, Lachner, Hische, Loose, & Scheiter (2020) used and which is more in line with typical utility measures (Wigfield & Eccles, 2000). The internal consistency of the respective utility scale was good ($\alpha = 0.86$; Taber, 2018).

3.2.2.2. Technological knowledge (TK). As our first measure of technology-related knowledge, we tested teachers' TK (i.e., computer literacy encompassing facets of technological and information literacy) using the paper-and-pencil Test of Technological and Information Literacy (TILT; Senkbeil & Ihme, 2015). The TILT assesses teachers' computer literacy as a unidimensional construct with 29 multiple-choice items that were Rasch-scaled via the Partial Credit Model (PCM). The items cover topics such as technological literacy (e.g., knowledge and skills to access word processing software) and information literacy (e.g., evaluate search engines). Whereas a few items assess factual knowledge, most focus on troubleshooting (i.e., accomplishing computer-based tasks by using realistic problems in authentic situations). We estimated a generalized partial credit model (GPCM) as a measurement model representing the construct. The GPCM describes the probability of obtaining zero, partial, and full credit for an item as a function of the person's ability, threshold parameters of the item categories, and item discriminations (i.e., slopes; Desjardins & Bulut, 2020). Unlike the PCM, the GPCM freely estimates the slopes and thus allows for a more flexible representation of the links between constructs and items than the PCM. Indeed, the comparison of the expected a posteriori reliabilities and the results of likelihood-ratio tests (lmtest package; Zeileis & Hothorn, 2002) indicated the preference of the GPCM over the PCM for the TILT data, χ^2 (28, N = 248) = 112.84, $p < .001$. We used the resultant weighted likelihood estimates (WLEs; Warm, 1989) to represent teachers' test performance (Penfield & Bergeron, 2005). The test has been shown to be reliable (EAP/PV reliability = .81; Senkbeil & Ihme, 2015). The EAP/PV reliability of the TILT was 0.68 for our sample, the test information function had a maximum around zero, and the unidimensional GPCM provided a good fit to the data (SRMR = 0.06, SRMSR = 0.07). For an example item, please see Senkbeil, Ihme, & Wittwer, 2013.

3.2.2.3. Technological pedagogical knowledge (TPK). As our second and third measures of technology-related knowledge, we measured teachers' TPK with a test comprising 20 items (Lachner, Backfisch, & Stürmer, 2019). The test covered two dimensions of TPK: (a) Conceptual TPK (i.e., knowledge about psychological principles for learning and teaching with technology and the potential of technology for teaching), measured with eight multiple-choice items (four answer options each of which 1 to 3 were correct; e.g., "Digital information and communication technologies as cognitive tools offer the potential that …"); and (b) Situational TPK, measured with 12 multiple-choice items that served as text-based vignettes (the same eight answer options for all 12 items of which 2 to 4 were correct; e.g., "Students work on a digital simulation"). All items of the test can be found in Lachner, Backfisch, & Stürmer (2019) publication. Circumventing the strict constraints of sum scoring (i.e., parallel model; McNeish & Wolf, 2020), we estimated a GPCM and used the WLEs to represent teachers' conceptual and situational TPK. In addition to expert judgments two validation studies demonstrated the discriminant validity of the TPK test (i.e., low correlations to TILT test scores: conceptual TPK [$r = 0.05$] and situational TPK [$r = 0.23$]). Overall, the test has been shown to be a reliable and valid measure of teachers' TPK (Lachner, Backfisch, & Stürmer, 2019). For conceptual and situational TPK, the WLE reliability coefficients were 0.72 and 0.52 for our sample, respectively. Similar to the TILT, both TPK tests could be described by a unidimensional GPCM (conceptual TPK: SRMR = 0.07, SRMSR = 0.09; situational TPK: SRMR = 0.06, SRMSR = 0.08), and their test information curves had maxima around zero. Despite these test characteristics, the small sample size relative to the number of items limited the test reliability.

3.2.2.4. Conscientiousness. We assessed teachers' conscientiousness with three items (e.g., "I am reliable, I can be counted on") from the BFI-2-XS (Soto & John, 2017) at the first time of participation on a 5-point rating scale ranging from 1 (*do not agree at all*) to 5 (*totally agree*). The internal consistency was moderate (α = 0.65). The wording of all items measuring conscientiousness is given in Table A1 in the appendix.

3.2.3. Covariates and confounders

We controlled for teachers' *gender* ("Are you female or male?"; 0 = *male*, 1 = *female*) and teachers' *time in the profession*, both of which were measured at teachers' first time of participation ("Please indicate how long you have been working in the teaching profession"; continuous in years). Furthermore, we controlled for teachers' self-reported *participation in technology-related PD* (PDP) in the past 6 months using a dichotomous and adapted item from the Willingness for Professional Development scale (Ehmke et al., 2004) that indicated whether a teacher 1 (*did*) or 0 (*did not*) participate in technology-related PD ("Have you attended at least one professional development session on tablets in the past half year?"). In addition, we included teachers' perceptions of technology-related *PD availability* ("There is a lack of sufficient professional development in the field of tablet computers"). Teachers rated this item on a 4-point rating scale ranging from 1 (*do not agree at all*) to 4 (*totally agree*). Finally, we included the time point at which teachers first participated in the survey as a confounding variable. That is, teachers could have started to participate at any of four measurement points and we used three dichotomous variables to map four different measurement points (t_0, t_1, t_2, t_3; t_3 was the reference category).

3.3. Statistical analyses

3.3.1. Structural equation modeling (SEM)

To address our research questions, we specified sequential, multiple, and (non)linear regression models in the SEM framework (Finch & French, 2015; Gana & Broc, 2019; Kline, 2016) and estimated them in the R package *lavaan* version 0.6–12 (Rosseel, 2012). *Sequential* means that we first used an intercept-only model (M0) as a baseline model. Second, we included all covariates (M1). Third, we introduced the utility value of technology in classrooms as a predictor (M2). Next, we added TK and TPK as additional predictors (M3) and finally added conscientiousness as a predictor (M4; Fig. 2).

For the two constructs utility value and conscientiousness, we accounted for measurement error (Desjardins & Bulut, 2020) and possible unreliability that might affect the structural parameters by representing them as latent variables (Hoyle, 2012). To evaluate the goodness of fit of the SEMs, we used the common cut-offs for fit indices (Root Mean Square Error of Approximation [RMSEA] below 0.08, Comparative Fit Index [CFI] above 0.95, and Standardized Root Mean Square Residual [SRMR] below 0.06; Hu & Bentler, 1999). We further supplemented the evaluation of the measurement models by generating dynamic model fit index cut-offs (McNeish & Wolf, 2021) using the R package *dynamic* version 1.1.0 (Wolf & McNeish, 2022).

We chose the sequential approach to test the additional relevance of the predictors for the variance they explained in the dependent variable. To do this, we used saturated correlates in the reduced models (Graham, 2003) as Hayes (2021) recommended for SEM frameworks when calculating the change in the coefficient of determination (i.e., ΔR^2). Utilizing the Wald test (Klopp, 2020), we further tested the equality of the standardized regression coefficients across the different predictors in the full model (M4).

We used linear models to investigate linear associations between the predictors and the continuous dependent variable and nonlinear models to explore possible quadratic regressions. To create the respective quadratic terms, we used a product-indicator approach for the latent predictors (Marsh, Wen, & Hau, 2004) with double-mean centering, as recommended by Kolbe & Jorgensen, 2018. To test the differential effects across gender (RQ4) and across reform initiatives (RQ6), we extended the final model (M4) to a multigroup model with gender and reform initiatives (0 = *teachers in non-tablet condition*, 1 = *teachers in tablet condition* [i.e., basic equipping of teachers and students with one-to-one technology]) as grouping variables and tested whether measurement invariance held (van de Schoot, Lugtig, & Hox, 2012). We found that strong measurement invariance could be assumed across gender and reform initiatives. For RQ5, we tested the differential effects via the product-indicator approach.

Our analyses were based on cross-sectional data. We prepared and analyzed the data in *R* version 4.1.1 (R Core Team, 2022) and *RStudio* version March 1, 1073 (RStudio Team, 2020). To scale the TK and TPK tests, we used the R package *TAM* version 3.7–16 (Robitzsch et al., 2021) according to the test manuals' specifications. The data, syntax, and updated analyses can be retrieved from our OSF project at https://osf.io/bt4gj/?view_only=ac976ed6597f42deab7192818a56a5c7.

3.3.2. Robustness checks

To check the robustness of our results, we included all covariates and possible confounders in all models. Furthermore, we prevented biased estimation due to the clustering of teacher data in schools by using cluster-robust standard errors because ignoring even small intraclass correlations can bias the significance test results in regression analyses (Cohen et al., 2003; Geiser, 2013). Cluster-robust standard errors are recommended if the clustering is a nuisance factor resulting from the data collection (McNeish, Stapleton, & Silverman, 2017). To control the false discovery rate due to multiple tests, we applied the Benjamini-Hochberg (1995) adjustment to all models.

3.3.3. Missing data treatment

Missing values occurred because some items were not answered (NA). Moreover, the teachers took either the online questionnaire or the paper-and-pencil test. We tested for whether missing values occurred completely at random (MCAR) with Little's MCAR test (1988) as implemented in the *R* package *naniar* version 0.6.1 (Tierney et al., 2021). In our data set, we found a non-significant MCAR test χ^2 (147, $N = 321$) = 154.62, $p = .317$. However, inspecting the 21 patterns of missing values (most important combinations of missingness across cases are shown in Fig. 1), we assumed that missingness was at least (conditionally) at random.

In total, 25% of the dependent variable, and 34% of the independent and control variables were missing. We handled missing data in the continuous predictors via FIML estimation—a model-based estimation procedure that typically outperforms traditional methods such as listwise or pairwise deletion (Graham, 2012; van Buuren, 2018). To explore the sensitivity of our results with these missing data treatments, we first compared the results of all analyses with those obtained after we multiply imputed the data. Specifically, we generated 50 complete data sets using the R package *mice* version 3.14.0 (van Buuren & Groothuis-Oudshoorn, 2011). Second, we compared the results of all analyses with those when cases with missing values in the categorical outcome variable are deleted (listwise deletion; 242 cases remained in the analyses).

4. Results

4.1. Descriptive statistics, model fit, and covariates

To get an overview of the distributions, we inspected the means and standard deviations of the variables (Table 1). On average, PD intentions were above the scale midpoint, indicating that the teachers in the sample were generally willing to engage in PD on the use of technology in classrooms in the future. The utility of technology in the classroom was, on average, slightly above the scale midpoint. Teachers were, on average, more likely to be described as conscientious. Looking at the valid responses per variable (Table 1) and the most important combinations of missingness across cases (Fig. 1), we noticed that the number of missing values was high for

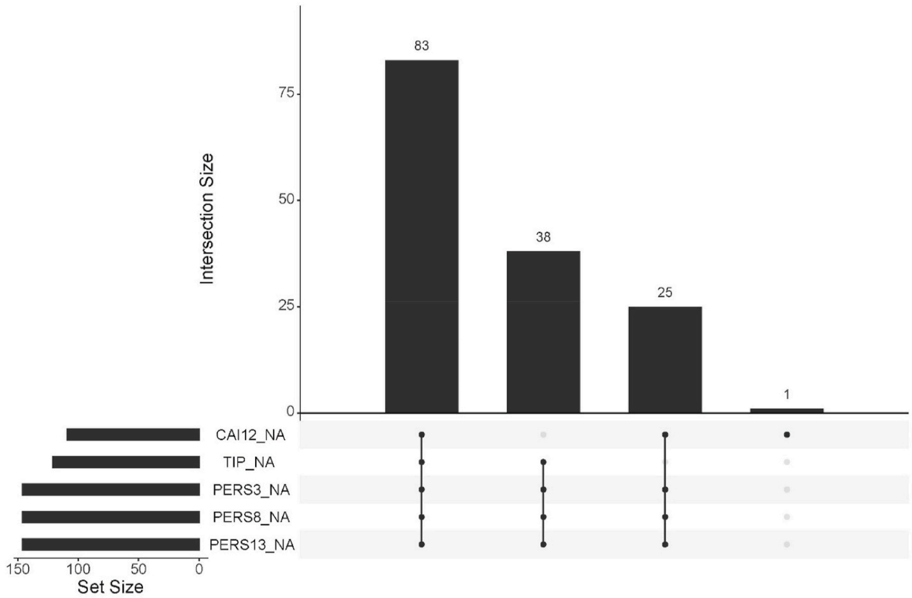

Fig. 1. Matrix Layout for the Most Important Combinations of Missingness Across Cases
Note. NA = not answered. CAI12_NA = missing values on one of the four indicators of the utility value of technology in classrooms; TIP_NA = missing values of the variable teachers' time in the profession; PERS3_NA, PERS8_NA, and PERS13_NA = missing values of indicators of teachers' conscientiousness. Dark circles indicate variables that are part of the intersection (see Lex & Gehlenborg, 2014). The bars indicate how many cases in the data set have a particular pattern of missing values. In total, 25% of the dependent variable, and 34% of the independent and control variables were missing.

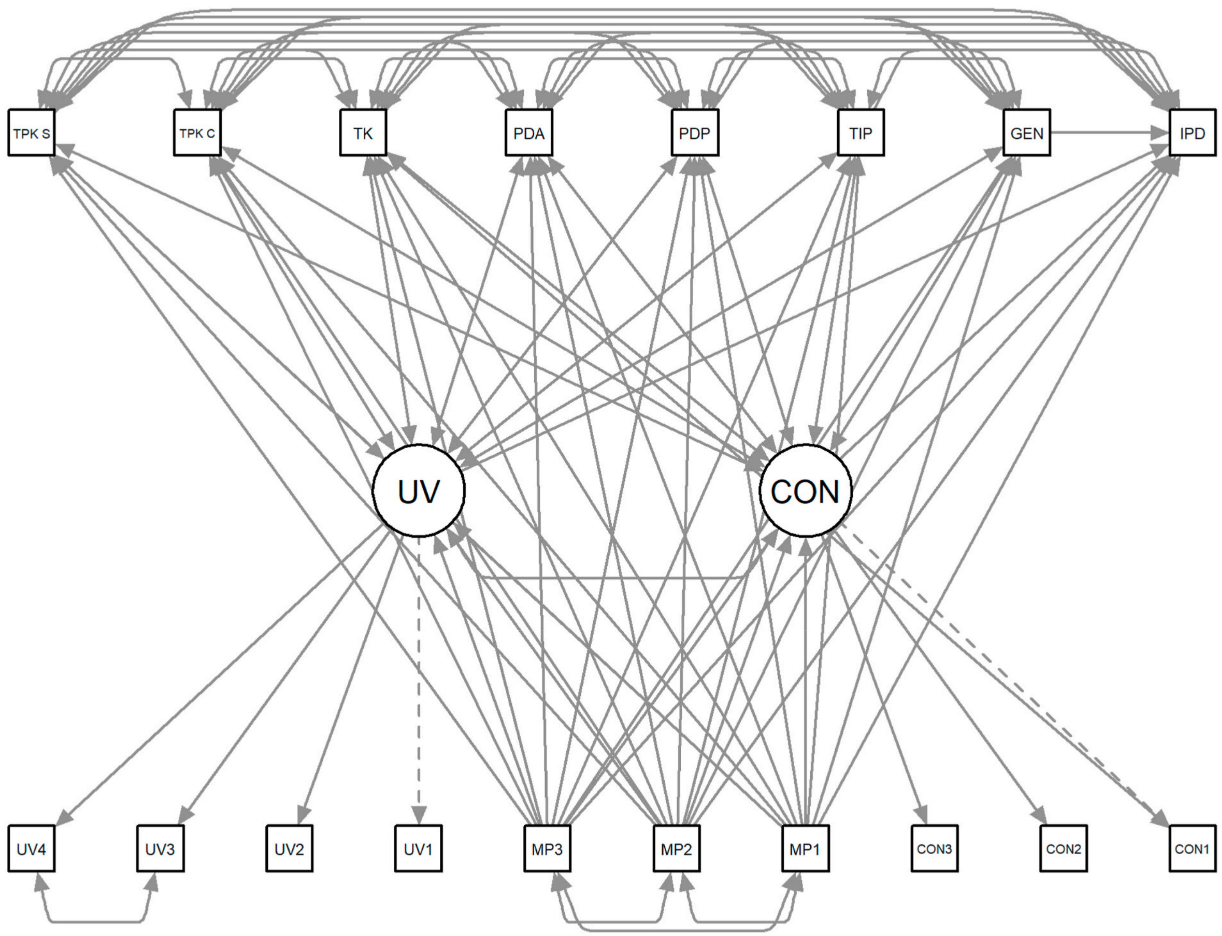

Fig. 2. Conceptual Model of the Full Model (M4)
Note. IPD = PD intentions (dependent variable), UV = Utility value, CON = Conscientiousness, MP = The first time teachers participated in the survey, GEN = Gender, TIP = Time in profession, PDP = Participation in technology-related PD, PDA = PD availability, TK = Technological knowledge, TPK C = Conceptual technological pedagogical knowledge, TPK S = Situational technological pedagogical knowledge.

Table 1
Descriptive Statistics for the Variables and Scales.

	All teachers			Men (n = 148)			Women (n = 224)		
	n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
PD intentions [a]	242	3.12	0.86	112	3.15	0.89	130	3.09	0.83
Utility [a]	212	2.76	0.67	97	2.78	0.75	115	2.75	0.60
Technological knowledge [b]	248	0.01	1.41	73	0.36	1.50	97	−0.19	1.47
Situational technological pedagogical knowledge [b]	235	0.14	1.48	107	0.12	1.46	128	0.17	1.50
Conceptual technological pedagogical knowledge [b]	230	0.00	1.52	106	−0.10	1.60	124	0.10	1.45
Conscientiousness [c]	175	3.75	0.75	76	3.82	0.72	99	3.69	0.77
Teaching experience in years	200	11.13	8.03	87	11.92	7.77	113	10.52	8.22
PD availability [a]	216	1.70	0.71	96	1.64	0.70	120	1.75	0.71
	n	% G1	% G2	*n*	% G1	% G2	*n*	% G1	% G2
Participation in technology-related PD [d] (G1: did not participate; G2: participated)	242	51.65	48.35	113	49.56	50.44	129	53.49	46.51
Gender [d] (G1: Male; G2: Female)	243	46.50	53.50	–	–	–	–	–	–

[a] 1 = *I do not agree at all* to 4 = *I strongly agree.*
[b] WLE score.
[c] 1 = *I do not agree at all* to 5 = *I strongly agree.*
[d] Dichotomous.

Table 2
Regression Analysis Results.

Teacher	Model M0			Model M1			Model M2			Model M3			Model M4		
	B	*SE*	*p*	*B*	*SE*	*p*	*B*	*SE*	*p*	*B*	*SE*	*p*	*B*	*SE*	*p*
Intercept PD intentions	3.149	.114	<.001	2.687	.237	<.001	2.854	.192	<.001	2.819	.220	<.001	2.811	.222	<.001
Utility							.488	.095	<.001	.482	.084	<.001	.490	.084	<.001
Technological knowledge										.097	.059	.164	.078	.066	.319
Situational technological pedagogical knowledge										−.043	.045	.407	−.044	.045	.406
Conceptual technological pedagogical knowledg										.013	.052	.836	.012	.050	.831
Conscientiousness													−.068	.081	.413
Covariates															
Teaching experience				−.117	.066	.129	−.042	.070	.608	−.039	.067	.623	−.045	.070	.580
Gender				−.044	.083	.368	−.049	.090	.359	−032	.089	.543	−.043	.095	.443
Participation in technology-related PD				.441	.141	<.001	.234	.110	<.001	.216	.106	<.001	.210	.112	.001
PD availability				.086	.115	.367	.076	.086	.286	.071	.090	.340	.080	.095	.310
R^2	.026			.244			.429			.437			.441		
R^2_{adj}	.026			.234			.420			.423			.425		

Note. $N = 321$. Robust model fit M0: $\chi^2(69, N = 321) = 84.894$, $p = .094$, SRMR = 0.036, CFI = 0.979, and RMSEA = 0.027 (90% CI [0.000, 0.045]). Regression weights are standardized.

conscientiousness and teaching experience.

Whereas three items were used to measure *conscientiousness* and therefore a saturated model is given for this construct (i.e., perfect model fit), the measurement model of construct *utility value of technology in classrooms* showed the following fit indices: SRMR = 0.016, RMSEA = 0.117, CFI = 0.993. According to the dynamic fit index cut-offs, the fit indices for the measurement model underlying M4 (SRMR = 0.043, RMSEA = 0.028, CFI = 0.996) were within the generated thresholds (SRMR = 0.074, RMSEA = 0.089, CFI = 0.963). According to Hu & Bentler (1999; see also Schermelleh-Engel et al., 2003), the fit of all SEMs was good. Specifically, the robust fit indices for the full model (M4, see Table 2) were as follows: χ^2 (69, N = 321) = 84.894, p = .094, SRMR = 0.036, CFI = 0.979, and RMSEA = 0.027 (90% CI [0.000, 0.045]).

Previous participation in technology-related PD was important for future participation in PD. If a teacher had already participated in technology-related PD, their intentions to participate in future PD were stronger. The comparison of the explained variance between the intercept-only model (M0) and M1 showed that including the covariates explained an additional 21% of the variance in teachers' intentions. However, of the covariates, only previous PD participation emerged as a statistically significant predictor, β = 0.441, SE = 0.141, $p < .001$.

4.2. *Motivation and intentions to participate in PD (RQ1)*

We addressed the question about how teachers' motivation (i.e., perceived social and personal utility of technology in the classroom) is associated with teachers' intentions to participate in technology-related PD by assessing M2 (Table 2).

As expected, we found that teachers' motivation was a moderate, positive, and statistically significant predictor of teachers' intentions to participate in technology-related PD (β = 0.488, SE = 0.095, $p < .001$, $R^2_{adj} = 0.42$). That is, the more teachers perceived the social and personal utility of technology in the classroom, the more likely they intended to participate in technology-related PD. Compared with M1, which included only the covariates, teachers' motivation explained an additional 19% of the variance in teachers' intentions. The exploratory analyses showed that the relationship was not quadratic (β = 0.008, SE = 0.135, p = .911). That is, we found no "optimal level" of motivation that could predict teachers' highest possible intentions to participate in technology-related PD.

4.3. *Motivation, skills, and intentions to participate in PD (RQ2)*

To address the question about how much additional variance teachers' technology-related knowledge can explain in teachers' intentions to participate in technology-related PD, we inspected the results of regression model M3 (Table 2). Whereas teachers' motivation was still a statistically significant predictor, the three technology-related knowledge facets (i.e., TK, situational TPK, conceptual TPK) were not. The exploratory analyses on possible quadratic associations indicated that the relationships were not quadratic.

4.4. *Motivation, skills, conscientiousness, and intentions to participate in PD (RQ3)*

To address the question about how much additional variance teachers' conscientiousness can explain in teachers' intentions to participate in technology-related PD, we looked at the results of the full regression model M4 (Table 2). We found that teachers' conscientiousness did not contribute additional variance toward explaining teachers' technology-related PD intentions when linear (β = −0.068, SE = 0.081, p = .413) or quadratic associations were examined.

All these findings from linear models were robust when the listwise deleted and the imputed data sets were used. All statistically significant regression weights were still statistically significant after the Benjamini-Hochberg (1995) correction.

Table 3
Differential Effects of Gender on Predictions of PD Intentions.

Teacher	Men (n = 113)			Women (n = 130)			Δp_{mf}
	B	*SE*	*p*	*B*	*SE*	*p*	
Intercept PD intentions	2.111	.351	<.001	3.110	.291	<.001	.030
Utility	.455	.121	<.001	.565	.163	<.001	.113
Technological knowledge	.040	.098	.752	.104	.081	.321	.696
Situational technological pedagogical knowledge	−.148	.072	.069	.005	.067	.953	.165
Conceptual technological pedagogical knowledge	.142	.068	.077	−.180	.069	.023	.004
Conscientiousness	−.154	.149	.271	−.074	.072	.409	.536
Covariates							
Teaching experience	.021	.085	.827	−.156	.062	.042	.166
Participation in technology-related PD	.184	.172	.058	.216	.141	.011	.889
PD availability	.319	.117	.001	−.058	.086	.437	.001

Note. Robust model fit: χ^2(132, N = 243) = 170.417, p = .014, SRMR = 0.064, CFI = 0.951, and RMSEA = 0.049 (90% CI [0.022, 0.070]). Δp_{mf} = p-value of differences in estimates (Bs) between the groups of women (f) and men (m). Regression weights are standardized.

4.5. Exploratory results (RQ4-RQ6)

To address the exploratory question about how teachers' gender moderates the extent to which teachers' motivation, technology-related knowledge, and conscientiousness predict teachers' intentions to participate in technology-related PD (RQ4), we looked at the results of the multiple-group model (Table 3). First, by examining the intercepts, β_0, we found that the average baseline level of teachers' intentions to participate in technology-related PD was significantly higher ($\Delta\beta_0 = 0.999$, $SE = 0.462$, $p = .030$) for women ($\beta_0 = 3.110$, $SE = 0.291$) than for men ($\beta_0 = 2.111$, $SE = 0.351$). Second, we found that teachers' conceptual technological pedagogical knowledge was statistically significantly more predictive ($\Delta\beta = -0.322$, $SE = 0.097$, $p = .004$) of women's intentions to participate in PD ($\beta = -180$, $SE = 0.069$, $p = .023$) than men's ($\beta = 0.142$, $SE = 0.068$, $p = .077$). Third, in contrast to teachers' conceptual technological pedagogical knowledge, we found that the perception of PD availability was significantly more predictive ($\Delta\beta = 0.376$, $SE = 0.146$, $p = .001$) of men's PD intentions ($\beta = 0.319$, $SE = 0.117$, $p = .001$) than women's ($\beta = -0.058$, $SE = 0.086$, $p = .437$). For women, perceived PD availability was not associated with their PD intentions. Descriptively, teachers' motivation is more important for women than for men. Finally, we did not find any further gender differences in the regression coefficients.

Regarding the exploratory question about how teachers' motivation and technology-related knowledge interact in predicting teachers' PD intentions (RQ5), we found no interaction effects (TK: $\beta = -0.002$, $SE = 0.117$, $p = .985$; situational TPK: $\beta = -0.015$, $SE = 0.054$, $p = .785$; conceptual TPK: $\beta = 0.002$, $SE = 0.079$, $p = .979$). For example, teachers' motivation seems to be important for their intentions to participate in technology-related PD regardless of their level of knowledge (e.g., no compensatory effect).

Similarly, we did not find differences in the prediction of teachers' PD intentions between teachers who were part of a reform initiative to provide one-to-one technology in classrooms and teachers who were not part of this reform initiative (RQ6; see Table 4).

5. Discussion

5.1. Predictors of teachers' intentions to participate in technology-related PD

Technology-related PD is crucial for preparing in-service teachers to use technology for effective teaching. A teacher's intention to participate in technology-related PD is an important prerequisite for actually participating in technology-related PD. In this study, we aimed to systematically investigate the relative importance of different teacher characteristics for their intentions to participate in technology-related PD. A unique finding of this study that could only be detected because motivational, cognitive, and personality characteristics were included simultaneously as predictors of teachers' technology-related PD intentions is that teachers' motivation (i.e., the social and personal utility of technology in the classroom) was a stronger predictor than technology-related knowledge (e.g., technological pedagogical knowledge [TPK]) and conscientiousness.

The significance of teachers' perceived utility of technology in the classroom is in line with findings from previous research regarding teachers' general PD participation showing that teachers' interest in a specific topic is positive related to their PD participation (e.g., D. Richter, Kleinknecht, & Gröschner, 2019; E. Richter, Richter, & Marx, 2018; for adults see, e.g.,: Gorges, 2015, 2016). For instance, in a systematic literature review, Krille (2020) found that teachers' interest in the PD topic was teachers' most important reason for participating in PD. Moreover, as teachers are experienced learners, it is reasonable that they link their learning motivation to the utility of the learning material and to the anticipated utility (Lipowsky & Rzejak, 2015). In line with this, Gorges & Hollmann, 2015 showed for $N = 6064$ adults that the subjective value of PD participation predicted actual PD participation. Based on the findings of a German study on the use of technology in schools from a teachers' perspective (BITKOM, 2011), in which mathematics and science teachers attended technology-related PD more often than teachers of different subjects, Krille (2020) concluded that these teachers already have a higher interest in technology. This assumption fits with the findings of Drossel & Eickelmann, 2017, who showed that, for instance, teachers who use computers more frequently in the classroom engage more often in technology-related PD. However,

Table 4
Differential Effects of the Reform on Predictions of PD Intentions.

Teacher	No reform ($n = 89$)			Reform ($n = 147$)			Δp_{nr_r}
	B	*SE*	*p*	*B*	*SE*	*p*	
Intercept PD intentions	2.873	.430	<.001	2.973	.243	<.001	.841
Utility	.508	.209	.002	.432	.094	<.001	.341
Technological knowledge	.236	.127	.123	.054	.067	.603	.264
Situational technological pedagogical knowledge	.042	.100	.697	−.084	.062	.371	.423
Conceptual technological pedagogical knowledge	.134	.118	.252	−.051	.063	.588	.203
Conscientiousness	.162	.215	.340	−.041	.072	.681	.306
Covariates							
Teaching experience	.067	.102	.611	−.041	.063	.625	.458
Gender	−.067	.199	.538	.001	.108	.986	.580
Participation in technology-related PD	.209	.270	.090	.125	.110	.093	.346
PD availability	.039	.170	.744	.036	.077	.664	.906

Note. Robust model fit: $\chi^2(147, N = 236) = 190.755$, $p = .009$, SRMR = 0.063, CFI = 0.937, and RMSEA = 0.050 (90% CI [0.025, 0.070]). Δp_{nr_r} = *p*-value of differences in estimates (*B*s) between the group of teachers working in classes where all students and teachers were not (nr = no reform) and were (r = reform) equipped with tablet computers. Regression weights are standardized.

Krille (2020) emphasized that her assumption cannot be verified, and therefore more research is needed. The systematic approach in our study makes it possible to support this assumption with empirical findings.

In contrast to positive associations of self-assessed technology-related knowledge and skills (e.g., ICT self-efficacy) and PD participation by teachers found in previous studies (e.g., Drossel & Eickelmann, 2017; Kao, Wu, & Tsai, 2011), the findings in our study revealed that teachers' conceptual TPK (i.e., knowledge about facts, concepts, and principles regarding technology in classrooms; Lachner, Backfisch, & Stürmer, 2019) was less important for women than for men. Except conceptual TPK for women, we found that the level of objectively measured technology-related knowledge was not related to teachers' intentions to participate in technology-related PD. On the one hand, this finding is surprising because teachers' skills (specifically their knowledge levels) are key in both an educative and a catalytic function of PD (Desimone, Smith, & Ueno, 2006). Moreover, findings from previous studies have suggested that "teachers align their PD activities with their perceived need for enhanced knowledge" (Krille, 2020, p. 91). On the other hand, for instance, teachers might not have recognized an objectively identified need for PD (i.e., were not able to assess their skills accurately; Maderick, Zhang, Hartley, & Marchand, 2016). Alternatively, teachers may have accurately assessed their skills but did not want to leave their comfort zone. However, the difference in conceptual TPK may suggests that for women it is more likely that PD fulfills an educative function and for men it is more likely that PD fulfills a catalytic function.

Conscientiousness did not predict teachers' intentions to participate in technology-related PD. On the one hand, this finding was surprising because conscientiousness has been shown to be significant in areas that require self-discipline or persistent effort (i.e., PD as a crucial part of the teaching profession can be considered such an area; Avalos, 2011). On the other hand, this finding is in line with results of some recent studies on the relationships between teachers' personality traits and teachers' PD behavior (Bareis et al., 2023). One possible explanation is, for example, that conscientious teachers may believe that they need to focus all their energy on teaching and that participating in PD would detract from this goal. That is, if conscientious teachers were characterized by taking their core task (i.e., teaching) seriously, then these teachers would also spend their available time outside of class on preparing and following up on lessons, while spending time participating in PD would tend to be considered less important.

Furthermore, as expected, teachers' previous PD behavior was shown to be important for teachers' intentions to participate in technology-related PD. One explanation is that teachers' PD behavior is stable over time (Fütterer, Hübner, Fischer, & Stürmer, 2023). Another assumption is that previous PD behavior already includes important person characteristics (e.g., general occupational commitment) and that these person characteristics explain the corresponding correlations.

Regarding the results from the exploratory analyses, it is noteworthy that the extents to which person characteristics and the covariate predicted teachers' intentions to participate in technology-related PD were not significantly different between teachers who were part of a reform initiative and teachers who were not. This finding is surprising because it could be assumed that perceiving an opportunity for PD as suitable would play a subordinate role in reforms as teachers may realize that they need PD to fulfill the goals of the reform. Furthermore, it could have been expected that conscientiousness would be a significant predictor in the reform situation as conscientious teachers would likely participate in PD because they would want to successfully implement the reform (see Borko, 2004; Garet et al., 2001; Penuel, Fishman, Yamaguchi, & Gallagher, 2007). However, it is also possible that effects of the reform on PD behavior were only evident immediately after the reform began or that the school administrators did not explain to the teachers that they needed to engage in PD.

Finally, an adequate technology-related PD availability seemed to be a stronger predictor of men's PD intentions than women's.

5.2. Limitations and future directions

The results of this study must be interpreted in light of at least three limitations. First, we had only cross-sectional data, which do not allow for causal inferences. Therefore, the results of this study must be interpreted as correlational. Furthermore, using cross-sectional data does not make it possible to examine statements about the manifestation of PD intentions in actual PD participation because past behavior can be only retrospectively surveyed, and only current behavior can be assessed in cross-sectional research. This means that, although intentions have been shown to be important for actual behavior in prior research across domains, it remains the task of future research to use longitudinal data to investigate causal relationships between factors of influence and intentions to participate in technology-related PD as well as actual participation.

Second, we had a selective sample, as data were available only from teachers working in schools that had already shown a commitment to pushing the topic of digitization forward. That is, the schools included in this study had to submit a didactic concept for the use of technology in the classroom to apply for the school trial. Thus, teachers at these schools were probably already familiar with digital teaching compared with teachers in "average schools" in Germany. Generalizing the results across school conditions is thus not possible.

Third, although a considerable part of the variance in teachers' intentions to participate in technology-related PD was already explained by our full model ($R2\text{adj} = 0.43$), it is evident that important variables were not included in the models (*omitted variable bias*). For instance, the fit between opportunities for PD and teachers' schedules (Fütterer, Hübner, Fischer, & Stürmer, 2023) or indicators of school climate and the role of school leadership (e.g., Krille, 2020) are known to be an important reason for whether teachers participate in PD or not.

5.3. Implications and future research

This study has several implications for theory, practice, and future research. First, the results suggest that objectively assessed levels of technology-related knowledge did not play a dominant role in the formation of teachers' intentions to participate in technology-related PD. Therefore, detached from PD questions, it might be worthwhile to systematically investigate the meaning of skills for the integration of technology in teaching, as postulated in the will, skills, tool model (e.g., by including objective measures). In addition, regarding PD, the validity of the catalytic function (Desimone, Smith, & Ueno, 2006) with respect to cognitive prerequisites should also be tested using objective rather than self-report measures (e.g., using test-based knowledge). Furthermore, the organization of PD is often based on the assumption that PD fulfills an educative function (Desimone, Smith, & Ueno, 2006). If the current level of technology-related knowledge has no meaning in PD systems where PD is self-selected (i.e., PD is chosen according to teachers' need but not demand), then the educative function becomes invalid (see also the administrator's dilemma, Desimone, Smith, & Ueno, 2006; or Matthew effect, E. Richter, Kunter, Marx, & Richter, 2021). Against this background, it is useful to discuss how stakeholders in PD practice can incorporate monitoring mechanisms to a greater extent. However, not only generic prerequisites of teachers (e.g., TPK) but also subject-specific prerequisites (e.g., technological content knowledge) should be considered, which is also likely to be important for teachers' intention to participate in technology-related PD.

Second, the findings of our study suggest that it may be worthwhile to take a closer look at gender differences in the validity of PD functions. That is, the results indicate that different measures are promising for motivating both genders to participate in PD. For both genders, but descriptively more so for women, the perception of the utility of technology for teaching is significant for the formation of an intention to participate in technology-related PD. In addition, the educative function of PD seems to rather apply to women. Thus, if the intention is to attract women to participate in technology-related PD, it would be advisable for PD providers to particularly emphasize the benefits of the PD content for digital teaching. For the development of men's PD intentions, it also seems to be important to ensure a sufficient PD availability (e.g., overcome a poor fit between PD opportunities and one's schedule; Fütterer, Hübner, Fischer, & Stürmer, 2023; Krille, 2020).

Finally, the data were collected prior to the COVID-19 school closures, which resulted in teachers being asked to implement digital-based distance learning. On the one hand, the school closures may have acted as a natural intervention, which may have served as a utility intervention, as teachers realized the potential that technology has for teaching (Fütterer et al., 2021). On the other hand, teachers may have been too overburdened to use technology effectively for their teaching, and their motivation to use technology in-person teaching after COVID-19 school closures may have ceased. Future research should follow up on these potential COVID-19 effects to monitor teachers' willingness to participate in technology-related PD. The natural interventions may also have acted as a corrective to the assessment of technology-related knowledge and skills (e.g., TPK). The need to use technology for teaching may have given teachers immediate feedback on the extent of their knowledge and skills. Teachers may have a more realistic picture of their technology-related knowledge and skills, and some teachers who previously tended to overestimate themselves may have developed greater intentions to participate in technology-related PD.

Credit statement

Tim Fütterer: Conceptualization, Methodology, Formal analysis, Data Curation, Visualization, Writing - Original Draft, Project administration. **Ronny Scherer**: Conceptualization, Formal analysis, Writing - Original Draft. **Katharina Scheiter**: Writing - Review & Editing. **Kathleen Stürmer**: Writing - Review & Editing. **Andreas Lachner**: Conceptualization, Writing - Review & Editing.

Declaration of competing interest

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Data availability

The data, syntax, and updated analyses can be retrieved from our OSF project. We shared a link in the manuscript.

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Appendix A. Supplementary data

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