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Digital learning in schools: What does it take beyond digital technology?

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HIGHLIGHTS

- Teachers from a representative sample (Bavaria, Germany) report how they use technology in class.
- Teachers are employing digital technologies frequently in their teaching.
- In a significant amount of the time of technology use students are passive.
- Availability of technology does not relate to the type of teachers' technology use.
- Teachers' skills are positively related to frequency and types of technology use.

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ABSTRACT

We investigated how often teachers apply digital technology in their teaching *and* which student learning activities teachers initiate. Further, we analyzed factors relating to technology use. 410 teachers in our sample, representative for the state of Bavaria (Germany), reported that they spend a substantial amount of time using digital technologies in a typical lesson. Results indicated that rather teachers' basic digital skills and technology-related teaching skills than digital technology resources are crucial. Even though a certain threshold level of digital technology is necessary in school, our results suggest shifting the focus from equipping schools to teachers' skills using technologies effectively.

1. Introduction

Technology has become an integral part and distinct feature of modern societies (Fraillon, Ainley, Schulz, & Friedman, 2014). The successful navigation of complex digital landscapes is proposed as an important prerequisite to participate in economic, social, and cultural life (OECD, 2015). The Covid-19 pandemic further emphasized the crucial role of technology in our daily lives – especially for teaching and learning in schools at home (Seufert, Guggemos, & Sailer, 2021). Schools play a major role in preparing students for the challenge of using technology consciously and responsibly. Technology not only opens doors for social inclusion in modern societies, it also offers diverse opportunities for both students and educators to support teaching and learning processes (e.g., Castillo-Manzano, Castro-Nuño, López-Valpuesta, Sanz-Díaz, & Yñiguez, 2016; Janssen & Bodemer, 2013). However, simply being surrounded by digital technologies does not mean that we are able to use them effectively to our and others' benefit (Considine, Horton, & Moorman, 2009). Discussions about whether teachers and schools are taking advantage of the opportunities of digital technology in classrooms often results in discussions about technical facilities and availability of digital technology in schools. In anticipation of a successful implementation of digital learning in schools, governments around the world have arranged considerable investment in digital technology in schools (Kearney, Schuck, Aubusson, & Burke, 2018). In light of the expectation that investments in digital technologies could result in improved learning achievement, findings from the *Programme for International Student Assessment* (PISA) study 2012, which show mixed results regarding the relationship of computer usage in classrooms and students'

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performance, might be considered devastating. On the one hand, students who use computers moderately at school tend to have better learning outcomes than students who use computers rarely. On the other hand, students who use computers very frequently at school perform substantially worse in most of the included learning outcome measures (OECD, 2015). Moreover, PISA 2015 showed that a very frequent use of technology was negatively related to an important outcome relevant for learning in the 21st century, namely collaborative problem solving. A possible explanation is that the way students interact with computers might displace learning content and other types of interactions (see OECD, 2017). Thus, the consideration of additional variables may be relevant when analyzing the relationship between technology usage and students' learning outcomes. A crucial factor might be the type of student learning activities involving digital technology. From our perspective, an integrated approach to the frequency of digital technology use during teaching *and* student learning activities involving digital technologies in schools is needed in research.

One possible interpretation of the PISA 2012 and 2015 results is that teachers do not yet have sufficient skills to make the most out of the digital technologies in schools (OECD, 2015, 2017). Though, PISA 2018 results based on principal reports that showed no significant relation between students' reading performance and the statement that teachers have skills to integrate digital devices into instruction seem to contradict that (see OECD, 2020). However, it is a big step from principal reports to what is actually done by the teachers, e.g. with respect to learning activities, which are investigated in our study. Furthermore, these interpretations have stimulated discussions around what skills teachers need to integrate digital devices into instruction and to succeed in high-quality teaching with technology. Is it enough for teachers to have basic digital skills, in the sense of the ability to understand, evaluate and to communicate with digital technology in daily routines to apply technologies beneficially in classrooms? Approaches such as the TPACK model emphasize that besides teachers' basic digital skills, technological knowledge, technological-pedagogical knowledge, technological-content knowledge, and technological-pedagogical-content knowledge is necessary for successful teaching with technology (Mishra & Koehler, 2006). More recently, the idea of problem-solving skills in different phases of teaching with technology (e.g., planning, implementing, evaluating, and sharing) has become increasingly emphasized (see Digital Campus of Bavaria research group, 2017; Sailer et al., 2021; Ertmer & Ottenbreit-Leftwich, 2010; Zimmerman & Campillo, 2003). Such approaches define technology-related teaching skills as a knowledge base combined with teaching skills. They claim that technology-related teaching skills are relevant for fostering learning activities, in which students actively use digital technologies (Digital Campus of Bavaria research group, 2017). A recent study highlights that teachers' technology-related teaching skills show strong relationships with sophisticated students' learning activities involving digital technology (Sailer et al., 2021). Although further empirical validation that includes several types of teachers' skills requires an extensive study program involving qualitative and quantitative methods, we aim at providing a conceptual framework that gives insights about teachers' basic digital skills and technology-related teaching skills. Further, we want to investigate to what extent and how teachers use digital technology in classrooms. In addition, we want to investigate how different types of teachers' skills relate to their technology use in classrooms to derive implications for teachers' (further) education. We use a representative survey methodology based on structured telephone interviews to address these questions.

1.1. Digital learning in schools

The frequency of digital technology use has been previously investigated from students' and teachers' perspectives. While the results from PISA 2009 and 2012 refer to data collected from students, the *International Computer and Information Literacy Study* (ICILS) 2013 and 2018 data reported here refer to data collected from teachers. PISA 2009 and PISA 2012 included basic indicators of technology usage from students by reporting the proportion of students who use computers at schools regularly and at least once a week. The average of all participating countries shows that in 2009, 71% of students use computers at school regularly, while in 2012, 72% of students use computers at school regularly (OECD, 2012; 2015). ICILS 2013 included the perspective of teachers regarding their technology usage during lessons and found that across all participating countries, 62% of teachers use computers frequently (Fraillon et al., 2014). However, technology usage *during lessons* varies considerably between countries. For example, in Germany, 34.4% of teachers were using computers frequently in their teaching (Eickelmann, Gerick, & Bos, 2014). Results from ICILS 2018 show that almost half of the teachers are using digital technologies during their daily teaching. Again, results vary between countries, e.g. in Germany only 23% of teachers report to use digital technologies in their daily teaching (Fraillon, Ainley, Schulz, Friedman, & Duckworth, 2019). These results show that digital technologies are spreading into schools and are part of teaching and learning practices. What these results do not show is *how* digital technologies are applied in classrooms. The mode of learning and teaching with technology is important, as the mere frequency of digital technology use shows mixed relationships with students' learning outcomes in PISA 2012 (OECD, 2015). In the German sample in the ICILS 2013, computer usage in school even shows a negative relationship with students' information literacy (Eickelmann, Gerick, & Bos, 2014).

In light of these findings, the results from PISA and ICILS about different types of technology usage and different technology-related tools used in classrooms are of further interest. In PISA 2012, nine activities with digital technology, ranging from browsing the Internet for schoolwork to working on simulations at school, were included in a student questionnaire. Most frequently (42%), students were browsing the Internet for schoolwork, and least frequently, students were working on simulations at schools (11%; OECD, 2015). In ICILS 2013, different educational tools used by teachers were included in the teacher questionnaire: 30% of teachers used word processing and presentation software in most or all of their lessons, 23% of teachers used computer-based information resources in their lessons, and only 15% were using interactive digital learning resources (Fraillon et al., 2014). In ICILS 2018, teachers used word processing software (43%), presentation software (43%), and computer-based information resources (32%) most often. Interactive digital learning resources were used in most lessons by 22% of the teachers (Fraillon et al., 2019). These results demonstrate an increase in all activities involving digital technology from 2013 to 2018, but the overall pattern persists. Instructional approaches and related tools where learners are active participants, such as inquiry-based learning (see Donnelly, Linn, & Ludvigsen, 2014; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011), simulation-based learning (see Sitzmann, 2011), game-based and gamified learning (see Clark, Tanner-Smith, & Killingsworth, 2016; Wouters, Van Nimwegen, Van Oostendorp, & Van Der Spek, 2013; Sailer & Homner, 2020), or computer-supported collaborative learning (see Vogel, Wecker, Kollar, & Fischer, 2017; Radkowitsch, Vogel, & Fischer, 2020), have been implemented less often by teachers in their lessons (Fraillon et al., 2014, 2019; OECD, 2015). Ironically, digital technologies have the most promising potential to improve learning via such active learning approaches (Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). Learning is a process that should lead to relatively stable changes in the representations of attitudes, knowledge, and skills in the long-term memory of students. Active cognitive processing is a prerequisite for transferring knowledge to the long-term memory. Therefore, active cognitive processing is crucial for effective and sustainable learning (Wouters, Paas, & van Merriënboer, 2008). The results from PISA and ICILS provide the first evidence that teachers are not yet succeeding in fostering learning activities, in which students actively use digital technologies (Fraillon et al., 2014, 2019; OECD, 2015).

To further investigate the modes of students' learning with digital technologies, we suggest a systematic approach that distinguishes different levels of students' cognitive engagement when using digital technologies. The ICAP model offers such a systematic framework for levels of cognitive engagement by focusing on different types of student learning activities with digital technology (Chi, 2009; Chi & Wylie, 2014). Cognitive engagement can be conceptualized as a student's investment in learning (Chi et al., 2018). The ICAP model assumes different cognitive processes that underlie the different learning activities. These cognitive processes are partly reflected through the student learning activities. Learning activities are directly observable sequences of actions in a learning context (Chi, 2009). Such learning activities can be differentiated as passive, active, constructive, and interactive activities, and the activities can be regarded as a continuum with passive activities as lower end learning activities and interactive activities as upper end learning activities (Chi & Wylie, 2014). During passive learning activities, the underlying cognitive processes are related to storing the presented information. Passive learning activities imply students are not to exploring or manipulating the environment, e.g., when following a digital presentation by a teacher or watching a video without taking notes (Chi, 2009). The model suggests that during active learning activities, existing knowledge is activated, and new knowledge can be connected with it. Active learning activities are series of overt actions that include some physical manipulation, without generating new information (Chi et al., 2018). Examples for active learning activities are taking digital notes, underlining or copying-and-pasting some parts of a text, or practicing via a digital vocabulary training program (Chi & Wylie, 2014). For students' acquisition of declarative knowledge, active and passive learning activities that are on the lower end of the learning activities taxonomy might be sufficient. However, for students' skill and competency development, constructive and interactive learning activities are necessary. Constructive learning activities lead to generating and inferring new information that go beyond the presented information. Students being constructive go beyond the given learning material and produce their own ideas or solve problems based on the learning material at hand (Chi et al., 2018). Thus, such activities can be characterized as generative. Examples of constructive learning activities include drawing a digital concept map, justifying or providing reasons, or creating digital content in general (Chi, 2009). Interactive learning activities include constructive activities but in a co-constructive manner, meaning that learning partners build upon each other's contributions. In the ICAP model the term *interactive* refers to interactions between two or more peers in dyads or small groups, often through dialogs (Chi et al., 2018), where the individual contributions are constructive in nature. Interactive learning activities include for example solving problems together in a computer-supported collaborative learning environment like peer assessment activities on storyboards for the creation of explanation videos (Chi, 2009; Chi & Wylie, 2014).

In addition to indirect evidence for the ICAP continuum (Chi, 2009; Chi & Wylie, 2014), there is also experimental evidence showing that interactive activities lead to better learning than constructive activities, that constructive activities lead to better learning than active learning activities and that active learning activities have advantages over passive learning activities in terms of learning outcomes (Menekse, Stump, Krause, & Chi, 2013). This order is considered particularly relevant for learning of complex skills, such as problem-solving skills, in contrast to pure acquisition and retention of declarative knowledge.

When we speak of upper and lower ends of the ICAP continuum we do not want to imply that learning is always improved when we are employing learning activities towards the upper end (i.e., constructive and interactive). As introduced earlier, the different activities have optimal effectiveness for different types of learning outcomes (i.e., declarative knowledge vs. problem-solving skills). Probably, good teachers are able to orchestrate their lessons employing several types of learning activities in effective and efficient sequences. What seems important is that teachers know how and are able to initiate and guide the different types of learning activities. In this respect, digital technologies pose additional demands but also provide new opportunities to initiate and guide learning activities. Hence, it will be interesting to find out about the conditions under which teachers are also employing digital technologies to initiate and guide constructive and interactive activities with digital technologies.

Both the frequency of digital technology use during teaching and the type of student learning activities involving digital technology are probably influenced by teachers' skills and by the digital technologies available in the school. We will introduce these factors in the following sections (see 1.2 and 1.3).

1.2. Teachers' skills

What types of teachers' skills are potentially relevant for the frequency of digital technology use during teaching and types of student learning activities involving digital technology? Teachers' basic digital skills in terms of an "individual's ability to use computers to investigate, create, and communicate in order to participate effectively at home, at school, in the workplace, and in society" (Fraillon et al., 2014, p. 17) may also affect the use of digital technology during teaching. In addition to basic digital skills, specific technology-related teaching skills during planning, implementing, and evaluating digital learning and teaching scenarios potentially relate to students' constructive and interactive learning activities and frequency of digital technology use during teaching. We will introduce these types of teachers' skills in the following sections (see 1.2.1–1.2.2).

1.2.1. Basic digital skills

Basic digital skills can be defined as a set of individual's abilities to effectively and responsibly participate in economic, social, and cultural life via digital technologies (see OECD, 2015). To do so, a variety of basic digital skills is necessary. Based on the ICILS 2013 framework, understanding computer use, gathering information, producing information, and digital communication reflect central digital skills (Fraillon et al., 2014). Understanding computer use refers to the basic knowledge and skills in order to process information via digital technologies. Gathering information refers to searching, accessing, evaluating and managing information. Producing information with digital technologies refers to the transformation and creation of new products that may build upon existing ones. Communication refers to the exchange of information via digital technologies (Digital Campus of Bavaria research group, 2017; Fraillon et al., 2014; KMK, 2016).

For teachers, these basic digital skills are the foundation of their professional digital skills that we will come to call digital teaching skills. For students, basic digital skills are the target skills to acquire or further develop in schools. In other words, as a prerequisite, teachers seemingly need to have basic digital skills at their disposal to apply digital technology in the classroom and to foster their students' basic digital skills (KMK, 2016; Krumsvik, 2011). Basic digital skills have found their way into school curricula for students and qualification profiles for teachers all over the world (Digital Campus of Bavaria research group, 2017; Kelly & McAnear, 2002; KMK, 2016; Krumsvik, 2011; Thomas & Knezek, 2008). The ICILS 2013 study (Fraillon et al., 2014) as well as SITES 2006 (Law, Pelgrum, & Plomp, 2008) and the School Net 2013 study (European Commission, 2013) found that teachers who are confident in their personal use of technology are more likely to integrate technology in their teaching, as well. These results can be interpreted such that basic digital skills might be related to teaching with digital technology, at least regarding the frequency of usage. However, are teachers' basic digital skills that they apply in their daily lives also sufficient for fostering all of the different learning activities of students when using digital technologies in classrooms?

1.2.2. Technology-related teaching skills

We consider technology-related teaching skills as being distinct of the teachers' basic digital skills and necessary for effective use of digital technologies in classrooms. Based on the TPACK model certain types of knowledge are considered necessary for using technology effectively while teaching (Mishra & Koehler, 2006). Building on the widespread suggestion by Shulman (1986), the model emphasizes the interplay between three types of knowledge: content knowledge, pedagogical knowledge and technological knowledge. These interactions include pedagogical content knowledge, such as knowledge of instructional approaches in mathematics education; technological content knowledge, such as knowledge about specific technology used in mathematics education; technological pedagogical knowledge, such as knowledge about the effective use of technology in pedagogical situations; and technological pedagogical content knowledge, such as knowledge about an effective integration of technology in a mathematics teaching situation (Koehler & Mishra, 2009; Valtonen, Sointu, Mäkitalo-Siegl, & Kukkonen, 2015). However, most of the research on TPACK is on its measurement, professional development or its relation with teacher beliefs (e.g., Voogt, Fisser, Pareja Roblin, Tondeur, & Van Braak, 2013; Harris, Phillips, Koehler, & Rosenberg, 2017). Minimal research has been conducted on its relation with the type of use of digital technology. Whereas, for example, Endberg and Lorenz (2017) showed that TPACK can significantly predict the frequency of digital technology use during teaching, its relation to different student learning activities involving digital technologies is less clear.

Pedagogical, technological, and content knowledge can be the professional knowledge base for teachers using technology efficiently, but recent approaches propose a more action-oriented perspective associating teaching skills with more general phases in teaching and initiating learning activities with digital technologies. An attempt to conceptualizing such skills was made with the National Educational Technology Standards for Teachers (NETS), which is widely used in the US (Kelly & McAnear, 2002; Thomas & Knezek, 2008). NETS suggests a definition for what all teachers are expected to *be able to do* with technology to be considered digital literate educators. NETS includes skills that refer to planning and designing learning environments and experiences, implementing methods and strategies for applying technology to maximize student learning, and assessing and evaluating student learning and technology-based instructional approaches (Kelly & McAnear, 2002).

Another approach to conceptualizing technology-related teaching skills, which will be used in this study, was developed by Bavaria research group (2017). Their so-called K19 model defines core skills for teachers to teach in a digital world and integrates basic digital skills and technology-related teaching skills. The model's general approach is to postulate that basic digital skills are prerequisites for teaching with technology, but they are not sufficient for fostering and employing all types of student learning activities. Teachers need to have a sufficient knowledge base, as outlined by the TPACK model, and technology-related skills that build upon that knowledge base and that are oriented towards general action stages in different phases of teaching with technology (Zimmerman & Campillo, 2003): planning, implementing, and evaluating teaching with technology. These phases are complemented by a phase called *sharing*. The 19 postulated technology-related teaching skills can be assigned to the four different phases of technology usage in classrooms: *planning*, *implementing*, *evaluating*, and *sharing* technology-related teaching scenarios. Planning includes the skills to plan evidence-based use of technology in classroom. During implementing technology, teachers need to be able to diagnose and foster their students' learning processes with the help of adaptive scaffolding. Evaluation skills include the collection of data and reflection on digital technology usage based on self-collected data about learning processes and student outcomes in class. Lastly, the sharing of technology-related teaching scenarios means documenting, communicating and handing over the developed and described scenarios and searching, adapting and employing scenarios that have been created and described by others (Sailer et al., 2021).

From the perspective of the K19 model, technology-related teaching skills include a knowledge base for technology use in classrooms as well as skills to engage in planning, implementing, evaluating, and sharing of technology-related teaching scenarios. These technology-related teaching skills of teachers are supposed to be the core drivers of orchestrating lessons employing several types of learning activities in effective and efficient sequences (Digital Campus of Bavaria research group, 2017).

1.3. Digital technology in schools

In addition to technology-related teaching skills, the availability of digital technologies in schools is potentially related to the use of technology and learning activities involving technologies. Digital technologies are computer-based technologies that present domain-general and domain-specific content and/or allow for interaction with or about the content and support teachers and/or students during that interaction (Stegmann, 2020). This broad definition includes the use of computers for presentation purposes as well as computer-supported collaborative learning systems. Even though the availability of digital technologies can be seen as a prerequisite for its use during teaching (Fraillon et al., 2014), it is no guarantee of its effective use for student learning (Considine, Horton, & Moorman, 2009). PISA 2012 results demonstrate that resources invested in educational technologies do not relate to improved student achievement in reading, mathematics or science (OECD, 2015). PISA 2018 data showed a positive relation of the availability of digital devices as well as of internet connectivity with students' performance (OECD, 2020). Also, teachers in the ICILS 2013 study reported higher frequency of digital technology use when there were fewer limitations of resources (Fraillon et al., 2014).

Thus, a base amount of technology-related school equipment is supposed to be necessary for the frequency of digital technology use during teaching and likely predictive of it. However, it is not yet clear whether this relation holds true for different types of student learning activities with digital technologies as well. With respect to these learning activities, even though empirical evidence is scarce, it might be that the influence of the availability of technology is strongly moderated by teachers' basic digital skills and technology-related teaching skills.

2. The present study

In this study, we investigate the extent to which teachers apply digital technology in their teaching *and* which student learning activities involving digital technology teachers initiate. This study's data was collected in German public secondary schools with teachers of all subjects in the state of Bavaria between March 6th and April 10th 2017. The state of Bavaria, one of the 16 German states, consists of both rural as well as urban areas. Teachers from all areas were included in the study. There are three different types of secondary schools, namely, *Mittelschule* (lower track secondary school), *Realschule* (middle track secondary school), and *Gymnasium* (higher track secondary school preparing students to attend a university). Teacher education in Bavaria is structured with an initial education at university level and a second phase called preparatory service at school. Regarding the use of digital technology, schools received systematic funding through large implementation projects such as a Moodle-based leaning management system (mebis) and various pilot projects (e.g. Lernreich 2.0). However, the systematic use of digital technology in many Bavarian schools is still depending on some enthusiastic teachers and quite some concerns exist among many teachers in Germany as to whether digital technology can be used effectively for teaching and learning (Fraillon et al., 2019). In this context, we investigate the following research questions:

RQ1. How do teachers perceive their basic digital skills and their technology-related teaching skills?

As technology has become an integral part of our daily lives (Fraillon et al., 2014), we expect teachers' technology usage outside of classrooms to be at an advanced level. However, compared to the use of digital technology in our daily lives, teaching and learning with digital technology has not been so pervasive in teacher education and schools. Technology-related teaching skills may thus be less advanced in teachers. Because basic digital skills are supposed to be the basis for technology-related teaching skills, we hypothesize that teachers assess their basic digital skills as being substantially more advanced than their technology-related teaching skills (H 1).

RQ2. How often do teachers use digital technologies and what types of students learning activities do teachers foster with digital technology in the classroom?

On the basis of the previous studies that investigated the frequency of digital technology use during teaching (Fraillon et al., 2014, 2019; OECD, 2015), we hypothesize that digital technology is used in classrooms and a considerable part of teaching is supported by digital technology. Previous studies that included the type of use and the type of digital technologies used in classrooms indicate that teachers are not yet making the most out of digital technologies in classrooms and are not substantially using them for purposes in which learners are active participants (Fraillon et al., 2014, 2019; OECD, 2015). We suppose that teachers are not yet succeeding in fostering students' constructive and interactive learning activities involving digital technologies that are located at the upper end of the ICAP continuum. We thus hypothesize that teachers more often foster students' passive learning activities involving digital technology than constructive and interactive learning activities involving digital technology (H2.1). Further, we also hypothesize that active learning activities involving digital technology occur more often than constructive and interactive learning activities involving digital technology (H2.2).

RQ3. To what extent can we predict the frequency of digital technology use and the types of student learning activities involving digital technology with teachers' skills and availability of digital technology in school?

We hypothesize that teachers' basic digital skills, technology-related teaching skills, and digital technology in school are positively related to the frequency of digital technology use during teaching in the classroom (H 3.1; Sailer et al., 2021; Endberg & Lorenz, 2017; European Commission, 2013; Fraillon et al., 2014; Law et al., 2008).

Finally, we hypothesize that technology-related teaching skills can contribute to explaining variance in types of student learning activities involving digital technology in the classroom beyond basic digital skills and technology-related school equipment. Thus, we expect that technology-related teaching skills will help teachers to orchestrate a broader portfolio of different learning activities in their classrooms (H 3.2; Digital Campus of Bavaria research group, 2017; Sailer et al., 2021).

3. Method

3.1. Sample

A representative survey with $N = 410$ in-service teachers was conducted in German public secondary schools in the region of Bavaria. The sample was collected based on reference data for teachers in administrative districts of Bavaria and information about teachers in the three different types of secondary schools, namely, *Mittelschule* (lower track secondary school), *Realschule* (middle track secondary school), and *Gymnasium* (higher track secondary school preparing students to attend a university). The proportion of teachers in each district and school type in the sample was similar to the Bavarian teacher population to ensure representativeness. Teachers were randomly drawn based on this information from districts and school types. In all, 243 (59.3%) of the teachers were female, and 167 (40.7%) were male. The mean age of the teachers was 48 years ($M = 48.29$; $SD = 9.40$). On average, the interviewed teachers were in-service for 20 years ($M = 19.84$; $SD = 9.49$) and used technology in their teaching for 14 years ($M = 13.98$; $SD = 6.49$).

3.2. Procedure

A survey was performed via structured telephone interviews that took 24 min on average. The survey was performed between March 6th 2017 and April 10th 2017. The interview started with demographic questions followed by questions about the equipment at the teachers' school. Then, teachers were asked about the frequency of their digital technology use while teaching as well as student learning activities involving digital technology that the teachers are fostering. The interview concluded with questions about their basic digital skills and their technology-related teaching skills. The market research institute, GMS Dr. Jung GmbH, which has expertise in conducting large-scale data collections for research institutes via telephone interviews. In addition, the institute ensured access to representative panels of participants of which the sample was drawn.

3.3. Measurement of latent variables

An overview of the items used for the latent variables of teachers' *basic digital skills, technology-related teaching skills,* and availability *of digital technology in school* is shown in Table 1. For these latent variables, we performed confirmatory factor analyses to assess whether these constructs were measured consistently. Model fit was evaluated using the following model fit indices: Confirmatory fit index (CFI), for which values greater than 0.90 indicated acceptable fit; standardized root mean square residual (SRMR); and root mean square error of approximation (RMSEA), with values less than 0.08 indicating acceptable fit. We performed analyses of these measurement models with Mplus Version 7.11 (Muthén & Muthén, 2012). All items used in this study are included in the Appendix.

We assessed *basic digital skills* by six self-estimation items following the suggestions of KMK (2016). Teachers were asked how often they used technology professionally and privately for specific purposes. These items included researching, communicating, collaborating, producing content via technology, using technology for their own learning and general usage of technology. We assessed the items on a 5-point Likert-scale ranging from "never" to "very often". The measurement model of basic digital skills indicated post hoc modifications and suggested covarying *general technology usage* (ml1) and *research* via *technology* (ml2). After this modification, the measurement model showed good model fit. Table 2 shows an overview of the model fit of all measurement models.

Technology-related teaching skills cover the knowledge base for technology use in classrooms as well as skills to engage in planning, implementing, evaluating, and sharing of technology-related teaching and learning activities. Accordingly, we assessed the knowledge base by four self-report items from the scale by Schmidt et al. (2009). The four items cover all technology-related aspects postulated in the TPACK model, namely, technological knowledge, technological pedagogical knowledge, technological content knowledge, and technological pedagogical content knowledge (Koehler & Mishra, 2009). For technical knowledge, we used Item number 4 from the Schmidt et al. (2009) scale. For technological pedagogical knowledge, we used Item number 35. For technological content knowledge, we used an adapted version of item number 31. For technological pedagogical content knowledge, we used an adapted version of item number 40. For the last two items, we changed the subject reference of "mathematics" to a more general "subject content". The proposed add-on to these knowledge types that focus on teaching skills that are oriented towards general problem-solving stages when teaching with digital technologies were assessed with four self-report items, which covered evidence-based planning, implementing, evaluating, and sharing of technology-related teaching scenarios (Digital Campus of Bavaria research group, 2017). These self-developed items cover the central aspects of each phase of teaching with digital technologies. We assessed all items on a 5-point Likert-scale. For *technology-related teaching skills*, post hoc modifications suggested covarying *evaluating of technology use in class* (tts7) and *sharing of technology use in class* (tts8). After this modification, the measurement model showed sufficient model fit (see Table 2).

We assessed the availability of *digital technologies in school* by one item asking about teachers' satisfaction with the digital technologies in school on a 5-point Likert-scale ranging from "strongly disagree" to "strongly agree" and by eleven items regarding the coverage and breadth of digital technology resources at their schools. For coverage, we asked teachers if certain technologies were accessible *in certain classrooms* in their school. For breadth, we asked teachers if certain technologies were accessible *in all classrooms* in their schools. In total, we asked teachers about eleven technologies: desktop computers, notebooks, tablets, projectors, smartboards/whiteboards, digital (photo and video) cameras, document cameras/visualizers, CD/DVD/Blu-ray-players, TVs, smartphones, and interactive tables. Thus, the coverage and breadth of technology-related school equipment could range from "0" meaning no technologies available in all/certain classrooms to "11" meaning all listed technologies were available in all/certain classrooms. The measurement model for *digital technologies in school* was fully saturated and had no degrees of freedom left (see Table 2).

Table 1
The acronym, minimum (*Min.*), maximum (*Max.*), mean (*M*), standard deviation (*SD*), and sample size (*N*) for single items used for the four groups of predictor variables, basic digital skills, technology-related teaching knowledge, technology-related teaching skills, and digital technology in school.

	acronym	*Min.*	*Max.*	*M*	*SD*	*N*
Basic digital skills						
General technology usage	bds1	2	5	4.73	.61	405
Research via technology	bds2	2	5	4.61	.65	407
Communication via technology	bds3	2	5	4.52	.65	406
Collaboration via technology	bds4	1	5	3.59	1.13	398
Production of content via technology	bds5	1	5	3.97	1.10	392
Learning via technology	bds6	2	5	4.21	.78	400
Technology-related teaching skills						
Technological knowledge	tts1	1	5	3.97	1.04	401
Technological pedagogical knowledge	tts2	1	5	4.15	.81	402
Technological pedagogical content knowledge	tts3	2	5	4.23	.63	399
Technological content knowledge	tts4	1	5	4.19	.81	403
Planning technology use in class	tts5	1	5	2.60	1.16	398
Implementing technology use in class	tts6	1	5	2.95	1.11	395
Evaluating technology use in class	tts7	1	5	3.05	1.21	395
Sharing experiences of technology usage	tts8	1	5	2.85	1.43	397
Digital technology in school						
Satisfaction with digital technology resources	dt1	1	5	3.84	1.11	399
Breadth of digital technology resources	dt2	4	11	7.70	1.31	410
Coverage of digital technology resources	dt3	1	9	4.35	1.45	410

Note. All items were assessed on 5-point Likert scales, except breadth and coverage of digital technology resources, which could range from "0" (meaning "no digital technology available") to "11" (meaning "11 different types of digital technologies available").

Table 2
Chi-square test (χ^2, *df*, and *p*), confirmatory fit index (CFI), standardized root mean square residual (SRMR), and root mean square error of approximation (RMSEA) for measurement models and structural models.

	χ^2	*df*	*p*	*CFI*	*SRMR*	*RMSEA*
Measurement models						
Basic digital skills	8.22	8	.413	.998	.022	.008
Technology-related teaching skills	26.33	19	.121	.961	.037	.031
Digital technology in school	<.001	0	<.001	1.00	<.001	<.001
Structural models						
Frequency of digital technology use during teaching	146.23	128	.129	.963	.041	.019
Student learning activities with digital technologies	196.86	170	.078	.971	.042	.020

3.4. Measurement of the frequency of digital technology use during teaching and student learning activities involving digital technologies

For the *frequency of digital technology use during teaching*, we asked participants about the percentage of time digital technology is used during a typical lesson. Participants were able to score from 0% to 100%.

For *student learning activities involving digital technologies*, we divided the variable *frequency of digital technology use* in up to four categories, namely students' passive, active, constructive, and interactive learning activities. The resulting four outcome variables represent percentages of the four types of student learning activities involving digital technologies in a typical lesson. To calculate the single proportions of types of student learning activities, we presented the teachers with short descriptions of four scenarios. We asked the teachers to indicate how often they apply technology during teaching in a way similar to the scenarios. 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. To calculate the proportion of single learning activities relative to all learning activities, we divided the Likert score for single activities by the sum score of all four Likert Items. In a last step, we multiplied the resulting proportion of single learning activities with the frequency of digital technology use during teaching. As we operationalized the variable *frequency of digital technology use during teaching* as percentages of the overall technology use in a typical lesson, we obtained percentages of single learning activities involving digital technologies relative to a typical lesson. We applied this procedure to all four types of student learning activities and thus received four variables, which can be interpreted as percentages: *student passive, active, constructive,* and *interactive learning activities involving digital technologies.*

3.5. Statistical analysis

To investigate RQ1, we computed paired *t* tests between the latent variables of teachers' basic digital skills and technology-related teaching skills. To investigate RQ2 regarding the types of student learning activities involving digital technology, we used paired *t* tests between students' passive and constructive, passive and interactive, active and constructive, and active and interactive learning activities involving digital technology. We used Cohen's *d* as a measure of effect size for RQ1 and RQ2. The Cohen's *d* correction was applied as suggested by Morris (2008). We conducted these analyses with SPSS Version 24. To investigate RQ3, we applied a structural equation modeling (SEM) approach with robust maximum likelihood estimation (MLR) with standard errors and a chi-square test statistic. MLR corrects for possible non-normality-induced bias in the standard errors (Finney & DiStefano, 2008). We conducted two SEMs for the frequency of digital technology use during teaching and student learning activities involving technologies. The first one included the outcome variable *frequency of digital technology use during teaching* and the predictors *teachers' basic digital skills, technology-related teaching skills*, and *digital technology at school*. The second SEM included the four outcome variables of students' *passive, active, constructive, and interactive learning activities involving digital technology* and the same predictors as the first SEM. We standardized all coefficients in both SEMs before reporting.

4. Results

4.1. Teachers' skills

According to Hypothesis 1, teachers' basic digital skills are substantially more developed than their technology-related teaching skills. Descriptive results show that teachers evaluated their *basic digital skills* with $M = 4.28$ ($SD = 0.44$) and their *technology-related teaching skills* with $M = 3.50$ ($SD = 0.49$). A paired *t*-test indicated that teachers perceived their basic digital skills to be significantly more developed than their technology-related teaching skills ($t(409) = 25.70$; $p < .001$; $d = 1.66$). These results are in support of Hypothesis 1.

4.2. Frequency of digital technology use during teaching and student learning activities involving digital technologies

Table 3 shows an overview of the frequency of digital technology use during teaching and the different types of students' passive, active, constructive, and interactive learning activities involving digital technology. In our sample, teachers reported that they used digital technology in some way during teaching 43.03% ($SD = 24.54$) of the time in a typical lesson. The high variance in the frequency of digital technology use during teaching indicates that some teachers use digital technologies to a great extent in their lessons, whereas some use digital technologies only selectively. For types of student learning activities involving digital technology, we hypothesized that teachers more often foster students' passive learning activities compared with constructive and interactive learning activities, both of which are located at the upper end of the ICAP continuum. The results from $N = 368$ teachers who answered all relevant questions for these analyses showed that students' passive learning activities occur most often (13.35%; $SD = 8.42$), followed by interactive (10.45%; $SD = 7.62$), constructive (10.05%; $SD = 7.76$), and active (8.92%; $SD = 7.80$) learning activities. Paired *t* tests showed that the difference between passive and constructive ($t(367) = 8.13$; $p < .001$; $d = 0.41$) as well as passive and interactive ($t(367) = 8.46$; $p < .001$; $d = 0.42$) was significant. These results supported Hypothesis 2.1 by showing that passive learning activities involving digital technologies are fostered more frequently than constructive and interactive learning activities involving digital technology.

Table 3
The minimum (*Min.*), maximum (*Max.*), mean (*M*), standard deviation (*SD*), and sample size (*N*) for frequency of digital technology use during teaching and students' passive, active, constructive, and interactive learning activities involving digital technology.

	Min.	*Max.*	*M*	*SD*	*N*
Frequency of digital technology use during teaching	5	100.00	43.03	24.54	395
Students' passive learning activities involving digital technology	.91	40.00	13.35	8.42	368
Students' active learning activities involving digital technology	0	45.00	8.92	7.80	376
Students' constructive learning activities involving digital technology	0	42.22	10.05	7.76	372
Students' interactive learning activities involving digital technology	.91	44.44	10.45	7.62	368

Note. All items can be interpreted as percentages, meaning they could range from 0 to 100. They refer to the percentage of time spent on the respective activity during a typical lesson.

Further, we hypothesized that teachers from our sample more often foster students' active learning activities compared with constructive and interactive learning activities. Paired t tests showed significant differences between active and constructive ($t(368) = -2.19$; $p = .029$; $d = 0.11$) as well as active and interactive ($t(381) = -3.00$; $p = .003$; $d = 0.16$) in favor of constructive and interactive learning activities. These results indicate that constructive and interactive learning activities involving digital technologies occur more frequently than active learning activities, even though the effect size is rather small. Thus, these results do not support Hypothesis 2.2; they even show a pattern that is in the opposite direction of our expectations.

4.3. Relationships with frequency of digital technology use during teaching and student learning activities involving digital technologies

Descriptive results of the items used for the latent variables *basic digital skills, technology-related teaching skills,* and availability of *digital technologies in school* are shown in Table 1. Acronyms used in the SEMs are listed in Table 1, as well. Descriptive results of the outcome variables of *frequency of digital technology use during teaching* and types of *student learning activities with digital technology* are shown in Table 3. For the availability of *digital technologies in school*, descriptive results showed that a majority of teachers in our sample were satisfied with the digital technology available in their schools. In addition, both breadth and coverage of digital technology resources was quite high (see Table 1).

For the frequency of digital technology use during teaching, we hypothesized that teachers' basic digital skills, technology-related teaching skills, and digital technologies in school would be positively related to the frequency of digital technology use during teaching. $N = 370$ teachers answered all relevant questions and were thus included in the analyses. Table 4 shows the estimated correlations among all variables. In a SEM for the frequency of digital technology use during teaching, we included all three predictors. The SEM appears to be a good fit to the data (see Table 2). The analysis indicated no necessary post hoc modifications. The model is depicted in Fig. 1. In this SEM, teachers' basic digital skills were related to the frequency of digital technology use during teaching ($\beta = 0.41$). Both technology-related teaching skills and digital technology in school were not significantly associated with the frequency of digital technology use during teaching in the SEM. Thus, these results partly support Hypothesis 3.1 because teachers' basic digital skills were related to the frequency of digital technology use during teaching, but technology-related teaching skills and digital technology at school were not.

For different types of student learning activities involving digital technology, we hypothesized that teachers' technology-related teaching skills bring new types of student learning activities involving digital technologies to the portfolio of teachers. A sample of $N = 364$ teachers answered all relevant questions and were thus included in the analyses. Table 5 shows the estimated correlations among all variables included in these analyses. The small differences in the size of the correlations between Tables 4 and 5 resulted from missing data for the different analyses. We included all three predictors in a SEM for student learning activities involving technologies. The model fit of the SEM was good (see Table 2) and no post hoc modifications were indicated. The model is depicted in Fig. 2. Similar to the SEM for frequency of digital technology use during teaching availability of digital technology in school was not related to any of the student learning activities involving digital technology. Regarding teachers' basic digital skills, we found positive relationships with students' passive ($\beta = 0.37$), active ($\beta = 0.29$), and interactive learning activities involving digital technology ($\beta = 0.34$). We found no significant relationship between basic digital skills and constructive learning activities. However, teachers' technology-related teaching skills were related to students' constructive learning activities involving digital technology ($\beta = 0.30$). Although basic digital skills explain substantial parts of the variances in three out of four types of learning activities, one important learning activity is significantly depending on a higher level of technology-related teaching skills. These results partly support Hypothesis 3.2.

5. Discussion

The results of this study show that teachers in Bavarian secondary schools are employing digital technologies frequently in their teaching – however with substantial heterogeneity between the teachers. This result is in line with the results of other studies (e.g., ICILS 2013, 2018; and PISA 2012) that investigated the frequency of digital technology use in school (Fraillon et al., 2014, 2019; OECD, 2015). The result supports the claim that digital

Table 4
Estimated correlation matrix of basic digital skills, technology-related teaching knowledge, technology-related teaching skills, digital technology in school, and frequency of digital technology use during teaching.

	1.	2.	3.	4.
1. Basic digital skills	1			
2. Technology-related teaching skills	.518*	1		
3. Digital technology in school	.104	.075	1	
4. Frequency of digital technology use during teaching	.507*	.404*	.028	1

Note: *p < .05.

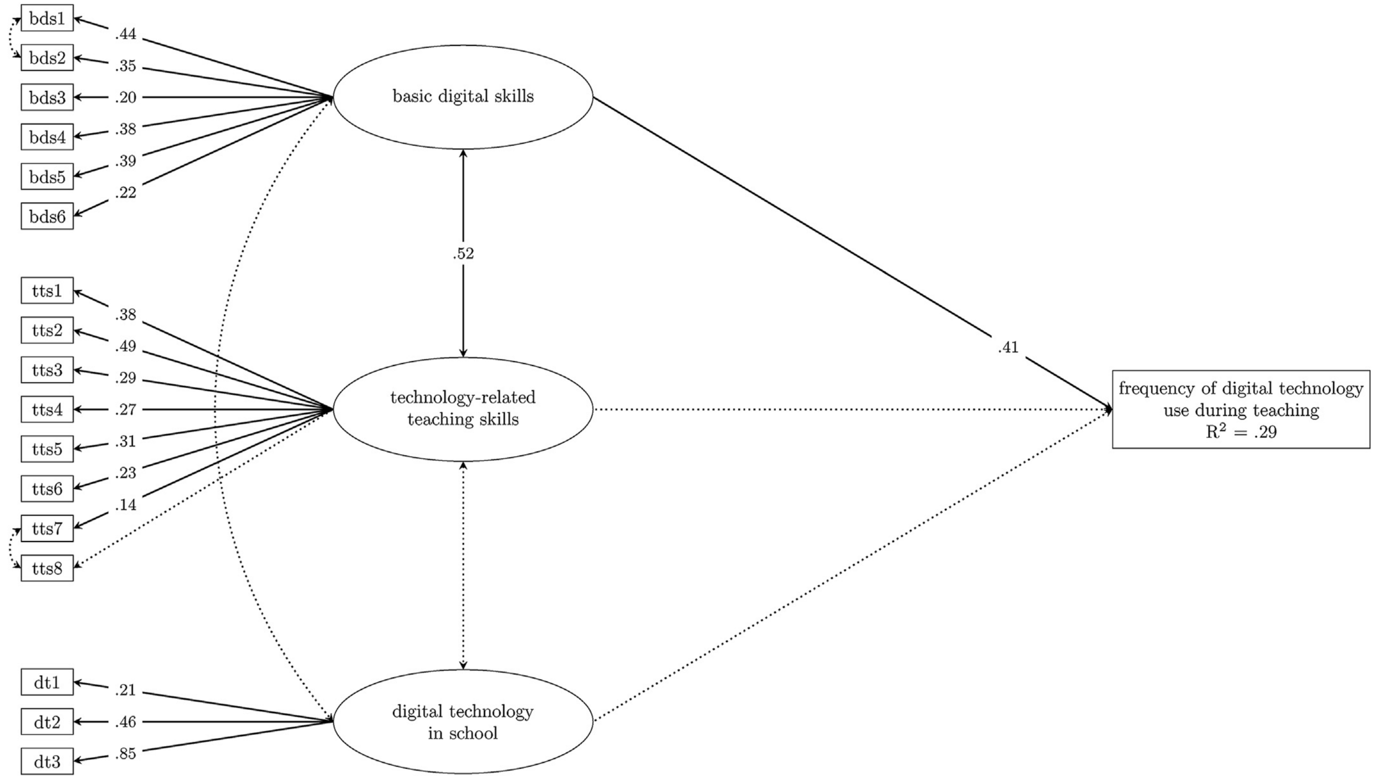

Fig. 1. Structural equation model (SEM) including frequency of digital technology use during teaching, basic digital skills, technology-related teaching skills, and digital technology in school. Circles represent latent variables and rectangles represent measured variables. Lines indicate significant relationships, and dotted lines indicate nonsignificant relationships. The given values are beta-values.

Table 5
Estimated correlation matrix of basic digital skills, technology-related teaching knowledge, technology-related teaching skills, digital technology in school, and students' passive, active, constructive, and interactive learning activities involving digital technology.

	1.	2.	3.	4.	5.	6.	7.
1. Basic digital skills	1						
2. Technology-related teaching skills	.511*	1					
3. Digital technology in school	.089	.070	1				
4. Students' passive learning activities involving digital technology	.424*	.285*	.121	1			
5. Students' active learning activities involving digital technology	.367*	.303*	-.047	.437*	1		
6. Students' constructive learning activities involving digital technology	.327*	.386*	.040	.567*	.305*	1	
7. Students' interactive learning activities involving digital technology	.390*	.272*	-.015	.667*	.386*	.507*	1

Note: *p < .05.

technology is indeed spreading into schools (e.g., Castillo-Manzano, Castro-Nuño, López-Valpuesta, Sanz-Díaz, & Yñiguez, 2016; Janssen & Bodemer, 2013). The results of student learning activities involving digital technology show *how* digital technologies are used in Bavarian secondary school classrooms. On a descriptive level, digital technology is most frequently used in a way that supports students' passive learning activities compared with other learning activities. In line with previous research (Fraillon et al., 2014, 2019; OECD, 2015) and in support of our hypothesis, the larger proportion of technology use in class is on the passive level compared with the constructive and interactive levels of student learning activities. However, to a certain extent, all types of student learning activities involving digital technology occur in typical lessons. Contrary to our hypothesis, constructive as well as interactive learning activities involving digital technologies occurred even more frequently than active learning activities. Although this difference was significant, it was a rather small effect. These findings indicate that many teachers are able to stimulate constructive and interactive learning activities. Thus, our results are ambiguous, meaning that passive learning activities were dominant, but constructive and interactive activities, both of which are located at the upper end of the ICAP continuum, were present as well — even more frequently than active learning activities. On the one hand, as active learning activities involve taking (digital) notes or practicing via a digital drill and practice learning program, passive learning activities could easily be complemented by phases of active learning activities involving digital technologies (e.g., through digital quizzes). By doing so, teachers could apply a wider range of different learning activities. Possibly, phases of active learning activities (e.g., with digital drill and practice learning programs) occur during homework, which is not covered by our analyses. This could also explain why active learning activities occur least often; that is, they probably occur outside the lessons. On the other hand, results indicate that teachers from our sample more often focus on fostering constructive and interactive learning activities compared with active learning activities, which would be a step in the right

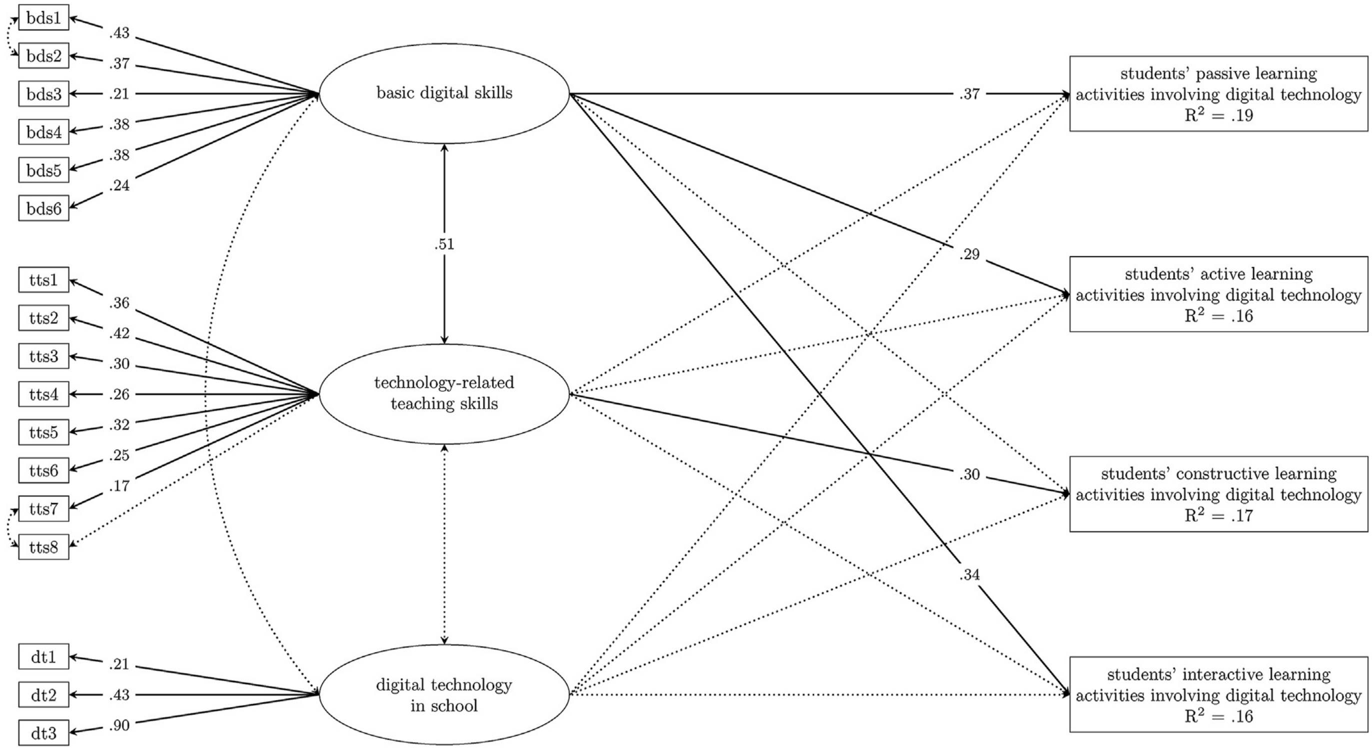

Fig. 2. Structural equation model (SEM) including students' passive, active, constructive, and interactive learning activities involving digital technology, basic digital skills, technology-related teaching skills, and digital technology in school. Circles represent latent variables, and rectangles represent measured variables. Lines indicate significant relationships, and dotted lines indicate nonsignificant relationships. The given values are beta-values.

direction for unfolding the full potential of digital technologies in classrooms. Compared with results from ICILS 2013, which show that instructional approaches where learners are active participants have been rarely implemented by teachers in their lessons (Fraillon et al., 2014), our results indicate that teachers in Bavarian schools might be in a transition phase towards employing constructive and interactive learning activities as well. This result is in line with ICILS 2018 that shows an increase for the majority of activities implemented via digital technologies. However, the pattern of approaches applied persists: teachers foster passive learning approaches more often compared to approaches in which learners are active, constructive, and interactive (Fraillon et al., 2019).

Furthermore, as passive and active learning activities might be adequate for students' acquisition of declarative knowledge, they do have merit in the classroom, even though they are considered to be less effective for the development of competences and skills (see Chi & Wylie, 2014; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). By applying passive and active learning activities with the help of digital technologies, teachers cannot fully take advantage of the potentials of digital technologies (see Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). Nevertheless, digital technologies might also have advantages when applied in contexts involving either passive or active learning activities (e.g., by visualizing complicated processes during teaching). Further, as an inspiring explanation by a teacher can also be a way to engage students and foster their knowledge acquisition, it might also be necessary to balance learning activities, independent of technology use. Digital technologies can be used to balance the overall learning activities in classrooms by focusing on constructive and interactive learning activities, which can effectively be initiated and guided with the help of digital technologies. This can be done by promoting and focusing on inquiry-based learning (see Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011), simulation-based learning (see Sitzmann, 2011), game-based learning (see Clark, Tanner-Smith, & Killingsworth, 2016), or computer-supported collaborative learning (see Radkowitsch, Vogel, & Fischer, 2020) with the help of digital technologies.

One central question of our study was whether teachers' skills are predictive of the frequency of digital technology use during teaching and types of student learning activities. First, for the frequency of digital technology use during teaching, the results showed that having basic digital skills was associated with more time spent teaching with digital technology. Technology-related teaching skills and digital technologies at schools were not related to the frequency of technology use in class in our SEM. This finding stands in some contrast to previous research (see Sailer et al., 2021; Endberg & Lorenz, 2017) that showed that technology-related teaching skills relate to the frequency of technology use. However, this prior research did not include teachers' basic digital skills, technology-related teaching skills, and digital technologies in school in one statistical analysis. Thus, our SEM approach with multiple latent factors included goes beyond these findings.

Furthermore, our focus on different student learning activities involving digital technology allowed for more differentiated considerations that have not been addressed in previous research. Teachers' basic digital skills related to students' passive, active, and interactive learning activities involving digital technologies. Thus, teachers' basic digital skills seem to be a necessary condition, but especially for constructive learning activities, teachers' ability to effectively and responsibly use technology independent of the teaching context was not a significant predictor. This result is in line with the theoretical considerations of the K19 model (Digital Campus of Bavaria research group, 2017) and emphasizes the need for technology-related teaching skills beyond basic digital skills that have also been emphasized by others before (Kelly & McAnear, 2002; Krumsvik, 2011). Our results can be taken as support for the claim that technology-related teaching skills are of relevance for fostering constructive learning activities involving digital technology, as there is a medium sized effect of technology-related teaching skills on students' constructive learning activities involving digital technology. Although correlational, our results support the hypothesis that there is a higher likelihood of employing the full range of learning activities involving digital technology if teachers have basic digital skills and additionally technology-related teaching skills. While basic digital skills not only relate with interactive learning activities, that are located at the upper end of the ICAP continuum, but also relate to the learning activities located at the lower end, technology-related teaching skills only relate to constructive learning activities that are considered important to foster students' skill and competency development (Chi, 2009; Chi & Wylie, 2014). Specifically fostering students learning activities on the upper end of the ICAP continuum seems to require technology-related teaching skills in addition to basic digital skills.

Let us turn to the digital technologies available in school. More often than not, they are the focus of discussions about digitalization of schools. In our study, the equipment at Bavarian schools was not related to frequency of digital technology use during teaching in general or to student learning activities involving digital technologies in particular. Even though it seems plausible that a basic amount of digital technology in school is a prerequisite for using digital technology during teaching (Fraillon et al., 2014), more equipment does not necessarily imply a higher amount of certain student learning activities involving digital technology. This result is in line with the findings of ICILS 2018, indicating that providing students or teachers with digital technologies is not enough. They also need sufficient skills and additional support (Fraillon et al., 2019). Taking descriptive results of digital technologies in school into consideration, a majority of teachers in our sample indicated satisfaction with the digital technology resources. In their view, the breadth and coverage of digital technology resources, i.e., accessibility of digital technologies in all (breadth) or certain (coverage) classrooms in school, were quite high. Teachers hardly reported that there was no digital technology available in their classrooms. Thus, availability of basic equipment for digital technology can be presumed for the teachers in our sample. We are aware that the results with respect to current school equipment cannot easily be generalized to different regions and educational systems in the world. We would argue, however, that the results can be generalized to school or specific region that is in a similar phase of digital technology implementation like Bavarian schools. The current phase in Bavaria can be described as an intermediate phase of technology implementation phase towards more systematic, and constructive and interactive technology use that are supported by large implementation projects. These projects and funding of equipment in schools in general might be the reason that some basic equipment for digital technology for learning and teaching is available for almost every teacher in our sample. With this assumption, our study results can be interpreted as supporting the hypothesis that more and better equipment is not predictive of the frequency of digital technology use during teaching or the type of student learning activities involving digital technologies in classrooms. Future research may address the question of whether the very low predictive value of digital technology resources in schools holds true for different types of technology and for schools in different phases of digital technology implementation.

In our SEMs we expected a relation between the availability of digital technologies in schools and teaching with digital technology in the sense of a pre-condition for the application of teachers' skills (Considine, Horton, & Moorman, 2009; Fraillon et al., 2014). Nevertheless, our results did not show a linear relation between the availability of digital technologies in schools and teaching with digital technology. However, the authors of ICILS 2018 argue digital technologies in schools are necessary to allow to unfold teachers' basic digital skills as well as their technology-related teaching skills while teaching in school (Fraillon et al., 2019). Based on this and based on our results, it might be more suitable to expect a non-linear relationship or a moderating role of the availability of digital technologies in schools for the application of basic digital skills and technology-related teaching skills. Future research might therefore investigate non-linear relationships or define a model in which the availability of digital technologies in schools is investigated as a moderator of the relations between basic digital skills and technology use as well as technology-related teaching skills and technology use. The resulting model could be a threshold model, which emphasizes the need of basic digital technology resources, however pointing towards the low predictive value of more digital technology resources beyond that basic threshold.

Taken together, teachers' basic digital skills were strongly related to the frequency of digital technology use during teaching, and the addition of technology-related teaching skills was relevant for an important component of the full range of student learning activities, namely constructive learning activities. Moreover, considering that teachers' basic digital skills are substantially higher than their technology-related teaching skills, it is not surprising that, currently, a considerable part of teaching is supported by digital technology, but students' passive learning activities involving digital technologies occur most frequently.

The factors in our SEMs explained variance in technology use (see Fig. 1) and student learning activities (see Fig. 2). However, a large proportion of the variance could not be explained by the factors included in our models. Important factors that could influence the amount and kind of technology use in schools are teacher-, student-, and school administration-related factors. On the teacher side, teachers' attitudes and beliefs about digital technologies (see Liu, 2011; Backfisch, Lachner, Stürmer, & Scheiter, 2021) and their (further) education could influence the frequency of digital technology use during teaching and student learning activities that the teachers are fostering. On the student side, students' increased basic digital skills and increased experience with learning activities supported by digital technology probably makes it easier for teachers to use technology beneficially in their classrooms. On the school administration side, the engagement of school principals, professional learning communities in and across schools, availability of technical and pedagogical support, as well as strategies and concepts for the implementation of digital technologies in the classroom may be further explanatory factors and possible starting points for improvements in digital learning at schools. These factors have not been assessed in our study, but they could be in focus of further research.

6. Limitations

The results of our study have to be considered in light of some limitations. One limitation is the comparatively small number of items that form the latent variables. This weakness is related to the use of telephone interviews as a data collection method. On the one hand, telephone interviews do not allow for complex questions and the duration and thus amount of questions are restricted in practice to avoid possible reactance. On the other hand, this methodological approach has the advantage of allowing for a large and representative sample. We took full advantage of the latter. Another limitation related to the data collection method is that our results relied on self-report by teachers. Self-report can be imprecise and suffers from social desirability bias. This weakness is also pertinent to the use of telephone interviews as a data collection method and the associated time restrictions. To address these known problems of self-reports, we included scenario-based assessment for student learning activities involving digital technologies and asked for frequencies of certain behaviors instead of asking for agreement with or rejection of certain claims. However, more objective test instruments of teachers' skills may yield a more valid picture. Further research may focus on the assessment of technology-related teaching skills with more objective test instruments, e.g., inspired by situational judgement tests (see Motowidlo, Dunnette, & Carter, 1990) or anchoring vignettes approaches (King, Murray, Salomon, & Tandon, 2004). The need for more objective instruments holds true for the assessment of learning activities with digital technology, which were assessed by the teachers in the current study. Students' objective learning outcomes and observations of actual learning activities would be optimal criteria but would be collected at the expense of representativeness and a large sample size. Furthermore, our findings may suffer from selection bias. Teachers who had sufficient basic digital skills and/or technology-related teaching skills were probably more likely to participate in the study than teachers that lacked basic digital skills and/or technology-related teaching skills. This selection bias was thwarted by drawing a random and representative sample.

A further limitation is that our research is not subject specific when assessing teachers' basic digital skills, technology-related teaching skills or the initiation of different student learning activities involving digital technology. However, based on the ICAP framework, which focusses on cognitive engagement and learning activities, cognitive engagement is important for learning in any content domain (Chi, 2009; Chi & Wylie, 2014). Based on this argumentation of the ICAP framework, we did not put a focus on differences between different subjects and domains in our study. This focus is also visible in the measurement of our skill variables that more strongly emphasize the technological pedagogical knowledge aspect than the technological content knowledge and technological pedagogical content knowledge aspects from TPACK model (see Mishra & Koehler, 2006). This does not imply that subject matter and domain specificity of teaching are not important. There is a large proportion of variance in this study that is not explained by the cross-domain measures which were used. Therefore, further studies need to address how different digital technologies can be used to facilitate learning activities in different subjects and emphasize the *content* aspect of TPACK in their measurement of knowledge and skills more strongly (see Mishra & Koehler, 2006).

Our sample of teachers is representative for the region of Bavaria (Germany). From our perspective, generalizations of our results are possible for teachers from other regions that are in a similar phase of digital technology implementation that can be characterized by an availability of at least some basic equipment with digital technology resources (wifi, computers, smartphones, access to learning management systems), increasing demands for more and more systematic use of digital technologies at schools, and systematic forms of continuing education on digital learning and teaching for the teachers). To what extent the model of relationships between different factors is also valid for other regions that struggle with availability of technologies and infrastructure, or for regions that are far more advanced, is an open question for future research.

Another limitation concerns the validity of the measurement of students' interactive learning activities involving digital technology that has been brought up by Chi et al. (2018). The assessment of interactive learning activities is in danger of rating simple interactions among students as interactive, while these interactions are not meeting the actual requirements of interactive learning activities, such as the students being constructive in the first place and that a sufficient amount of turn-taking is taking place (Chi, 2009). Our measurement of interactive learning activities could be affected by this misinterpretation.

7. Conclusions

Equipping schools with digital technologies did not relate to the frequency or different types of digital technology use in classrooms in our sample of teachers from Bavarian schools. We are aware that the use of digital technologies requires a threshold level of digital technology resources (Fraillon et al., 2014); however, more digital technologies beyond this threshold level do neither imply a higher frequency of digital technology use during teaching nor a broader bandwidth of initiated learning activities. Instead, teachers' basic digital skills seem much more important for both the frequency of digital technology use during teaching and for fostering a variety of student learning activities involving digital technology. These skills seem to be the foundation for teachers' technology use in class. However, for employing the full bandwidth of learning activities, including constructive learning activities, which are considered specifically beneficial for students' problem-solving skills (see Chi & Wylie, 2014), teachers' technology-related teaching skills seem necessary. In light of the Covid-19 pandemic and the need for teaching at a distance, teachers being equipped with those skills seem even more important.

Including technology-related teaching skills during initial teacher education and continuing education seems to be a way to increase the likelihood of students' constructive learning activities with digital technology. This is particularly important because teachers' technology-related teaching skills seem substantially less developed than their basic digital skills.

We can help unfold the unique potential of digital technologies for learning if we find ways of supporting teachers in orchestrating different types of learning activities, including a substantial portion of constructive and interactive learning activities (Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011; Chi, 2009; Chi & Wylie, 2014). How can this be achieved? By shifting the focus from digital technologies to the development of teachers' skills and how teachers apply these skills to enable student learning activities. These skills are among the main drivers of a wide range of student learning activities involving digital technology in schools.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tate.2021.103346.

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