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Technology-related teaching skills and attitudes: Validation of a scenario-based self-assessment instrument for teachers

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A R T I C L E I N F O

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A B S T R A C T

Instruments that assess teachers' skills and attitudes on the basis of a broad range of specific standards and demands for teaching with digital technologies are lacking to date. Based on the K19 framework, we validated the scenario-based instrument *IN.K19* that simultaneously assesses technology-related teaching skills and attitudes via self-assessment. In our study with N = 90 teachers and student teachers with teaching experience, we demonstrate that the instrument has satisfactory factorial validity in our confirmatory factor analyses. To investigate its predictive validity, we examined the instruments' relationships with teachers' frequency of technology use in class and teachers' initiation of different types of student learning activities involving technology. Results from structural equation modelling show relationships between self-assessed skills in different phases of teaching with technology and the self-reported initiation of student learning activities involving overt actions (active, constructive, and interactive learning activities), supporting the predictive validity of our instrument. Positive attitudes towards technology-related teaching also exhibit positive relationships with the initiation of learning activities involving digital technologies, but more specifically learning activities that do not include observable actions by learners (passive learning activities). Thus, teachers' self-assessed technology-related skills rather than attitudes might contribute to facilitating learning activities crucial for students' learning.

1. Introduction

Technology is spreading into schools, opening up diverse opportunities for both students and teachers. But merely being equipped with digital technology does not mean that students and teachers are able to use it effectively for learning and teaching (Considine, Horton, & Moorman, 2009). For that to happen, students and teachers need basic digital skills, i.e. skills to understand, evaluate and communicate with digital technology in daily routines (Ferrari, 2012; Fraillon, Ainley, Schulz, & Friedman, 2014; KMK, 2016; Krumsvik, 2011). Beyond basic digital skills, certain types of knowledge related to digital technology, instruction, and teaching content are assumed to be necessary for teachers when teaching with technology (see Mishra & Koehler, 2006). More recent approaches build upon knowledge-centered models, claiming that not only knowledge but also technology-related teaching skills are required to use digital technologies efficiently during teaching (Digital Campus of Bavaria [DCB], 2017; Ertmer & Ottenbreit-Leftwich, 2010; Kelly & McAnear, 2002; Krumsvik, 2011; Simons, Meeus, & T'Sas, 2017; Thomas & Knezek, 2008). Accordingly, teachers must be qualified to provide technology-supported learning opportunities for their students, be able to use digital technology and be aware of how digital technology can support students' learning (Kelly & McAnear, 2002).

Claiming that all teachers need to have such technology-related teaching skills means putting new challenges and responsibilities on teachers' shoulders. However, easy-to-use instruments to assess such teaching skills and thus indicate whether teachers are prepared to meet their new standards and demands are lacking. Teachers have been described as the ultimate change agents who need to engage in lifelong learning in order to successfully advance teaching through the inclusion of digital technologies (G. Fischer, 2000). In this respect, teachers may benefit from tools that guide them in their professional development. An instrument that reliably and validly measures self-assessed teachers' technology-related teaching skills can be helpful for teachers to identify areas of excellence, areas of progress and areas for improvement within

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this lifelong learning process.

In this study, we validated a scenario-based self-assessment instrument called *IN.K19,* which is based on the K19 framework developed by the interdisciplinary *Digital Campus of Bavaria* research group (DCB, 2017). It postulates 19 technology-related teaching skills inferred from and grouped according to three phases of action with respect to classroom instruction. The three phases address general problem-solving stages within teaching with technology (Ertmer & Ottenbreit-Leftwich, 2010; Zimmerman & Campillo, 2003): planning, implementing, and evaluating teaching with technology. Also included was a *sharing* phase, which covers follow-up communication after lessons for the purpose of professional collaboration and development of lessons. The scenario-based instrument measures self-assessed technology-related teaching skills and attitudes towards technology-related teaching with respect to each of the four phases. *IN.K19* seeks to provide a reliable and accessible tool to gather comprehensive empirical data on teachers' self-assessed technology-related teaching skills to inform research and subsequent decision-making in the fields of teacher training, school development and educational policies. *IN.K19* is a generic instrument for all teachers, regardless of the subjects they teach. In this article, we seek to validate the instrument by assessing its factorial and predictive validity.

1.1. Technology-related teaching skills and attitudes

Generally, pre-service and in-service teachers are considered to require a certain level of competency to meet the standards and demands of a digitalized world (Kirschner, 2015). Competency in this broad sense refers to a combination of complex cognitive skills, highly integrated knowledge structures, and attitudes (Blömeke, Gustafsson, & Shavelson, 2015; Kunter, Klusmann, Baumert, Richter, Voss, & Hachfeld, 2013; Van Merriënboer & Kirschner, 2017). Taking teachers' knowledge about teaching with digital technologies as a starting point, research frequently builds on the TPACK model (Mishra & Koehler, 2006). TPACK, in turn, builds on Shulman (1986), who postulated that teachers need a combined knowledge of content and pedagogy known as pedagogical content knowledge. The TPACK model extends this perspective by adding a third component to Shulman's (1986) model of pedagogical knowledge (PK) and content knowledge (CK): technological knowledge (TK; Mishra & Koehler, 2006). Moreover, four hybrid components are formed at the intersections of the different knowledge areas, known as pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), technological content knowledge (TCK), and technological pedagogical content knowledge (TPCK; Mishra & Koehler, 2006; Schmid, Brianza, & Petko, 2020).

While TPACK focusses on different types of knowledge, research has moved beyond teacher knowledge to explore other, more comprehensive concepts (Petko, 2020). The notion of complex cognitive skills for teaching with digital technology puts a stronger focus on what teachers need *to be able to* do with technology in class to be digitally literate educators (DCB, 2017; Kelly & McAnear, 2002). We conceptualize *technology-related teaching skills* as the combination and integration of conceptual knowledge facets and action-oriented knowledge facets. Conceptual knowledge facets refer to knowledge on (scientifically based) models and frameworks that link digital technologies and successful teaching and learning in the classroom. Action-oriented knowledge facets enable enacting teaching and learning with digital technologies in the classroom, including solving emerging problems. These action-oriented knowledge facets may also include giving advice to other teachers on enacting (and solving problems in) technology enhanced teaching scenarios.

Referring back to teachers' competency to meet the standards and demands of a digitalized world (Kirschner, 2015), not only technology-related teaching skills, but also attitudes towards technology-related teaching are important to consider (Van Merriënboer & Kirschner, 2017). An attitude can be defined as a negatively to positively valenced evaluation of a topic, person, or event (Heddy, Danielson, Sinatra, & Graham, 2017). Thus, attitudes toward technology-related teaching refer to negatively to positively valenced evaluations of teaching with digital technologies.

1.2. Technology-related teaching skills in different phases of teaching with digital technology

Technology-related teaching skills focus on what teachers need in order to plan, design, and successfully implement their teaching activities and then to scaffold and support students' learning processes with digital technologies (Claro et al., 2018). Specifically, technology-related teaching skills include identifying and using appropriate technologies in a way that facilitates a broad range of learning activities, especially those relevant for students' knowledge application and skill development (Chi, 2009; Chi & Wylie, 2014).

Existing frameworks provide conceptualizations of teaching activities involving digital technologies (see Kelly & McAnear, 2002; Krumsvik, 2011). However, they do not offer a concrete operationalization of technology-related teaching skills, although this is precisely what is needed to design situational, adaptive learning opportunities to support students' learning outcomes. In contrast, the K19 framework, aims to establish a closer connection between technology-related teaching skills and actual technology-related classroom learning activities (DCB, 2017). Thus, the framework operationalizes technology-related teaching skills in different phases of teaching with and about digital technologies and seeks to outline and systematize the core technology-related skills teachers need in each of these phases. K19 is based on the assumption that teachers, just like their students and all people in a digitalized world irrespective of their profession, need basic digital skills, which combine conceptual and action-oriented TK facets. In addition to these basic digital skills, teachers are expected to not only have instrumental and critical skills regarding the use of digital technology in their everyday lives, but also skills related to teaching with digital technologies, which combine conceptual knowledge facets and corresponding action-oriented knowledge facets of TPK. Although it is clear that subject-specific conceptual knowledge facets and corresponding action-oriented facets of TPCK are important for teachers as well (Mishra & Koehler, 2006), the K19 framework is generic as it postulates technology-related teaching skills as relevant for all teachers. The framework comprises the 19 technology-related teaching skills that are rooted in problem-solving stages teachers typically proceed through in different phases of teaching with and about digital technology: planning (see Section 1.1.1), implementing (see Section 1.1.2), evaluating (see Section 1.1.3), and sharing (see Section 1.1.4) digitally supported learning environments (Ertmer & Ottenbreit-Leftwich, 2010; Zimmerman & Campillo, 2003). This ultimately cyclical model can be helpful to identify and specify which particular skills teachers need in order to solve the technology-related problems that typically arise in the preparation of lessons (planning), in the classroom (implementing), after lessons (evaluating) and as part of their collaborative development of lessons (sharing). An overview of the 19 technology-related teaching skills is provided in Fig. 1.

1.2.1. Planning (before class)

Planning digital technology use in class can be separated into nine distinct skills that relate to three aspects:

First, instruction in the digital age requires teachers to take into consideration the technology-related experiences students inevitably bring into the classroom and plan their lessons accordingly (see Prensky, 2001). It requires teachers to consider legal and ethical aspects of instruction when designing digital lessons such as copyright protection, data protection, and child welfare or value implications of the digital technology used in the classroom (see Edwards, 2015). It further requires them to consider emotional and motivational issues related to media socialization and the way digital technology influences how

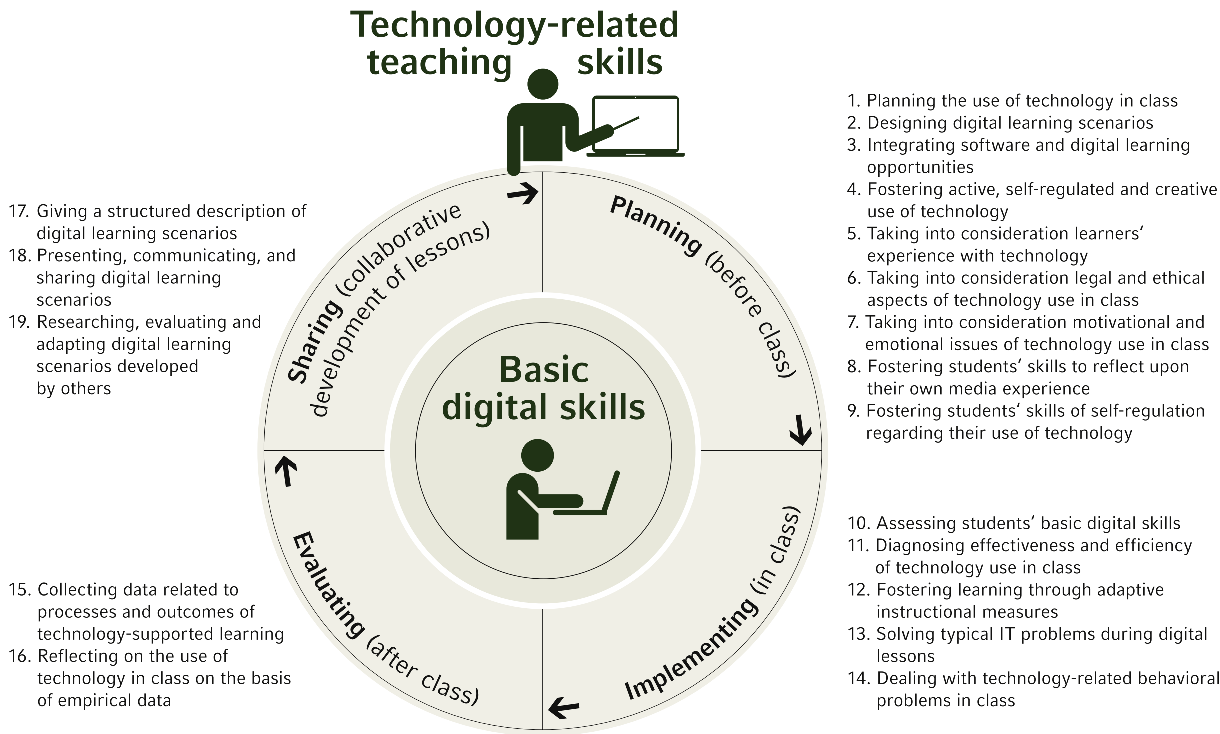

Fig. 1. Model of technology-related teaching skills in the planning, implementing, evaluating, and sharing phases that go beyond teachers' basic digital skills.

young people experience the world.

Second, teachers to be aware that instruction in the digital age inevitably involves general educational objectives that are independent of the subject and topic. Thus, teachers need to be able to plan lessons in such a way that their students can learn to reflect upon their own media experiences (see Buckingham, 2007). This involves being able to plan lessons that help students learn to enhance their self-regulation capacity with regard to attention, emotions, impulses and behavior (see Steffens, 2006). Ultimately, lessons should allow students to acquire the ability to use digital technologies actively and creatively for their own learning and personal development (see Hague & Payton, 2010).

Third, skills that are specific to the actual instructional design of digitally-supported lessons on the basis of research evidence and personal experience are crucial. These encompasses the skills to conceptualize and design digital lessons, implement them using digital technology such as learning management systems, and identify, adapt, and integrate high-quality educational software and digital learning scenarios developed by third parties into their lesson plan (see Edwards, 2015; Ng, 2012).

1.2.2. Implementing (in class)

The technology-related teaching skills for the implementing phase emphasize that teachers need specific skills in the digital classroom which come into play when things do not go according to plan. These skills comprise the ability to ensure the basis for learning in a digital classroom and the ability to provide adequate learning support for students.

Providing the basis for digital learning in the classroom stipulates that teachers need to be able to perceive behavioral problems in the digital classroom which might impede the learning process from going according to plan, and react appropriately to them (see Ehrlick, 2014). It also captures teachers' capacity to solve typical technological problems that may (and will) come up during digital lessons (see Ng, 2011), such as non-working devices or projectors. It could be argued that this skill is not pedagogical but rather technological in nature; however, as the problem-solving process in such situations takes place within the lesson, it necessarily acquires pedagogical significance: the teacher will inevitably act as a role model for his or her students.

Ensuring students' learning in the digital classroom comprises the diagnostic skill of being able to assess each student's basic digital skills (see UNESCO, 2013). It requires teachers to be able to form accurate judgements about whether the current use of digital technology in the classroom is helping students achieve their learning goals efficiently and effectively (see Ng, 2011). Furthermore, it consists of teachers' skill in supporting their students' learning based on the results of their diagnostic evaluations through adequate instructional measures, such as providing feedback or scaffolding (see Hattie & Timperley, 2007; Quintana et al., 2004).

1.2.3. Evaluating (after class)

The third group of technology-related teaching skills addresses what teachers need in order to professionally evaluate their own digital lessons so that they can adapt and improve their future teaching on the basis of robust data. It consists of two skills: the skill to systematically collect data about cognitive, motivational and emotional aspects and outcomes of students' learning processes in the digital classroom, and the skill to analyze, interpret, and draw conclusions from those data in light of domain-specific or domain-general concepts, research evidence and personal experience (see Poe & Stassen, 2002).

1.2.4. Sharing (collaborative development of lessons)

The last group of technology-related teaching skills draws attention to the fact that digitalization has not only profoundly transformed education and instruction, it also affects teaching as a profession and as a practice with specific routines. In particular, digitalization has made it possible to find, use, adapt, and share digital learning activities, instructional scenarios, lesson plans more easily than ever before. Digital technology provides teachers with the opportunity to communicate and collaborate in designing, adapting, and re-designing digital lessons (see Ferrari, 2012). Consequently, digitalization has led to a shift in the set of skills teachers need in their profession. Thus, teachers must be able to describe their digital lessons in a comprehensive, structured way in terms of learning goals, instructional design, classroom experience, outcomes, and consequences. They require skills in presenting, communicating and sharing their digital lessons successfully in the context of offline or online professional cooperations and further education, e.g. sharing them online as open educational resources. Conversely, they must also be able to seek out, analyze, assess and adapt digital lessons by others in order to profit from and use them in their own classrooms.

This framework of 19 teaching skills constitutes a comprehensive model permitting the systematic identification and analysis of the dimensionality and structure of technology-related teaching skills teachers need in the digital age. It can be regarded as a contribution to the conceptualization of a unique field of expertise and its subdivision into individual skills.

1.3. Teaching with digital technology

According to the previously described frameworks, technology-related teaching skills ought to ensure high-quality teaching with digital technologies (DCB, 2017; Kelly & McAnear, 2002; Krumsvik, 2011). However, research often focuses on the relationship of skills with the frequency of technology use in class. Indeed, studies show that teachers' digital skills and technology-related teaching skills are related to the frequency of technology use in class (Drossel, Eickelmann, & Gerick, 2017; Eickelmann & Vennemann, 2017). With respect to different types of teaching with digital technologies, research has differentiated between teacher-centered and student-centered teaching (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, Sendurur, 2012). On this basis, we suggest focusing on teachers' initiation of student learning activities as this reflects how technology is used. The ICAP model (*I*nteractive, *C*onstructive, *A*ctive, and *P*assive learning activities) can be used to systematically classify teacher-initiated student learning activities based on the degree of student activation and the associated benefits for learning (Chi, 2009; Chi & Wylie, 2014). The ICAP model fits well with the notion of active learning, which emphasizes the importance of students' active engagement in cognitive processes for effective and sustainable learning as well as deep levels of understanding (Wouters, Paas, & van Merriënboer, 2008). Thus, the ICAP-framework emphasizes the fact that they need not only be good at presenting and explaining of learning content via digital technology (*sage on the stage*), but also at initiating, guiding, and scaffolding student learning activities involving digital technology (*guide on the side*; see King, 1993).

The ICAP model distinguishes between *passive*, *active*, *constructive*, and *interactive* learning activities. It assumes that these different types of student learning activities with digital technology involve different levels of cognitive engagement, which refers to students' investments in learning (Chi, 2009; Chi et al., 2018; Chi & Wylie, 2014): Passive learning activities involve a lack of observable physical activity, e.g. watching a digital presentation or an explanation video. While engaging in *passive* learning activities, students are likely to engage in cognitive processes that relate to storing the presented information. *Active* learning activities involve students performing some overt action with the learning material or manipulating it, e.g. taking digital notes or completing an online quiz. During active learning activities, prior knowledge is activated, and new knowledge can be linked to it. An activity can be classified as *constructive* when learners produce content that goes beyond the learning material or solve problems and apply the learning content to another context, e.g. in simulation-based learning environments. Constructive learning activities are generative in nature. *Interactive* learning activities must fulfill the definition of constructive learning activities and additionally be applied in a co-constructive manner in dyads or groups of learners, meaning that the contributions of each individual learner have to build upon each other (Chi, 2009; Chi & Wylie, 2014).

The activities described in the ICAP model are located on a continuum from passive learning activities, which supposedly involve the lowest level of cognitive engagement, to interactive learning activities, which supposedly involve the highest level of cognitive engagement (Chi, 2009). Digital technologies are especially suitable for enhancing learning activities at the upper end of the ICAP spectrum (Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011).

Teachers' effective initiation of student learning activities involving digital technologies requires them to be equipped with technology-related teaching skills (DCB, 2017; Ertmer & Ottenbreit-Leftwich, 2010). Especially for the initiation of learning activities that involve students' actions (i.e. active, constructive, and interactive learning activities) teachers require skills to design (planning), scaffold (implementing), and assess the efficiency (evaluating) that digital lessons have (Kaendler, Wiedmann, Rummel, & Spada, 2015; Wiedmann, Kaendler, Leuders, Spada, & Rummel, 2019). Thus, we assume that teachers with higher levels of self-assessed technology-related teaching skills in different phases of teaching with digital technologies (see Section 1.2) are more likely to initiate learning activities with higher levels of cognitive engagement, namely active, constructive, and interactive learning activities.

1.4. The present study

Our research goal was to develop a self-assessment instrument for technology-related teaching skills and attitudes based on the K19 model. With respect to new challenges that arise with new digital technologies, some previously developed instruments are at risk of not fully capturing all relevant skills to be a digitally literate educator anymore (e.g. Brush, Glazewski, & Hew, 2008; Thompson, Mishra, Koehler, & Shin, 2009; Yurdakul, Odabasi, Kilicer, Coklar, Birinci, & Kurt, 2012). Further, most previous instruments to measure technology-related teaching skills via self-assessment are based on the TPACK model and focus on measuring different types of self-assessed conceptual knowledge rather than more action-oriented knowledge components (Schmid et al., 2020; Schmidt, Baran, Thompson, Mishra, Koehler, & Shin, 2009; Valtonen, Sointu, Kukkonen, Kontkanen, Lambert, & Mäkitalo-Siegl, 2017; Ozden, Mouza, & Shinas 2016; Thompson et al., 2009; Yurdakul et al., 2012). This can also be seen in the small amount of context information about knowledge and skill application in items of existing instruments. We assume that enriching self-report items with such contextual information can help teachers to estimate their self-assessed skills and attitudes more accurately and validly. From our perspective, a suitable scaffold for teachers are scenarios that refer to concrete situations in which it is crucial to apply corresponding technology-related teaching skills. Such scenarios can operate as anchors for teachers to assess their performance, helping them situate the corresponding skills in concrete and authentic situations.

Based on and inspired by the anchoring vignettes approach by King, Murray, Salomon, and Tandon (2004), a scenario can be introduced to provide a common standard for responding to questions (King & Wand, 2007). Such techniques have been applied to increase the validity of rating-scale responses by rescaling them based on a set of common vignettes that serve as anchors. With respect to teaching with digital technologies, scenarios can describe an exemplary situation in which the corresponding skill has to be applied; e.g. instead of asking participants to rate to what extent they are able to design digital learning scenarios (example technology-related teaching skill for the planning dimension; see Fig. 1) on a Likert scale, a scenario in which the execution of this skill is necessary can be introduced. Such a scenario-based approach makes it possible to assess both aspects relevant for teachers' competence (see Van Merriënboer & Kirschner, 2017) with respect to teaching with digital technology: technology-related teaching skills and attitudes towards technology-related teaching. These two aspects can be assessed via scenarios reflecting the 19 facets of the DCB (2017) model, which can be further grouped into four phases of teaching with digital technologies. On the one hand, technology-related teaching skills consist of having the respective knowledge, being able to perform a certain technology-related teaching skill, and being able to give advice to others so that they can master tasks related to teaching with and about digital technology. On the other hand, attitudes towards technology-related teaching consist of the value and meaningfulness that is attributed to a given technology-related teaching skill and the motivation to actually apply it (see Ertmer & Ottenbreit-Leftwich, 2010; Watson, 2006). A scenario-based approach allows for investigating these two factors and their relations with different outcomes.

Any new scale needs to demonstrate that it is factorially valid (i.e., that the latent constructs assumed can be found in the responses observed). In addition, it needs to demonstrate its usefulness by being predictively valid (i.e., relating empirically to external real-world criteria that are theoretically related) as it would remain purely theoretical otherwise (DeVellis, 2016). To test the measurement quality of the scenario-based instrument *IN.K19*, we examine both its factorial and predictive validity. We expect both self-assessed technology-related teaching skills and attitudes to reflect the four dimensions of the K19 model (planning, implementing, evaluating, and sharing). With respect to factorial validity, we investigate the following research question:

RQ1: Does the instrument's skill and attitude factor for each of the four phases of the K19 model (planning, implementing, evaluating, and sharing) have good psychometric properties?

Concerning the instrument's predictive validity, we investigate the following research questions and hypotheses:

RQ2: To what extent do self-assessed technology-related teaching skills and attitudes relate to the frequency of teaching with digital technologies?

Prior research investigated the role of technology-related knowledge and its relationship with the frequency of teaching with digital technologies. Endberg and Lorenz (2017) found that technology-related knowledge significantly predicts the frequency of teaching with digital technology. Furthermore, confidence in personal technology use is positively related to frequency of technology use in class (European Commission, 2013; Fraillon et al., 2014; Law, Pelgrum, & Plomp, 2008). Similarly, Drossel, Eickelmann, and Gerick (2017) as well as Eickelmann and Vennemann (2017) show that technology-related attitudes positively relate to the frequency of teaching with digital technologies. Thus, we expect all four dimensions (planning, implementing, evaluating, and sharing) of both self-assessed technology-related teaching skills and attitudes to be positively related with teaching with digital technology. We expect the use of digital technology in the classroom to be increasingly frequent among teachers with more advanced technology-related teaching skills and more positive attitudes.

H1.1: Self-assessed technology-related teaching skills regarding the four phases of planning, implementing, evaluating, and sharing positively relate to the frequency of teaching with digital technologies.

H1.2: Positive attitudes towards technology-related teaching regarding the four phases of planning, implementing, evaluating, and sharing positively relate to the frequency of teaching with digital technologies.

RQ3: To what extent do self-assessed technology-related teaching skills relate to the initiation of different types of students learning activities during teaching with digital technologies?

Technology-related teaching skills are considered crucial for ensuring high-quality teaching with digital technologies (DCB, 2017; Kaendler et al., 2015; Kelly & McAnear, 2002; Krumsvik, 2011; Wiedmann et al., 2019). Thus, we expect that all four dimensions (planning, implementing, evaluating, and sharing) of self-assessed technology-related teaching skills are most strongly related to teacher-initiated student learning activities that involve observable actions by learners and are thus associated with high levels of students' cognitive engagement.

H2: Self-assessed technology-related teaching skills regarding the four dimensions of planning, implementing, evaluating, and sharing show the strongest relations to the initiation of interactive activities involving digital technologies, followed by constructive, active, and passive activities.

2. Method

2.1. Sample and procedure

Our study employed a cross-sectional design. Data was collected between June and October 2018 through an online questionnaire hosted on the Unipark platform (Questback GmbH, 2018). The target group for our study were in-service teachers and student teachers with teaching experience. Moreover, as the survey was in German, a further inclusion criterion was that the teachers and students needed to be fluent in German. We recruited in-service teachers via teacher education contacts online advertisements, and personal visits at schools. With respect to recruitment of student teachers, we particularly tried to include students with substantial teaching experience in classrooms. Thus, we advertised our study in courses of postgraduate studies and courses that teacher students typically visit at the end of their studies. Students from these courses usually had done internships at school or in case of postgraduate studies, had been in-service teachers before they returned to university. Further, we used online advertisements and advertisements on campus.

While $N = 657$ participants started the survey, only 13.80% of them answered all relevant questions. Thus, the final sample consisted of $N = 90$ participants. 63.30% ($n = 57$) of the participants were female, and 35.60% ($n = 32$) were male. One person (1.10%) did not provide any information regarding gender. The final sample consisted of $n = 49$ student teachers and $n = 41$ in-service teachers.

Regarding student teachers, $n = 21$ (43%) of them were enrolled in postgraduate studies and had been in-service before. They had 23 months of teaching experience on average ($M = 22.88$; $SD = 36.08$) and were in their 5th semester of their postgraduate studies ($M = 5.00$; $SD = 3{,}76$). $N = 28$ (57%%) student teachers were in their first course of studies and their 7th semester ($M = 6.56$; $SD = 3.18$). All of these student teachers had done internships at schools and had 8 months of teaching experience on average ($M = 8.07$; $SD = 9.66$).

Overall, student teachers had on average 14 months of teaching experience (M = 13.80; SD = 24.37). The minimum teaching experience was 1 month, the maximum 120 months. Thus, teacher students had sufficient teaching experience to answer questions about lessons that they taught (see 2.2.2). On average, student teachers were 25 years old (M = 24.67; SD = 4.10).

In-service teachers had 15 years of teaching experience on average (M = 15.00; SD = 8.53). The minimum amount of teaching experience in the subsample was 1 year, the maximum 34 years. They were 43 years old on average (M = 42.97; SD = 10.14).

The participants took 48 min on average ($M = 48.29$; $SD = 23.96$) to complete the instrument. As an incentive, participants obtained immediate auto-generated graphical feedback on their self-reported values and could additionally take part in a raffle to win vouchers (student teachers) or digital learning workshops for their school (in-service teachers).

2.2. Measures

Our study began with a short section measuring participants' demographic data. Subsequently, we asked participants about their frequency of digital technology use during teaching a typical lesson and the student learning activities involving digital technologies that they initiate in a typical lesson. The self-assessment of technology-related teaching skills and attitudes made up the last part of the instrument. We used *IN.K19* version 1.0 in this study. This version of the instrument is available in English and German at an open science repository https://osf.io/95xaj/. All future versions of the instrument will be stored there as well. The variables presented in the next section are based on self-reports of our participants.

2.2.1. Frequency of digital technology use during teaching

For the *frequency of digital technology use during teaching*, we asked participants about the percentage of time digital technology is used during one of their typical lessons with one single item. Participants were able to select values from 0% to 100%.

2.2.2. Initiation of student learning activities involving digital technologies

For the *initiation of student learning activities involving digital technologies*, we split the variable *frequency of digital technology use* into four categories, namely students' passive, active, constructive, and interactive learning activities. The resulting four outcome variables represent the percentage of each of the four types of teacher-initiated learning activities that involve digital technologies in a typical lesson. To calculate these proportions, we presented the teachers with short descriptions of four scenarios (one for each ICAP learning activity). We asked the teachers to indicate for every scenario "how often do you use digital technology like this in a typical lesson of yours?" Participants rated the frequency on a 5-point Likert scale ranging from "never" (0) to "very often" (4). The four scenarios described students engaging in passive, active, constructive, or interactive learning activities during technology use. An example item for the initiation of passive student learning activities is: "Digital technology is used to present content. My students follow the presentation without engaging in any visible activities. Examples: Students follow a digitally supported presentation or watch a tutorial".

To calculate the proportion of each teacher-initiated learning activity in a typical lesson, we divided the Likert score of single learning activities (i.e. passive, active, constructive, and interactive) by the sum score for all four learning activity Likert items. In a last step, we multiplied the resulting proportion of teacher-initiated learning activity by the frequency of digital technology use during teaching. These calculations allowed us to obtain the percentage of time certain learning activities involving digital technologies that were initiated by a teacher in a typical lesson. We applied this procedure to all four types of student learning activities, obtaining four variables which can be interpreted as percentages: self-reported *initiation of student (1) passive, (2) active, (3) constructive, and (4) interactive student learning activities involving digital technologies.*

2.2.3. Technology-related teaching skills and attitudes

Based on and inspired by the anchoring vignettes approach by King et al. (2004), we developed 19 scenarios, one for each of the 19 technology-related teaching skills (see Section 1.1). These scenarios describe an exemplary situation in which the corresponding skill has to be applied. Based on these scenarios, we asked participants if they have sufficient knowledge and skills to respond to the described situation and if they would be able to advise a colleague in solving the problem stated in the scenario (self-assessed technology-related teaching skills). We also asked whether participants would be motivated to engage in the situation and whether they evaluate getting involved in such a situation as meaningful (technology-related teaching attitudes). Thus, for every scenario, participants had to rate five statements (knowledge, action, advice, motivation, meaningfulness) on a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Fig. 2 shows a sample Item for

The School Board donated 32 new tablets to your school to foster students' learning with new technologies in the classroom. In order to use these new digital tools appropriately, you need to prepare a lesson that will allow students to work in small groups. Your students have never participated in this kind of classroom activity before. Your overall goal is to teach them how to learn with digital technologies (in this case, with tablets).

Based on the scenario described above, please rate the following statements on a scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*):

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I know concepts and strategies that enable me to plan lessons involving digital technology in the classroom.	1	2	3	4	5
I have the skills to plan lessons involving digital technology in the classroom.	1	2	3	4	5
I can advise other teachers in how to plan lessons involving digital technology in the classroom.	1	2	3	4	5
I am motivated to plan lessons involving digital technology in the classroom.	1	2	3	4	5
I believe it us meaningful to plan lessons involving digital technology in the classroom.	1	2	3	4	5

Fig. 2. English version of a sample scenario for the skill *planning the use of digital technology in the classroom*, which belongs to the planning phase. The first, second, and third item belongs to the self-assessed technology-related teaching skills component; the fourth and fifth item belongs to the self-assessed technology-related teaching attitudes component.

the planning dimension referring to the skill *planning the use of digital technology in the classroom*. Three scenarios consisted of two sub-scenarios.

The instrument was initially validated with $N = 12$ experts in digital learning and teacher education, all holding a doctorate. They each completed the questionnaire and returned their responses via email. Furthermore, we completed think-aloud interviews with four experts and further revised the instrument based on the results.

In the final instrument that was used in this study, self-assessed technology-related teaching skills in the planning phase consist of 30 items, reliability was $\alpha = 0.97$. Attitudes in the planning phase consist of 20 items with an reliability of $\alpha = 0.92$. Self-assessed technology-related teaching skills in the implementing phase consist of 21 items with an reliability of $\alpha = 0.95$. Attitudes in this phase consisted of 14 items, reliability was $\alpha = 0.85$. Self-assessed technology-related teaching skills in the evaluating phase consist of 6 items with an reliability of $\alpha = 0.94$. Attitudes regarding this evaluating phase consisted of 4 items. Reliability was $\alpha = 0.74$. Self-assessed technology-related teaching skills in the sharing phase were measured with 9 items that reached a reliability of $\alpha = 0.95$. Finally, technology-related teaching attitudes in the sharing phase were measured with 6 items that reached a reliability of $\alpha = 0.82$.

2.3. Statistical analysis

We employed confirmatory factor analyses and latent modeling (Bollen, 1989) to examine the measurement models and investigate our research questions. To establish the instrument's factorial validity and address RQ1, we defined measurement models for each of the four phases of teaching with digital technology. In order to test our hypotheses regarding the scales' predictive validity, we defined multiple latent regressions with the self-perceived technology-related teaching skills and attitudes factors for the four phases of teaching with digital technology predicting the frequency of teaching with digital technology and the type of teacher-initiated learning activities involving digital technology.

Due to the rather small sample size, we estimated all models separately for the four phases. In addition, we used unweighted least squares estimation with robust corrections (ULSMV), which is recommended for suboptimal data (Savalei and Rhemtulla, 2013). As items represented responses on a five-category Likert scale, we expected medium to high factor loadings, and we did not expect extreme thresholds, this estimator should provide a reasonable Type I error rate and power. We are aware of the limitation posed by the small sample size, though, and discuss its implications on the interpretation of our results in the discussion section. Model fit was evaluated using standard model fit indices such as the root mean square error of approximation (RMSEA), with values less than 0.08 indicating acceptable fit; as well as the confirmatory fit index (CFI) and the Tucker Lewis Index (TLI), for which values greater than 0.90 indicate acceptable fit. Satorra-Bentler corrections were applied to all χ^2 values for model comparisons (Satorra & Bentler, 2010). To provide information on the robustness of the results, we estimated 95% confidence intervals for all regression coefficients. All analyses were conducted using Mplus 7.11 (Muthén & Muthén, 1998–2012). The respective syntax files can be found in the open science repository https://osf.io/95xaj/.

3. Results

3.1. Factorial validity

In a first step, we defined a self-assessed technology-related teaching skill factor indicated by all items measuring knowledge, action, and advice as well as a technology-related teaching attitudes factor indicated by all items measuring motivation and meaningfulness (Models 1–4). The upper part of Fig. 3 exemplarily illustrates this approach for the planning phase of teaching with digital technology. Table 1 summarizes

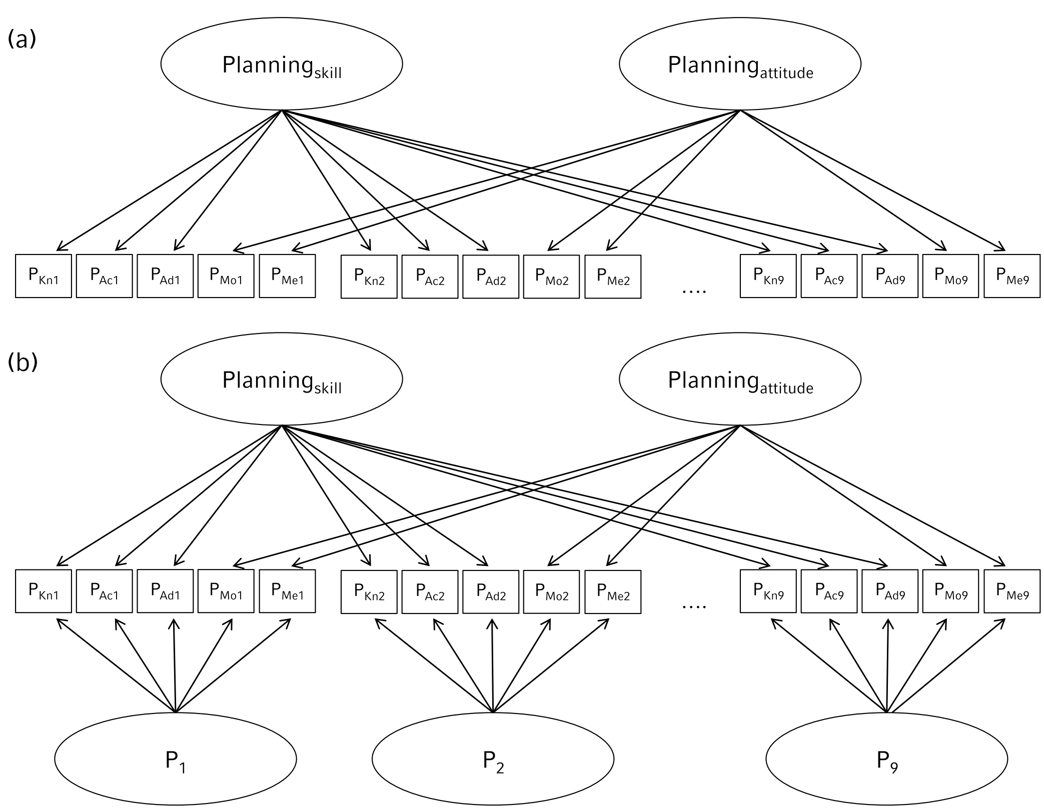

Fig. 3. Top (a): Illustration of the initial approach for the measurement model of the planning phase of teaching with digital technology. Bottom (b): Illustration of the measurement model approach for the planning phase of teaching with digital technology capturing scenario-specific covariance.

Table 1
Model fit for measurement models and structural models.

Model	Description	χ^2	df	*p*	RMSEA	CFI	TLI
Measurement Models							
1	Planning 2 factors	1611.47	1174	<.001	.064	.888	.883
2	Implementing 2 factors	1062.91	559	<.001	.100	.743	.726
3	Evaluation 2 factors	186.65	34	<.001	.223	.813	.752
4	Sharing 2 factors	177.16	89	<.001	.105	.938	.927
5	Model 1 with scenario-specific factors	1203.71	1080	.005	.036	.968	.964
6	Model 2 with scenario-specific factors	597.89	504	.003	.045	.952	.943
7	Model 3 with scenario-specific factors	24.47	24	.435	.015	.999	.999
8	Model 4 with scenario-specific factors	97.42	71	.021	.064	.981	.973
Structural Models							
9	Planning predicting quantitative use of technology	1326.58	1228	.026	.030	.991	.991
10	Implementing predicting quantitative use of technology	773.20	607	<.001	.055	.988	.987
11	Evaluation predicting quantitative use of technology	45.94	52	.710	.000	1.00	1.00
12	Sharing predicting quantitative use of technology	120.96	114	.310	.026	.999	.999
13	Planning predicting qualitative use of technology	1331.27	1372	.780	.000	1.00	1.00
14	Implementing predicting qualitative use of technology	694.17	706	.618	.000	1.00	1.00
15	Evaluation predicting qualitative use of technology	59.01	76	.925	.000	1.00	1.00
16	Sharing predicting qualitative use of technology	133.83	153	.866	.000	1.00	1.00

the fit statistics for all defined models. As can be seen from Table 1, none of Models 1–4 exhibited acceptable fit to the data, indicating a need for further refinement.

As there was considerable covariance among items referring to the same scenario (i.e., assessing different aspects of the same technology-related teaching skill), we added scenario-specific latent factors to the measurement models defined in Models 1–4. These factors were indicated by all five items related to each scenario, thus capturing the scenario-specific covariance (Models 5–8). The lower part (b) of Fig. 3 exemplarily illustrates this approach for the planning phase of teaching with digital technology, contrasting it with the first approach (a). In order for the model to converge, the latent correlations between all scenario-specific factors and the technology-related teaching skills and attitude factors were set to zero. As can be seen from Table 1, the addition of scenario-specific factors led to a substantial improvement of the models' fit to the data. The improvement in model fit was statistically significant for planning (χ^2 (94) = 276.70; $p < .001$), implementing (χ^2 (55) = 299.61; $p < .001$), evaluation (χ^2 (10) = 112.44; $p < .001$), and sharing (χ^2 (18) = 63.77; $p < .001$). There was no significant correlation between self-assessed skills and attitudes for any of the four phases. Models 5–8 all represented the data well and were thus retained as the measurement models for all further analyses. The results support the instrument's factorial validity as long as the scenario-specific covariance is accounted for.

3.2. *Predictive validity*

In order to test our hypotheses regarding the scale's predictive validity, we defined multiple latent regressions with the self-assessed technology-related teaching skills and attitudes factors for the four

Table 2
Regression coefficients for self-assessed technology-related teaching skills and attitudes towards technology-related teaching in different phases of teaching with digital technology (planning, implementing, evaluating, and sharing) on frequency of teaching with digital technologies and types of teacher-initiated student learning activities with digital technologies.

Model	Predictor	Frequency of technology use			Type of teacher-initiated student learning activities with digital technology											
					Passive			Active			Constructive			Interactive		
		β	95% CI	R^2	β	95% CI	R^2	β	95% CI	R^2	β	95% CI	R^2	β	95% CI	R^2
9	Planning															
	Skill	.52**	[.25; .78]													
	Attitude	.33*	[.04; .63]	.37												
10	Implementing															
	Skill	.40**	[.14; .66]													
	Attitude	.17	[-.11; .44]	.19												
11	Evaluation															
	Skill	.37**	[.15; .60]													
	Attitude	.09	[-.25; .42]	.15												
12	Sharing															
	Skill	.29**	[.08; .49]													
	Attitude	.28*	[-.01; .56]	.21												
13	Planning															
	Skill				.18	[-.05; .41]		.26*	[.04; .47]		.58**	[.35; .80]		.71**	[.46; .94]	
	Attitude				.42**	[.10; .74]	.21	.20	[-.06; .46]	.11	.17	[-.06; .46]	.36	.21	[-.11; .54]	.55
14	Implementing															
	Skill				.16	[-.07; .39]		.25*	[-.01; .51]		.40**	[.15; .66]		.49**	[.25; .73]	
	Attitude				.31*	[.01; .61]	.12	.06	[-.17; .30]	.07	.04	[-.23; .30]	.16	.02	[-.26; .30]	.24
15	Evaluation															
	Skill				.09	[-.12; .30]		.28*	[.04; .53]		.40**	[.18; .62]		.45**	[.22; .69]	
	Attitude				.13	[-.17; .42]	.02	.06	[-.26; .39]	.08	.04	[-.27; .36]	.16	.03	[-.31; .37]	.21
16	Sharing															
	Skill				-.04	[-.25; .16]		.20	[-.06; .46]		.36**	[.14; .57]		.47**	[.26; .67]	
	Attitude				.43**	[.15; .71]	.17	.08	[-.20; .36]	.06	.11	[-.17; .40]	.17	. 16	[-.15; .47]	.29

Note: *p < .05; **p < .01.

phases of teaching with digital technology predicting the frequency of teaching with digital technology (Models 9–12) and the type of teacher-initiated learning activities involving digital technology (Models 13–16). All factor loadings in the structural equation models were constrained to the values estimated for the final measurement models (Models 5–8) to avoid interpretational confounding (Bollen, 2007; Burt, 1976).

The lower part of Table 1 summarizes the fit statistics for all latent regression models, while Table 2 provides the regression coefficients. All models with the self-assessed technology-related teaching skills and attitudes factors for the four phases of teaching with digital technology predicting the frequency of technology use in teaching exhibited very good fit to the data. In line with H1.1, self-assessed technology-related teaching skills consistently predicted the frequency of teaching with digital technology across all four phases. In contrast, for attitudes towards technology-related teaching, only the attitudes towards planning and sharing, and not the attitudes towards implementing and evaluating phases predicted the frequency of teaching with digital technology. This partially contradicted H1.2. Among all phases, planning explained the frequency of technology use best, followed by sharing, implementing, and evaluation.

The models with the self-assessed technology-related teaching skills and attitudes factors for the four phases of teaching with digital technology predicting the type of teacher-initiated learning activities involving digital technology also exhibited very good fit to the data. As predicted in H2, the skill dimension was consistently related most strongly to students' interactive learning activities, followed by constructive and active learning activities. We found no significant relationship between skills and passive learning activities. This pattern of results was consistent across all phases of teaching with digital technology, with planning once again showing the strongest effect sizes. Attitudes towards technology-related teaching were consistently most strongly related to the passive use of technology, with almost no relation to the other types of technology use in teaching. The results support the instrument's predictive validity, as self-assessed technology-related teaching skills relate most strongly to the initiation of student learning activities that involve observable actions by learners, which are associated with high levels of cognitive engagement.

4. Discussion

In this study, we validated a scenario-based instrument called *IN.K19* to measure self-assessed technology-related teaching skills and attitudes by examining its factorial and predictive validity. Analyses of the factorial validity showed that the instrument has good psychometric properties as long as scenario-specific factors are included in the confirmatory factor analysis to account for scenario-specific covariance. Analysis of predictive validity showed that self-assessed technology-related teaching skills for the four phases of teaching with digital technology (planning, implementing, evaluating, and sharing) were positively and consistently related to the frequency of teaching with digital technology. In contrast to skills, results regarding attitudes towards technology-related teaching did not yield such a clear picture, as only positive attitudes related to the planning and sharing phases were associated with the frequency of teaching with digital technology. With respect to the initiation of student learning activities involving digital technologies, self-assessed technology-related teaching skills were associated with all types of learning activities that include observable actions by learners (active, constructive, and interactive learning activities). In line with our hypothesis, self-assessed technology-related teaching skills were most strongly related to the initiation of learning activities that involve the highest level of cognitive engagement by learners, namely interactive learning activities, followed by constructive and active learning activities. This order corresponds to the order of the ICAP continuum (Chi, 2009; Chi & Wylie, 2014). Furthermore, this pattern was consistent across all phases of teaching with digital technologies (planning, implementing, evaluating, and sharing). Positive attitudes towards technology-related teaching were only related to the initiation of passive student learning activities involving digital technology.

Our results show that self-assessed technology-related teaching skills are related to relevant outcomes regarding the frequency and type of digital technology use in classrooms, supporting the instrument's predictive validity. Furthermore, the instrument allows for a more differentiated analysis of the relations between self-assessed skills and attitudes regarding different phases of teaching with different types of teacher-initiated learning activities involving digital technology. Self-assessed skills regarding planning teaching with digital technologies had the strongest relationships with frequency of technology use as well as the two highest levels of initiated learning activities on the ICAP continuum (interactive and constructive learning activities). Thus, these self-assessed planning skills might have the most direct impact on technology use in the classroom in general, and specifically on high-quality technology use that facilitates students' knowledge application and competencies (Chi et al., 2018). In decreasing order regarding the strengths of the relationships, self-assessed implementing, evaluating, and sharing skills were also positively related to non-passive learning activities (active, constructive, and interactive learning activities). With respect to the initiation of passive learning activities involving digital technology, which are located at the lower end of the ICAP continuum (Chi, 2009; Chi & Wylie, 2014), we found no significant relationships with self-assessed technology-related teaching skills. This pattern of results indicates that teachers with different levels of self-assessed skills do not differ much when it comes to the initiation of merely passive and receptive technology use in the classroom, e.g. following teacher presentations or watching videos. Passive activities are used by teachers of all skill levels. Instead, the most interesting difference can be found on the initiation of more active levels of learning activities. Here, the rule seems to be, the more advanced a teacher's technology-related teaching skills, the higher the cognitive engagement level of the learning activities he or she initiates. However, technology-related teaching attitudes in the planning, implementing, and sharing phases are positively related to passive learning activities. Thus, our results indicate that the instrument measures two distinct factors exhibiting different result patterns: self-assessed technology-related skills relate to the initiation of activities on the upper end of the ICAP continuum by learners (active, constructive, and interactive learning activities), while positive attitudes towards technology-related teaching relate to activities on the lower end of the ICAP continuum that do not involve any overt form of action (passive learning activities).

Self-assessed technology-related teaching skills in each phase (planning, implementing, evaluating, and sharing) are associated with the frequency and different types of digital technology use in classrooms. The results thus support classifying skills oriented towards different phases of teaching with digital technology (DCB, 2017; Ertmer & Ottenbreit-Leftwich, 2010; Zimmerman & Campillo, 2003), as they all cover relevant aspects that affect technology use. Furthermore, the skills assessed by *IN.K19* seem to be a necessary part of teachers' competency to meet the standards and demands of a digitalized world (see DCB, 2017; Kirschner, 2015). Technology-related teaching skills are a crucial aspect of teachers' competency, as they explain variance in the learning activities located at the upper end of the ICAP continuum. In contrast, the benefit of having positive attitudes towards teaching with digital technologies is limited to the initiation of learning activities on the lower end of the ICAP continuum, namely passive learning activities. Future studies need to address the seemingly complex relationship between attitudes and technology use in the classroom. At least our findings show that we cannot predict the quality of technology use in the classroom from positive teacher attitudes.

Generally, our results show that simultaneously investigating the frequency of digital technology use during teaching *and* initiation of student learning activities involving digital technologies in class can be insightful. Previous research has examined frequency of technology use in class, but has not systematically considered the kind of technology use that is in fact more important with respect to its effects on students' learning (Tamim et al., 2011). The ICAP model allows for a more differentiated consideration of kinds of technology use that have not been addressed in previous research.

The goal of measuring self-assessed technology-related teaching skills and attitudes using scenarios was to provide a common measurement scale across respondents (King & Wand, 2007). Based on the results regarding the factorial and predictive validity of the scenario-based instrument, further adoption of the anchoring vignettes approach (King et al., 2004) seems promising. Both self-assessed technology-related teaching skills and attitudes explained a substantial amount of variance in the frequency and type of technology use in class, and the strengths of the relationships clearly follow the continuum postulated in the ICAP framework (Chi, 2009).

Further, the scenario-based approach shares commonalities with approaches that focus on competence beliefs as they both rely on self-assessments in different domains (see Muenks, Wigfield, & Eccles, 2018). However, from our perspective, the scenario-based approach enriches beliefs-oriented approaches in two ways: First, the scenario-based approach allows for parallel self-assessment of skills and attitudes within the same anchoring scenario and thus allows for differentiated analyses of the effects of both aspects. Second, by providing concrete scenarios that confront teachers with detailed activities in different phases of teaching with digital technology, measurement can become more accurate and eventually attenuate the problem of overestimation of their own skills (see Scherer, Tondeur, & Siddiq, 2017). As we externalize a common ground for answering items in our instrument (see King & Wand, 2007), we assume that our instrument measures rather self-assessed skills than competence beliefs that are more strongly connected to constructs like self-efficacy. However, scenario-based assessment is more time-intensive for the participants, which brings us to some limitations.

The present study had a relatively high drop-out rate during data collection. We assume that many in-service teachers and student teachers were interested in our study but did not complete it because of its duration. Indeed, 68% of the participants dropped out immediately after the introduction and data protection consent, where we provided information on the duration of the study. Since we only used data that was complete and do not have sufficient information about the teachers that opted not to participate, our sample may not be representative which limits the generalizability of our results. If the instrument were to be implemented in teacher education practice, creating or using a shorter version might be appropriate.

Associated with this, a major limitation in the interpretation of our results is the small sample size as both model fit indices and regression coefficients can be affected by low statistical power (Forero, Maydeu-Olivares, & Gallardo-Pujol, 2009). Post-hoc power estimations (Hancock and Mueller, 2013) showed acceptable power for general model fit for all models except the models for evaluating (Models 7, 11, and 15; see the osf repository for detailed results: https://osf.io/[BLINDED FOR REVIEW) but we found large confidence intervals for the regression coefficients, indicating substantial uncertainty in the results. Correspondingly, we need to be careful in interpreting the results beyond mere descriptive differences. Especially the apparent rank order of relations between technology-related teaching skills in each phase and the different types of digital technology use in classrooms show overlapping confidence intervals for many of the coefficients found. Thus, focusing on the more extreme comparisons (e.g., passive vs. interactive) are likely to lead to more reliable interpretations. In our study, we specified single models for phases in which technology-related teaching skills are relevant. Combining all phases in one statistical model is a next step which could also reveal potential interrelations between the skills in different phases. However, the statistical power in this study was not large enough to conduct this analysis. In addition, the small sample size did not allow us to adequately test for measurement invariance between student and in-service teachers. Given the expected practical implications of our results, it will be of critical importance to corroborate our findings with larger samples.

Finally, the instrument relies on self-assessment, and we know that self-assessment of skills can have issues, e.g. not capturing the "real" skills of in-service or pre-service teachers (Lachner, Backfisch, & Stürmer, 2019; Scherer et al., 2017). Conversely, objective measurements can be criticized for being highly resource-intensive and only measuring a small range of skills. Promising approaches with a stronger focus on the objective measurement of skills are test-based approaches with either a knowledge or a task focus. Lachner et al. (2019) developed a knowledge-based instrument for technological-pedagogical knowledge based on the TPACK model (Mishra & Koehler, 2006). However, this instrument focuses on teachers' knowledge base rather than on technology-related teaching skills. Claro et al. (2018) developed a task-based instrument that includes, among other variables, information and communication technology teaching competencies. They assessed these competencies with three tasks focused on scaffolding students during digital technology use. Thus, this instrument applies a narrow perspective on technology-related teaching skills by covering only a specific aspect. While knowledge- and task-based approaches are promising, they put participants in a test- or exam-like situation that might limit acceptance in practice. Our scenario-based approach allows for the self-assessment of technology-related teaching skills and attitudes using scenarios that reflect a broad range of skills in different phases of teaching with digital technology. Future research might build upon this integrated approach to the different phases and complement it with test-based approaches – which would also provide an objective criterion for validation. Besides that, as the K19 model and the *IN.K19* instrument also cover some aspects of teaching about digital technology, a validation with teachers' behavior reflecting aspects of teaching about digital technology is an important next step. Generally, expanding the criterion for validation of *IN.K19* with self-assessment scales as well as objective scales regarding the TPACK components in order to provide evidence of convergent validity are promising avenues for future research to investigate different types of instruments.

5. Conclusion

In our study, we developed a scenario-based instrument simultaneously measuring self-assessed technology-related teaching skills and attitudes based on and inspired by the anchoring vignettes approach of King et al. (2004). Our instrument showed satisfactory factorial validity in our confirmatory factor analyses. To investigate its predictive validity, we examined the relations with frequency of technology use and type of student learning activities involving digital technology based on the ICAP model (Chi, 2009). Our results are in line with frameworks suggesting that technology-related teaching skills regarding different phases of teaching with digital technology are crucial facets of teachers' competence in a digitalized world (DCB, 2017). Planning, implementing, evaluating, and sharing are relevant phases in which teachers need specific skills to use technology effectively to facilitate students' knowledge application and development of complex skills. Digital technologies are particularly suitable for learning activities that involve overt actions by students and thus high levels of cognitive engagement (Tamim et al., 2011). Our results show positive relationships between self-assessed skills in different phases of teaching with technology and initiation of all types of learning activities involving overt actions by learners (active, constructive, and interactive learning activities; Chi, 2009). These results support the predictive validity of our instrument and highlight the importance of teachers' technology-related teaching skills for exploiting the high potential of digital technologies to provide learning opportunities that go beyond students as passive recipients of information. Positive attitudes towards technology-related teaching, on the other hand, were associated with exactly these passive learning activities. The results suggest that attitudes may lead to a higher frequency of technology use, although the initiation of student learning activities by teachers with positive attitudes (but without the corresponding skills) might be less advanced and mostly consist of knowledge dissemination by the teacher.

From a practitioners' perspective, we wanted to develop an instrument that can be easily used and accepted in practice by not putting in-service teachers or student teachers in a test or exam situation. Our instrument assesses a broad range of self-assessed technology-related teaching skills and attitudes by applying an integral approach that covers different phases teachers cycle through while teaching with digital technologies. The assessment instrument can indicate teachers' strengths and weaknesses concerning different phases of teaching with digital technology. Thus, it allows for sophisticated feedback. Our instrument facilitates situational self-assessments of teachers by providing scenarios for each skill. Thus, we assume that the participants were successfully scaffolded in the direction of more accurate self-assessments.

Credit author statement

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Appendix A. Supplementary data and material

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