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On powerpointers, clickerers, and digital pros: Investigating the initiation of digital learning activities by teachers in higher education

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ABSTRACT

This study investigated the initiation of digitally supported learning activities and personal and institutional factors associated with them in different higher education courses, based on the C♭-model. The C♭-model is a theoretical framework that systematizes contextual factors, which influence students' learning activities as the most important facilitator of students' learning success. Using a self-assessment instrument with anchored scenarios in a sample of 1625 higher education teachers, we were able to identify three levels at which higher education teachers initiated digital learning activities: a low level (*powerpointers*), a moderate level (*clickerers*), and a high level (*digital pros*). The findings also support the relevance of the contextual factors specified in the C♭-model for initiating a high level of digital learning activities, namely digitalization policy and commitment of university administration, institutional equipment, technical and educational support, self-assessed basic digital skills, and self-assessed technology-related teaching skills. All of these factors explain a substantial amount of variance in the level of initiated digital learning activities. We conclude that a comprehensive approach rather than isolated measures might contribute to successful teaching and learning in higher education.

1. Introduction

The task of designing effective teaching scenarios with digital technology has been of great importance in the light of the ongoing process of digital transformation in higher education (see Redecker & Punie, 2017). The focus of research is often teacher-centered (see Schmid et al., 2017), however the frequency with which higher education teachers use digital technology does not per se guarantee students' learning success (Kirkwood, 2009; Sailer, Schultz-Pernice, & Fischer, 2021; Tamim et al., 2011). Further research on higher education teachers' technology use is also often directed toward the organizational purposes surrounding the courses (Bond et al., 2018). However, some (proximal) factors are closer to the learning processes as other (distal) factors and it is especially students' learning activities which are stronger associated with students' learning outcomes than, for example, organizational purposes (Seidel & Shavelson, 2007). Thus, if we take students' learning outcomes as the primary goal of technology use in higher education, research is needed which focuses rather on higher education teachers' use of technology to initiate students' learning activities and on how students cognitively engage during these digital learning activities (Kirkwood, 2009; Sailer et al., 2021; Wekerle et al., 2020). Thereby, the interplay of teachers and students becomes important in the effective use of technology for teaching and learning in order to promote students' knowledge and skills. So far, there has been a lack of systematic research on higher education teachers' initiation of learning activities involving digital technology as well as a lack of systematic research on institutional and personal factors that might influence these digital learning activities. Sailer et al. (2021) have put forth the C♭-model, which can be used as a guideline for conducting more systematic research on both the initiation of digital learning activities and factors of influence in the higher education context. The C♭-model suggests students' learning outcomes as the central benchmark of higher education. It places students' digital learning activities at the center by assuming that they are directly and causally related to students' knowledge and skill acquisition. The C♭-model also systematizes contextual factors for students' digital learning activities, ranging from factors regarding students and teachers to factors regarding equipment and institutions. The C♭-model further specifies relations between these factors and digital learning activities in

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higher education.

The aim of this study is to address the lack of systematic research on digitally supported learning activities and the institutional and personal factors associated with their occurrence in higher education. First, using the C♭-model (Sailer et al., 2021), we aim to assess which types of digital learning activities higher education teachers initiate. Second, we aim to investigate variations in how individual higher education teachers initiate digital learning activities, and we propose that these can be found in distinct levels of teacher-initiated digital learning activities. Third, using the C♭-model (Sailer et al., 2021), we aim to assess how higher education teachers' sets of skills, as well as the institutional environments that higher education teachers work in, are associated with their initiation of digital learning activities. Fourth, we aim to investigate how different types of teaching settings (e.g., lectures vs. seminars vs. online courses) are related to the initiation of digital learning activities. All measures were self-assessed by higher education teachers. Data collection for this study took place in 2018 and therefore before the Covid-19 pandemic.

1.1. Initiated digital learning activities

When looking at digital teaching and learning in higher education, a focus on students' learning activities involving digital technologies is indicated because digital learning activities might be closest to the advancement of knowledge and skills (Sailer et al., 2021).

The C♭-model (Sailer et al., 2021) suggests that students' digital learning activities should be systematized on the basis of the ICAP (Interactive, Constructive, Active, and Passive learning activities) framework (Chi et al., 2018; Chi & Wylie, 2014).

The ICAP framework emphasizes and expands on the concept of active learning, meaning that students should "engage cognitively" (Chi & Wylie, 2014, p. 219). Wouters et al. (2008) have also pointed out the importance of students actively engaging in cognitive processes for effective learning from instructional methods. The European University Association (2019) explicitly calls for promoting active learning in the higher education context. To do so, teaching and learning approaches should be student-centered: students should be active designers of their learning processes, while higher education teachers should facilitate students' learning process (European University Association, 2019). In their meta-analysis, Freeman et al. (2014) indeed showed that active learning in higher education increases students' learning outcomes.

According to the ICAP framework, digital learning activities can be differentiated into four types: passive, active, constructive, and interactive, each of which is associated with different types of cognitive processes and different resulting learning outcomes (Chi, 2009; Chi & Wylie, 2014). The ICAP framework also assumes that students' overt behavior and students' products in each learning activity reflect students' underlying cognitive engagement (Chi et al., 2018). During passive digital learning activities, students do not actively interact with the learning material that is presented to them beyond focusing their attention on the information that is presented. Thus, students store information, which enables them to recall knowledge in highly similar situations or activities (Chi, 2009; Chi & Wylie, 2014). During active digital learning activities, students physically manipulate learning materials but without generating new information or contents themselves. Thereby, students' prior knowledge is activated and connected with new knowledge, which enables them to apply knowledge in similar situations (Chi, 2009; Chi & Wylie, 2014). During constructive digital learning activities, students individually develop their own ideas or contents that go beyond what is presented to them, or they solve problems by applying the presented material. In doing so, students infer new knowledge, which enables them to transfer it to new contexts (Chi et al., 2018; Chi & Wylie, 2014). Interactive digital learning activities foremost include constructive digital learning activities but *additionally* include interactions with other students in co-creating ideas or contents or in solving problems together. Similar to constructive digital learning activities, students infer new knowledge, which enables them to transfer their knowledge to new contexts, with the addition of co-inferring, which enables them to co-create new ideas and contents with others (Chi & Wylie, 2014).

Focusing on learning outcomes, the ICAP framework is based on the assumption that cognitive engagement becomes more sophisticated as it moves from passive to interactive digital learning activities. The framework suggests that increasingly better learning outcomes will result when students "move" from passive to active, from active to constructive, and from constructive to interactive activities (I > C > A > P) (Chi, 2009; Chi & Wylie, 2014; Menekse et al., 2013; Wekerle et al., 2020). In this study, we consider the perspective of the actual implementation of the four digital learning activities during teaching and learning: It seems to be an important task of higher education teachers to initiate and guide their students through these digital learning activities in courses, for which we use the term *initiated digital learning activities* in this study.

With respect to the initiation of digital learning activities, it seems plausible that higher education teachers would (a) initiate a mixture of digital learning activities during their teaching and (b) more often use passive than active activities, more often use active than constructive activities, and more often use constructive than interactive activities (P > A > C > I). There are several reasons for these assumptions.

First, all four types of students' digital learning activities are relevant for teaching and learning and are based on different learning goals that higher education teachers might have (Sailer, Schultz-Pernice et al., 2021; Sailer, Stadler et al., 2021). Passive and active digital learning activities might be adequate for fostering the acquisition and retention of declarative knowledge (Sailer et al., 2021), while constructive and interactive digital learning activities often seem to be required for fostering students' complex skills, such as problem solving (Sailer et al., 2021). Therefore, we can assume that higher education teachers are likely to initiate a mixture of all four different types of digital learning activities with regard to the different types of learning goals they try to achieve.

Second, passive digital learning activities might be initiated most often because they have benefits from an economic perspective as they are often easier to initiate than active, constructive, and interactive digital learning activities, and they require less time, resources, and skills to implement. Especially constructive and interactive digital learning activities require more time and effort as teachers have to guide and scaffold students during an individualized learning process and provide feedback that is more complex. This might lead higher education teachers to prioritize passive digital learning activities (see Marcelo-García et al., 2015; Schmid et al., 2017), especially if such activities are sufficient for helping students achieve the goal of acquiring declarative knowledge. It is also important to consider that the learning outcomes from constructive and interactive digital learning activities might not always be superior to the outcomes from passive digital learning activities as the quality of each digital learning activity is based on how the digital learning activity is actually initiated and how students engage in such activities (Stegmann, 2020).

Third, digital learning activities can co-occur during the teaching and learning process and might (partially) build upon one another. It seems reasonable to assume that higher education teachers do not initiate only one type of digital learning activity during a teaching session but that several of them can co-occur. For instance, if a higher education teacher initiates an interactive digital learning activity such as an online discussion during a teaching session, students may have watched a video beforehand or they may have taken notes during the online discussion and thereby engaged in a combination of different digital learning activities. Which digital learning activities can occur or not occur with one another might be based on how digital learning activities build upon one another. According to the ICAP framework, interactive digital learning activities build on constructive digital learning activities, and thus, an interactive digital learning activity cannot occur without a constructive digital learning activity. Constructive digital learning activities in turn build on active digital learning activities (Chi et al., 2018; Chi & Wylie, 2014). In conclusion, active digital learning activities might be prerequisites for constructive and interactive digital learning activities, and, thus, constructive and interactive digital learning activities might only occur when active digital learning activities are present. This idea is in line with results from studies that have assessed digital learning activities in higher education (Marcelo-García et al., 2015; Schmid et al., 2017; Wekerle et al., 2020).

On the basis of these considerations, our aim in this study was to go one step beyond making general statements about how often higher education teachers initiate digital learning activities. We assume that we can find different levels of teacher-initiated digital learning activities in higher education. We define *level of initiated digital learning activities* as a specific mixture of the four types of digital learning activities (i.e., passive, active, constructive, interactive) that higher education teachers can initiate. On the basis of our preceding argumentation, we suggest that there are four different levels of teacher-initiated digital learning activities: We propose that higher education teachers at Level 1, the lowest level, will mostly initiate passive digital learning activities; those at Level 2 will mostly initiate passive and active digital learning activities; those at Level 3 will mostly initiate passive, active, and constructive digital learning activities; and those at Level 4, the highest level, will initiate all four types of digital learning activities. Whereas these hypotheses suggest that there are different levels of teacher-initiated digital learning activities in higher education, we do not assume that these levels are fixed, but we rather assume that they vary with certain factors or in certain teaching settings. In the following, we describe potential factors from the areas of higher education teachers' skills along with institutional, organizational, and administrative factors that the C♭-model proposes (Sailer et al., 2021). Additionally, we look at types of teaching settings as potential factors of influence, including online courses, lectures, and seminars.

1.2. Higher education teachers' skills

According to the C♭-model, higher education teachers' knowledge and skills are related to teachers' use of technology in their courses and thus to their initiation of digital learning activities (Sailer et al., 2021). An attempt to systematize the knowledge that is needed to teach successfully with digital technology is the TPACK model (Mishra & Koehler, 2006). Whereas the original TPACK model focused on types of knowledge, more recent conceptualizations that build on TPACK research have moved to more comprehensive constructs (Petko, 2020). Such conceptualizations focus on what higher education teachers need *to be able to do* when teaching with digital technology and emphasize basic digital skills and technology-related teaching skills as relevant types of skills that teachers need to have (Sailer et al., 2021; Seufert et al., 2020).

1.2.1. Basic digital skills

Higher education teachers' *basic digital skills* are necessary preconditions for them to initiate a high level of digital learning activities in both online and offline settings (Krumsvik, 2011; Sailer, Schultz-Pernice, & Fischer, 2021). They include the ability to (a) generally use digital technology, (b) search for and process information with digital technology, (c) communicate and cooperate with others via digital technology, (d) produce and present their own content via digital technology, (e) learn with digital technology and develop learning strategies, and (f) acquire knowledge about technology and apply it (Digital Campus of Bavaria research group [DCB], 2017; Fraillon et al., 2014; KMK, 2017). Obviously, these skills are particularly relevant when teaching online (see Hodges et al., 2020).

On the one hand, a lack of basic digital skills has been identified as a barrier to using technology in courses, by teachers themselves (Chitiyo & Harmon, 2009) and by their students (Margaryan et al., 2011). On the other hand, higher education teachers' basic digital skills can be beneficial for their use of technology in courses, as higher education teachers' self-assessed level of basic digital skills in the use of computer technology was found to be positively related to their self-assessed comfort in using computer technology in their teaching (Jorgensen et al., 2018). These results suggest that teachers' basic digital skills are an important prerequisite for initiating digital learning activities at a high level. Whereas basic digital skills alone are not sufficient for successful teaching and learning online and offline (DCB, 2017; Mishra & Koehler, 2006), they seem to be required as a basis for teachers to initiate a high level of digital learning activities during the teaching process.

1.2.2. Technology-related teaching skills

Whereas basic digital skills provide the foundation for higher education teachers' technology use, in order to successfully initiate students' digital learning activities, technology-related teaching skills should be built on top of these basic digital skills (Krumsvik, 2011; Sailer et al., 2021; Seufert et al., 2020). Higher education teachers themselves find their technology-related teaching skills to be relevant for them to be more effective as teachers (Galanek & Gierdowski, 2019). However, they see a lack of these skills as a hindrance to their ability to teach with digital technology (Chitiyo & Harmon, 2009; Mercader & Gairín, 2020). Technology-related teaching skills have been conceptualized along different phases of the teaching process as a whole, which involves planning, implementing, and evaluating the use of digital technology in teaching (Ertmer & Ottenbreit-Leftwich, 2010; Sailer et al., 2021). They can also go beyond the teaching process itself, for example, through an additional *sharing* phase that emphasizes collaboration and exchange between teachers (DCB, 2017). In each of these phases, in order to use technology in a meaningful way, higher education teachers must have specific skills (DCB, 2017; Sailer et al., 2021).

Empirical findings indicate that specific teaching skills are necessary for effectively initiating digital learning activities (Chitiyo & Harmon, 2009; Galanek & Gierdowski, 2019; Mercader & Gairín, 2020). Especially for the initiation of more complex digital learning activities (i.e., constructive and interactive), advanced technology-related teaching skills are necessary (Sailer et al., 2021). For example, creating a computer-supported collaborative learning environment and supporting students as they engage in it requires higher education teachers to have the skills needed to design digital learning environments (planning), scaffold students' learning while they are engaged in the environment (implementing), evaluate data on the learning process to assess the efficiency of the environment (evaluating), and exchange ideas with colleagues and further (co-)develop the environment (sharing; DCB, 2017; Kaendler et al., 2015; Sailer et al., 2021; Wiedmann et al., 2019). Basic digital skills and a certain level of technology-related teaching skills might be sufficient for higher education teachers to initiate a passive digital learning activity such as conveying information via a powerpoint presentation. The initiation of more complex digital learning activities that go beyond passive digital learning activities, however, often requires more advanced technology-related teaching skills (Sailer et al., 2021).

In conclusion, we assume that more advanced technology-related teaching skills are an important prerequisite for initiating digital learning activities at a high level.

1.3. Institutional, organizational, and administrative factors

Besides higher education teachers' skills, on an organizational level, specific factors regarding the university and its administrative processes might play a supporting or hindering role for higher education teachers' initiation of a high level of digital learning activities. Based on the C♭-model, these factors include digitalization policy and commitment of the university administration, institutional infrastructure, and technical and educational support (Sailer et al., 2021).

1.3.1. Digitalization policy and commitment of the university administration

Universities, as at least partially autonomous institutions, might play an important role in providing guidelines for digital teaching and learning, as well as in shaping the conditions (e.g., the goals, learning environments) for digital teaching and learning in ways that might lead higher education teachers to initiate digital learning activities on a higher level (Orr et al., 2018; Schneckenberg, 2009). This can be achieved by a clear strategy for digital teaching and learning of the university that is supported by staff on all levels (Czerniewicz & Brown, 2009; Liu et al., 2020; Mercader & Gairín, 2020; Orr et al., 2018; Schneckenberg, 2009). Czerniewicz and Brown (2009) found that institutions with a structured institutional strategy reported more online courses, a higher frequency of technology use, better support for technology use, and the availability of more digital resources. Similarly, Hanson (2003) found that the university's strategy was an important factor for higher education teachers' technology use. Because universities are complex institutions, it also seems to be important that stakeholders on multiple levels, including the higher education teachers, are committed to some extent to the strategic approach to digital teaching and learning (Liu et al., 2020; Porter et al., 2014; Schneckenberg, 2009; Wannemacher, 2016).

In conclusion, and in accordance with the C♭-model, digitalization policies and the commitment of the university administration to digital teaching and learning might result in the initiation of digital learning activities at a higher level in individual university courses.

1.3.2. Institutional infrastructure

Institutional infrastructure for digital teaching and learning refers to access to an online learning management system, digital technology laboratories, software for teaching and learning, or WiFi at the university, both onsite and offsite (Sailer et al., 2021). On the one hand, the availability of institutional infrastructure, or a lack thereof, has been identified as an important factor for influencing higher education teachers' technology use (Jorgensen et al., 2018; Liu et al., 2020; Mercader & Gairín, 2020; Reid, 2014). On the other hand, the available digital infrastructure is effective for students and teachers if it is of high quality, up-to-date, and adequate for the needs of higher education teachers (Chitiyo & Harmon, 2009; Garrison & Vaughan, 2013; Liu et al., 2020; Margaryan et al., 2011; Mercader & Gairín, 2020; Porter et al., 2014).

With respect to the initiation of digital learning activities by higher education teachers, institutional infrastructure might be a crucial prerequisite. We assume that when teachers want to initiate high-level digital learning activities, a more stable and more sophisticated infrastructure might be required. As soon as not only higher education teachers but also the students are supposed to be actively engaging with devices (i.e., in active, constructive, and interactive digital learning activities), the demands on stability and equipment increase.

1.3.3. Technical and educational support

Based on the C♭-model, technical and educational support are factors that affect higher education teachers' use of technology in their courses (Sailer et al., 2021). Technical support means helping higher education teachers and students with hardware or software problems, whereas educational support refers to helping higher education teachers choose the right methods for using digital technology in the teaching process (Sailer et al., 2021). A support system has been identified as an important factor for either hindering or promoting higher education teachers' use of technology (Garrison & Vaughan, 2013; Lloyd et al., 2012; Mercader & Gairín, 2020; Porter et al., 2014; Reid, 2014). Galanek and Gierdowski (2019) found a positive relation between higher education teachers' satisfaction with technology-related support and their overall experience with technology. Additionally, they found a positive relation between the use of IT support and higher education teachers' overall satisfaction with technology experiences. Wannemacher (2016) found that higher education teachers considered support systems as one of the most important factors for digital teaching and learning.

With respect to the initiation of a high level of digital learning activities, higher education teachers, on the one hand, might be encouraged by the availability of technical support to try out more complex digital learning activities that they would not initiate if they were left alone with the implementation of it. On the other hand, educational support can suggest the implementation of a higher level of initiated digital learning activities or help to bring conceptual ideas into practice. Thus, we assume that both types of support enhance the level at which digital learning activities are initiated.

1.4. Teaching setting

Additionally, we assume that the teaching setting in which higher education teachers hold their courses might be relevant for the level of initiated digital learning activities. In this study, we focus on three common types of teaching settings, which are lectures, seminars, and online courses. Whereas lectures and seminars are traditional types of higher education teaching settings, online courses have become more popular in recent years (Zhu et al., 2018). These three types are different in several respects, which can promote or hinder the initiation of digital learning activities at higher levels. They can differ in the number of students in their courses as well as in the types of technology that are used and the ways in which higher education teachers can design their courses. Thus far, research has been inconclusive regarding the role that online courses play in supporting higher levels of initiated digital learning activities. Some see online courses as inferior to traditional teaching settings regarding the teaching methods that are used and have criticized that online courses are only an online version of offline teaching that focuses on more passive digital learning activities (e.g., showing videos, online lectures). However, others see potential in online courses as they might be beneficial for more complex digital learning activities (see Surma & Kirschner, 2020).

2. Research questions

First, with this study, we aim to assess the extent to which higher education teachers initiate digital learning activities and we aim to determine whether we can find different levels of teacher-initiated digital learning activities. Second, we aim to examine which institutional factors, personal factors, and teaching settings might be related to the level at which digital learning activities are initiated as well as how these factors might have different degrees of relevance for the level at which digital learning activities are initiated.

We investigate the following five research questions:

RQ1: How often do higher education teachers initiate different types of digital learning activities in their courses?

We hypothesize that higher education teachers will initiate passive digital learning activities more often than active digital learning activities, active more often than constructive, and constructive more often than interactive ($P > A > C > I$; H1).

RQ2: To what extent can we identify different levels of teacher-initiated digital learning activities in higher education?

We hypothesize that we will identify four levels of teacher-initiated digital learning activities in higher education. At Level 1, teachers initiate passive digital learning activities, at Level 2 teachers initiate passive and active digital learning activities, at Level 3 teachers initiating passive, active, and constructive digital learning activities, and at Level 4 teachers initiate all four types of digital learning activities (H2).

RQ3: To what extent are higher education teachers' self-assessed basic digital skills, teachers' self-assessed technology-related teaching skills, the university administration's digitalization policy and commitment, the university's technical and educational support, and institutional infrastructure related to the level at which digital learning activities are initiated?

On the basis of the C♭-model (Sailer et al., 2021), we hypothesize the following relations between factors and levels of initiated digital learning activities: First, higher education teachers' self-assessed basic digital skills will be positively related to the level at which digital learning activities are initiated (H3.1). Second, higher education teachers' self-assessed technology-related teaching skills will be positively related to the level at which digital learning activities are initiated (H3.2). Third, digitalization policy and commitment of the university administration will be positively related to the level at which digital learning activities are initiated (H3.3). Fourth, technical and educational support will be positively related to the level at which digital learning activities are initiated (H3.4). Fifth, institutional infrastructure will be positively related to the level at which digital learning activities are initiated (H3.5).

RQ4: To what extent are there differences in the relevance of the five factors (self-assessed basic digital skills, self-assessed technology-related teaching skills, digitalization policy and commitment of the university, technical and educational support, and institutional infrastructure) for the level at which digital learning activities are initiated?

We hypothesize that there will be differences in the relevance of the five factors for the level at which digital learning activities are initiated (H4).

RQ5: How is the type of teaching setting (i.e., lecture, seminar, online course) related to the level at which digital learning activities are initiated?

As the teaching settings typically differ with respect to numbers of students, types of technology used, and the ways in which higher education teachers can design their courses, we hypothesize that the settings will differ in their relevance for the level of teacher-initiated digital learning activities (H5).

3. Method

3.1. Sample

In the present study, we used a large sample of 1625 higher education teachers from the study by Sailer, Schultz-Pernice, Chernikova, Sailer, & Fischer (2018). Thus, our sample size appeared to be satisfactory for complex SEM analyses (Kline, 2005; Schumacker & Lomax, 2010,). In all, 514 (32%) of the higher education teachers were women and 1048 were men (64%), with 63 (4%) providing no information on their gender. On average, they were 44 years of age ($M = 43.51$; $SD = 11.57$; 17% did not provide information). The higher education teachers taught either at one of nine universities (60%) or at one of 16 universities of applied science (40%) in the federal state of Bavaria. Their mean duration of teaching at a university was 11 years ($M = 11.1$; $SD = 8.96$; 10% did not provide an answer), and they had used technology for an average of eight years in their teaching ($M = 8.28$; $SD = 6.32$; 11% did not provide an answer). We dealt with missing data through pair-wise deletion. As we did not use demographic variables and the above mentioned further variables for our statistical model analysis, the missing values were not problematic.

3.2. Procedure and instrument

We acquired participants through university mailing lists in most cases. Participants filled out a computer-based online survey that took an average of 30 min to fill out. The survey took place between April 16th and August 10th 2018 (and therefore before the Covid-19 pandemic). The survey included a total of 26 questions (including filter questions). For this study, we used a subset of questions that were relevant to our variables of interest. Regarding these questions, the survey began with questions related to higher education teachers' universities, including a question about the types of teaching settings the higher education teachers had taught courses in. It then continued with questions about the digitalization policy and commitment of the university administration, institutional infrastructure, and technical and educational support, followed by questions about initiated digital learning activities, higher education teachers' self-assessed technology-related teaching skills, and higher education teachers' self-assessed basic digital teaching skills. The survey ended with demographic questions. We conducted the online survey in collaboration with the market research institute GMS Dr. Jung GmbH.

3.3. Measures

The independent variables consisted of institutional, organizational, and administrative factors (e.g., digitalization policy and commitment of the university administration, institutional infrastructure, technical and educational support), higher education teachers' skills (e.g., self-assessed basic digital skills, self-assessed technology-related teaching skills), and teaching settings (e.g., lecture, seminar, online course). An overview of the independent variables including item examples and number of items for each variable is presented in Table 1. A comprehensive overview of the items used for each of the independent variables and descriptive statistics is presented in Appendix A. Further measures include initiated digital learning activities that will later form the dependent variable level of initiated digital learning activities.

3.3.1. Measurement of higher education teachers' skills

In accordance with suggestions made by DCB (2017), we measured the latent variable *self-assessed basic digital skills* with six self-estimation items. We used higher education teachers' private and professional use of digital technology as an indicator of their self-assessed basic digital skills. Higher education teachers had to answer how often they used technology professionally and privately for specific purposes, including searching, communicating, collaborating, producing content via technology, using technology for their own learning, and their general use of technology. We assessed the items on a 5-point rating scale ranging from 0 (*never*) to 5 (*very often*).

We measured the latent variable *self-assessed technology-related teaching skills* of higher education teachers by combining short scenarios for each type of digital learning scenario based on the ICAP framework and items covering technology-related knowledge and skills with respect to each of the four general phases of the teaching process (i.e., planning, implementing, evaluating, sharing; DCB, 2017; Sailer et al., 2021). We first presented higher education teachers a scenario for the respective ICAP phase. Each scenario included a sentence about the aim of using digital technology for the specific ICAP phase (e.g., for passive digital learning scenario: **"**Digital technology is used to present content"**)**, students' cognitive activity level in that phase (e.g., for passive digital learning scenario: **"**My students follow the presentation of content without doing anything visibly active"), as well as brief examples of how students overtly engage in digital learning activities (e.g., for passive digital learning scenario: "Students follow a digitally supported presentation, students watch recorded lesson contents.“). The specific contents of each digital learning scenario can be found in Appendix B.

Each scenario was then followed by 10 items for measuring the four phases of the teaching process - three items each for the phases planning and implementing (two assessing knowledge, one assessing skill), and two items each for the phases evaluating and sharing (one assessing knowledge, one assessing skill). Higher education teachers had to indicate on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*) how much a statement applied to them.

3.3.2. Measurement of institutional, organizational, and administrative factors

Institutional, organizational, and administrative factors included digitalization policy and commitment of the university administration, technical and educational support, institutional infrastructure, self-assessed basic digital skills, and self-assessed technology-related teaching skills.

Table 1
Overview of predictor variables.

Type	Predictor variable	Sample item	Number of items
Institutional, organizational, and administrative factors	Digitalization policy and commitment of the university	It is of great importance for the quality of teaching that the university has a strategy for digital teaching and learning.	4
	Technical and educational support	There is sufficient technical support at my university for teachers to conduct „ digital teaching and learning".	2
	Institutional infrastructure	There is sufficient equipment available at my university for „digital teaching and learning" (e.g., computer, software, internet access).	4
Higher education teachers' self-assessed skills	Self-assessed basic digital skills	I use digital technology to communicate with others.	6
	Self-assessed technology- related teaching skills		40
	Planning	I have technical knowledge that is useful for professionally planning such a teaching and learning situation [*combined with one of the four ICAP scenarios*].	12
	Implementing	I know didactical concepts, which are useful for professionally implementing such a teaching and learning situation [*combined with one of the four ICAP scenarios*].	12
	Evaluating	I am able to professionally evaluate the learning success and process in such a teaching and learning situation [*combined with one of the four ICAP scenarios*].	8
	Sharing	I am able to document and share such a teaching and learning situation, including its digital elements [*combined with one of the four ICAP scenarios*].	8
Teaching setting	Lecture	Did you teach courses during the last semester? Yes, one or more lectures.	1
	Seminar	Did you teach courses during the last semester? Yes, one or more seminars or tutorials.	1
	Online Course	Did you teach courses during the last semester? Yes, one or more online courses.	1

We measured *digitalization policy and commitment of the university administration* with four items. The first three items were part of one multiple-choice question that asked whether (a) the university, (b) the faculty, and/or (c) the chair had a coherent strategy for digital teaching and learning. The fourth item asked participants to rate whether "digital teaching and learning in courses is playing an important role in the external appearance of the university" on a 5-point rating scale ranging from 1 (*not at all true*) to 5 (*absolutely true*).

We measured *technical and educational* support with two items that were rated on a 5-point rating scale ranging from 1 (*not at all true*) to 5 (*absolutely true*). The first item asked whether enough technical support was available for higher education teachers to conduct digital teaching and learning, and the second item referred to educational support.

We measured *institutional infrastructure* with four items that asked about higher education teachers' satisfaction with equipment, internet access, internet speed, and types of accessible digital infrastructure at the university. Participants assessed the items regarding higher education teachers' satisfaction with equipment, internet access, and internet speed on a 5-point rating scale ranging from 1 (*not at all true*) to 5 (*absolutely true*). For types of digital infrastructure, we asked higher education teachers whether certain types of digital infrastructure were available at their university. We asked about five types of digital infrastructure in total, namely, learning management system (LMS), learning platforms (e.g., Moodle), software for teaching and learning offered to higher education teachers and students, access to online data bases, digital technology laboratories, and a media library. Multiple answers were possible. We then calculated the sum score for these five items so that the final variable *types of digital infrastructure* could range from 0, meaning no types of digital infrastructure were available, to 5, meaning all of the presented types of digital infrastructure were available.

3.3.3. Measurement of teaching setting variables

Furthermore, we included three variables regarding the kind of setting that higher education teachers held their courses in: *lecture*, *seminar*, and *online course*. Higher education teachers were asked whether they had taught any of the following types of courses during the last semester (winter term 2017–2018): (a) a lecture, (b) a seminar, or (c) an online course. Multiple answers were possible.

3.3.4. Measurement of initiated digital learning activities

We measured *initiated digital learning activities* with four brief scenarios for each phase of the ICAP framework, meaning passive, active, constructive, and interactive learning scenarios. These scenarios were also used to assess higher education teachers' self-assessed technology-related teaching skills. Each scenario included a sentence about the aim of using digital technology for the specific ICAP phase, cognitive activity level in that phase, as well as brief examples of how students overtly engage in digital learning activities (see section 3.3.1). The specific contents of each digital learning scenario can be found in Appendix B. Higher education teachers were then asked to indicate how often they applied digital technology in a way similar to the scenarios in (a) a typical lecture, (b) a typical seminar, and (c) a typical online course. These three options depended on the earlier question about teaching settings (see section 3.3.3). For this question, multiple answers were possible. For example, only if a higher education teacher had taught a lecture during the last semester were they asked how often they applied digital technology in a way that was similar to the scenarios in a typical lecture. Participants rated the frequency on a 5-point rating scale ranging from 0 (*never*) to 4 (*very often*). Thus, higher education teachers could answer a maximum of three items per ICAP scenario, making it a maximum of 12 items for assessing *initiated digital learning activities.* For further statistical assessment, we calculated the mean of all three types of teaching settings for each ICAP phase.

3.4. Statistical analysis

3.4.1. Descriptive statistics, t tests, and cluster analysis for initiated digital learning activities

We used R studio version 4.02. for our analyses. We dealt with missing data through pair-wise deletion. To address RQ1, we computed descriptive statistics for the four variables *initiated passive*, *active*, *constructive,* and *interactive digital learning activities* and further computed paired t tests to assess differences between each pairing of the four variables.

To address RQ2, we performed an exploratory cluster analysis (k-means clustering method, Euclidean distance) with the four variables *initiated passive*, *active*, *constructive,* and *interactive digital learning activities.* Cluster analysis is a multivariate type of data analysis that is aimed at grouping observations in homogenous clusters on the basis of how similar they are to one another. Observations in one cluster should then be more similar to one another than to observations in another cluster (Gore, 2000; Jain, 2010). In k-means clustering, the optimal number of clusters (k) has to be determined first before the observations can be assigned to the best-fit cluster (see Hastie et al., 2017; Jain, 2010). We conducted these two steps with the packages dplyr (version 1.0.2), purr (version 0.3.4), cluster (version 2.1.0), and ggplot2 (version 3.3.2) in R.

First, we applied the elbow method and the silhouette analysis to determine the optimal number of *k* clusters. Both methods estimate *k* empirically. For the elbow method, we calculated the total within-cluster sum of squares across multiple values of *k* (1-10), which were depicted in a curve. The point at which the curve began to flatten out indicated the optimal number of *k* (Boehmke & Greenwell, 2020). For the silhouette analysis, we calculated the average silhouette width across multiple values of *k* (1-10). The value of *k* with the highest average silhouette width indicated the optimal number for *k* (Rousseeuw, 1987). Second, we ran the k-means cluster analysis with the recommended optimal number of *k* in R studio, assigning the data to the best-fit cluster.

We further used the results from the cluster analysis in the statistical model analysis as one dependent ordinally scaled variable *level of initiated digital learning activities*.

3.4.2. Statistical model analysis of personal and institutional factors and teaching settings related to the level of initiated digital learning activities

We computed a statistical model analysis to determine the relations between the five latent variables and the dependent variable *level of initiated digital learning activities* (RQ3), as well as the three independent teaching setting variables and *level of initiated digital learning activities* (RQ5). We first evaluated the fit of the measurement models for the five latent variables through confirmatory factor analysis. Second, we evaluated how well the statistical model fit the data. We conducted the analyses of the measurement models and the statistical model in Mplus Version 7.11 (Muthén & Muthén, 2012) with weighted least squares means and variance adjusted (WLSMV) estimation for ordered categorical data as recommended by Finney and DiStefano (2006). To assess the fit of the measurement models and the statistical model, we used the Chi-Square goodness-of-fit statistic and additional fit indices that were available for WLSMV estimation in Mplus: the root mean square error of approximation (RMSEA) and the comparative fit index (CFI). Model fit was evaluated according to the following values, which indicate good model fit between the hypothesized model and observed data: Chi Square $p \geq .05$, CFI ≥ 0.95, RMSEA ≤ 0.06 (Hu & Bentler, 1999). If a model did not show a good fit according to the three fit indices described above, we performed a sequential specification search by examining the modification indices given by Mplus. A specification search involves modifying the initial model to improve its fit to the data and then assessing the fit of the new model (Schumacker & Lomax, 2010). After ensuring that the modification made sense theoretically, we added the parameters with the highest modification indices to the model one by one in order to examine the changes in the fit values after each addition. This process continued until model fit was observed.

Furthermore, we analyzed the correlations of the five latent variables to check for multicollinearity. To address RQ4, we compared the sizes of the correlations between each of the five latent variables and the *level of initiated digital learning activities* in Mplus. Similarly, to address RQ5, we compared the sizes of correlations between each teaching setting variable and the *level of initiated digital learning activities* in Mplus.

4. Results

4.1. Frequency of types of initiated digital learning activities

To address RQ1, we assessed how often higher education teachers initiated digital learning activities. Table 2 presents descriptive results for the four types of initiated digital learning activities (i.e., passive, active, constructive, interactive). The results showed that higher education teachers most often initiated passive digital learning activities ($M = 2.47$; $SD = 1.27$), followed by active ($M = 2.06$; $SD = 1.24$), constructive ($M = 1.06$; $SD = 1.17$), and interactive ($M = 0.89$; $SD = 1.09$) digital learning activities. Paired *t* tests showed that, on average, higher education teachers initiated passive digital learning activities significantly more often than active digital learning activities, $t(1464) = 11.174$; $p < .001$; $d = 0.327$; active digital learning activities significantly more often than constructive digital learning activities, $t(1447) = 27.317$; $p < .001$; $d = 0.830$; and finally, constructive digital learning activities more often than interactive digital learning activities, $t(1439) = 7.126$; $p < .001$; $d = 0.150$. These results showed a decreasing frequency in the initiation digital learning activities from passive, to active, to constructive, to interactive and thus showed support for H1.

4.2. Level of initiated digital learning activities

To address RQ2, we assessed to what extent we would find different levels of teacher-initiated digital learning activities. Both the elbow method and the silhouette analysis suggested that the best-fit-number of clusters was three, meaning that higher education teachers can best be grouped into three clusters with respect to the levels of digital learning activities they initiate. Table 3 shows the number of higher education teachers as well as the mean scores of initiated digital learning activities in each of the three clusters. Descriptive statistics for demographic variables (e.g., age, gender) and further variables (e.g., duration of teaching, duration of technology use during teaching) for the clusters can be found in Appendix C. There was no meaningful difference in these variables in the clusters. First, the results showed that the number of higher education teachers in each cluster was balanced. Cluster 1 contained the largest number of higher education teachers ($N = 483$), followed by Cluster 2 ($N = 477$), and Cluster 3 ($N = 437$). Higher education teachers in Cluster 1 initiated digital learning activities on a low level, as they mostly initiated passive digital learning activities ($M = 1.54$) but they rarely initiated active ($M = 0.92$), constructive ($M = 0.36$), or interactive ($M = 0.26$) digital learning activities. Higher education teachers in Cluster 1 initiated digital learning activities the least often out of the three clusters. Higher education teachers in Cluster 2 initiated digital learning activities at a moderate level. They mostly initiated passive ($M = 3.39$) and active digital learning activities ($M = 2.69$), but they rarely initiated constructive ($M = 0.58$) and interactive digital learning activities ($M = 0.39$). Higher education teachers in Cluster 2 initiated digital learning activities overall more than higher education teachers in Cluster 1. Higher education teachers in Cluster 3 initiated digital learning activities at a high level, as they initiated all four digital learning activities with a similar frequency. They initiated active digital learning activities the most ($M = 2.60$) followed by passive digital learning activities ($M = 2.48$), constructive digital learning activities ($M = 2.38$), and interactive learning ($M = 2.14$). Higher education teachers in Cluster 3 initiated digital learning activities the most out of the three clusters. These results can be taken to provide partial support for H1 as we found three levels of teacher-initiated digital learning activities instead of the hypothesized four.

We further used the three clusters as one dependent ordinally scaled variable called *level of initiated digital learning activities* in the statistical model. This variable can take on the values *low*, *moderate* and *high* level of initiated digital learning activities.

Table 2
Descriptive statistics (Minimum, Maximum, Mean, Standard Deviation and N) for the four types of initiated digital learning activities: passive, active, constructive and interactive.

	Min.	*Max.*	*M*	*SD*	*N*
Passive	0	4	2.47	1.27	1487
Active	0	4	2.06	1.24	1501
Constructive	0	4	1.06	1.17	1484
Interactive	0	4	.89	1.09	1449

Table 3
Descriptive results (N, Mean) from the cluster analysis for the four types of initiated digital learning activities: passive, active, constructive and interactive.

	Low level (Powerpointers)	Moderate Level (Clickerers)	High Level (Digital Pros)
N	483	477	437
Passive (M)	1.54	3.39	2.48
Active (M)	.92	2.69	2.60
Constructive (M)	.36	.58	2.38
Interactive (M)	.22	.36	2.14

*Note.*N is used to represent the sample size of higher education teachers in each cluster. M is used to represent the mean scores of the four types of initiated digital learning activities in each of the three clusters. Mean scores could range from 0-4.

4.3. Model analysis of personal and institutional factors and teaching settings related to level of initiated digital learning activities

4.3.1. Measurement models of personal and institutional factors related to level of initiated digital learning activities

To address RQ3 and RQ4, we assessed relations between higher education teachers' self-assessed basic digital skills, higher education teachers' self-assessed technology-related teaching skills, the university administration's digitalization policy and commitment, the institutional infrastructure, technical and educational support, and the level of initiated digital learning activities. To do so, as a first step, we assessed the fit of the five measurement models for *digitalization policy and commitment of the university administration* (four variables, all categorical), *technical and educational* support (two variables, all categorical), *institutional infrastructure* (four variables, three categorical), *self-assessed basic digital skills* (six variables, all categorical), and *self-assessed technology-related teaching skills*. The measurement model for self-assessed technology-related teaching skills was different from the other four measurement models, as we used a two-level measurement model. The latent variable self-assessed technology-related teaching skills was defined by the four latent variables depicting the phases of teaching: planning (10 items, all categorical), implementing (10 items, all categorical), sharing (eight items, all categorical), and evaluating (eight items, all categorical). Additionally, we controlled for the four ICAP phases, which were included in the measurement of self-assessed technology-related teaching skills, by building four ICAP factors (12 items each). The fit indices for each measurement model are shown in Table 4. Overall measurement models showed good model fit and were thus included in the next step of the analysis. For the measurement model for *institutional infrastructure,* post hoc modifications suggested covarying higher education teachers' satisfaction with equipment (ii1) and types of digital infrastructure (ii4). For the measurement model for *self-assessed technology-related teaching skills*, post hoc modifications suggested covarying the two phases planning and implementing. The measurement model for *self-assessed technology-related teaching skills* is shown in Fig. 1.

4.3.2. Statistical model of personal and institutional factors and teaching settings related to level of initiated digital learning activities

To address RQ3 and RQ4, in a second step, we included the final five measurement models for digitalization policy and the commitment of the university administration, institutional infrastructure, technical and education support, self-assessed basic digital skills, and self-assessed technology-related teaching skills as five latent, independent variables in the statistical model and allowed them to correlate. To address RQ5, we further included three types of teaching settings (i.e., lecture, seminar, and online course) as independent variables in the statistical model. The variable level of initiated digital learning activities was added to the statistical model as one ordinally scaled dependent variable.

In the first step, we assessed the correlations among the five latent variables to check for multicollinearity. The results showed positive, significant, medium to high correlations between all three latent institutional variables, indicating multicollinearity. The strongest relation was between institutional infrastructure and technical and educational support ($r = .799^{**}$), followed by the relation between digitalization policy and commitment of the university administration and technical and educational support ($r = 0.660^{**}$), and the relation between digitalization policy and institutional infrastructure ($r = 0.431^{**}$).

Table 4
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 the measurement models and the statistical model.

	χ^2	*df*	*p*	*CFI*	*RMSEA*
Measurement models					
Digitalization policy and commitment of the university administration	9.911	2	.01	.97	.05
Technical and educational support	<.001	0	<.001	1	<.001
Institutional infrastructure	9.911	2	.01	1	<.001
Self-assessed basic digital skills	358.387	9	<.001	.96	.16
Self-assessed technology-related teaching skills	4807.041	685	<.001	.99	.06
Statistical model	6906.644	1624	<.001	.99	.05

Note. Fit criteria for all measurement models and the statistical model were Chi-Square $p \geq .05$, CFI ≥ 0.95, RMSEA ≤ 0.06.

In the second step, we assessed the fit of the statistical model with correlations between the five latent independent variables, the three independent teaching setting variables, and the dependent variable level of initiated digital learning activities. The model showed a good fit, which is shown in Table 4. The minimum R^2 of our final model was 0.12, and the maximum was 0.34, meaning that 12%–34% of the variance in the level of initiated digital learning activities could be explained by the final model. The final statistical model with standardized correlations of the five latent independent variables, as well as the three types of teaching settings with the level of initiated digital learning activities is shown in Fig. 2. The measurement model for the latent independent variable self-assessed technology-related teaching skills is shown in Fig. 1.

To investigate RQ3, we looked at the correlations between each of the five latent variables (i.e., digitalization policy and commitment of the university administration, technical and educational support and institutional infrastructure, self-assessed basic digital skills, self-assessed technology-related teaching skills), with the level of initiated digital learning activities (see Fig. 2). Results showed that the five latent variables were all significantly positively related to the level of initiated digital learning activities, thus supporting H3. Digitalization policy and commitment of the university administration had the strongest relation to the level of initiated digital learning activities ($r = 0.342^{**}$). This relation was followed by the relations that self-assessed basic digital skills ($r = 0.281^{**}$), self-assessed technology-related teaching skills ($r = 0.231^{**}$), institutional infrastructure ($r = 0.169^{**}$), and technical and educational support ($r = 0.153^{**}$) showed with the level of initiated digital learning activities.

To address RQ4, we compared the correlations of the five latent variables with the level of initiated digital learning activities. The results supported H4, as we found differences in the relevance of the five latent variables for the level of initiated digital learning activities. Differences are shown in Table 5. As the strongest correlation, digitalization policy and the commitment of the university was significantly more strongly associated with the level of initiated digital learning activities than (a) the institutional infrastructure ($p < .05$) and (b) the technical and educational support ($p < .05$) were. However, it was not significantly more strongly associated with level of initiated digital learning activities than self-assessed basic digital skills ($p > .05$) and self-assessed technology-related teaching skills ($p > .05$) were. Self-assessed basic digital

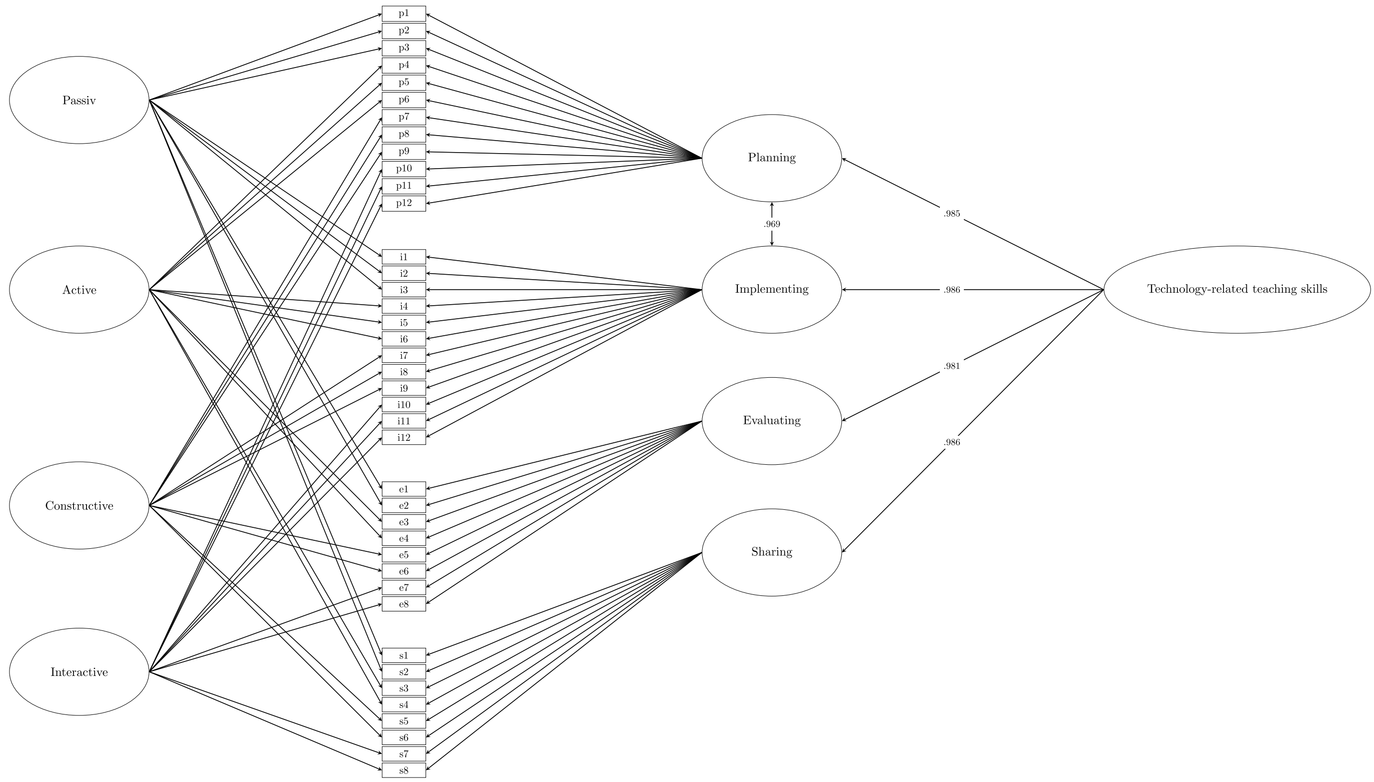

Fig. 1. Measurement model of technology-related teaching skills. *Note.* Circles represent latent variables and rectangles represent measured variables. Lines indicate significant relationships.

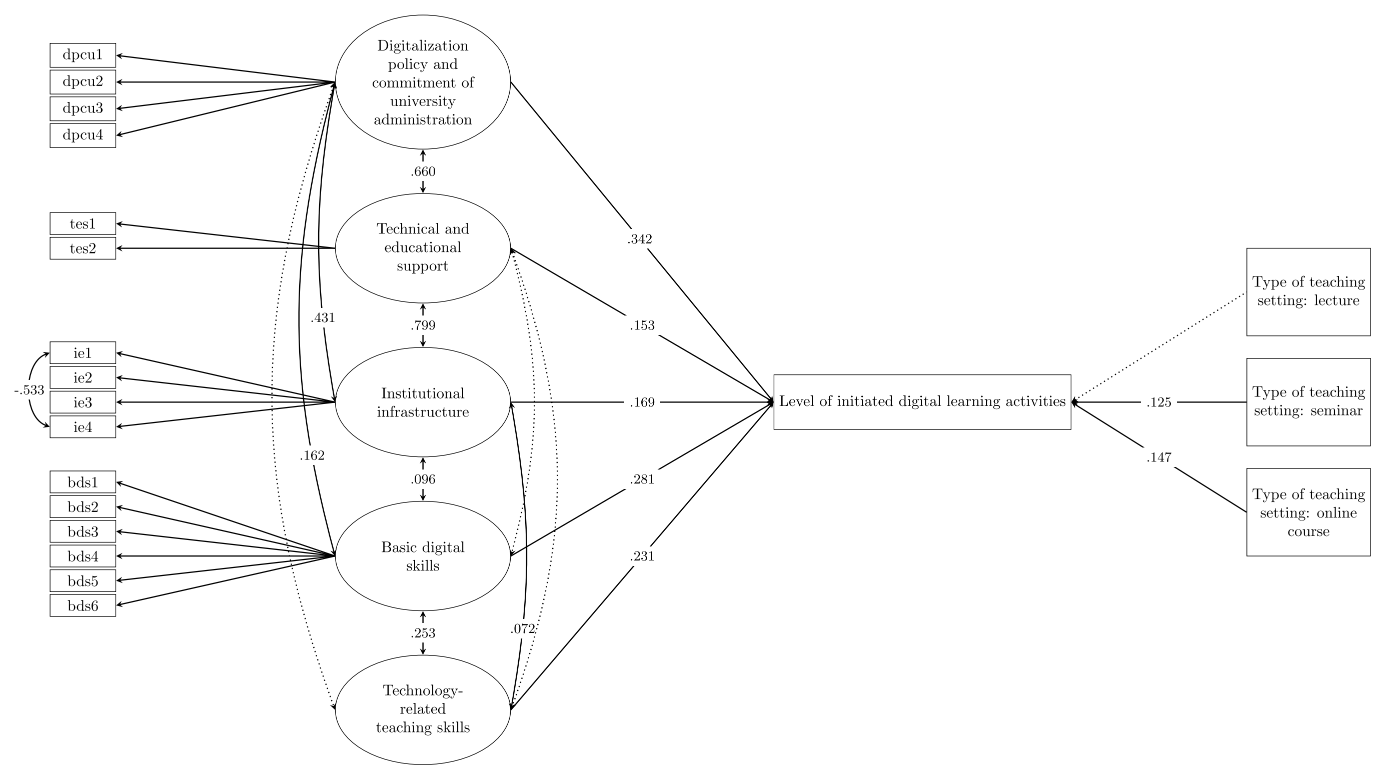

Fig. 2. Statistical model of level of initiated digital learning activities. *Note.* Circles represent latent variables and rectangles represent measured variables. Lines indicate significant relationships, and dotted lines indicate nonsignificant relationships.

Table 5
Comparison of relevance of variables digitalization policy and commitment of the university administration, institutional equipment, technical and educational support, self-assessed basic digital skills, self-assessed technology-related teaching skills, lecture, seminar, and online course for level of initiated digital learning activities.

Correlate Variable A with level of initiated digital learning activity	Correlate Variable B with level of initiated digital learning activity	Difference in relevance for level of initiated digital learning activity
Digitalization policy and commitment of the university administration	Self-assessed basic digital skills	No
	Self-assessed technology-related teaching skills	No
	Institutional Equipment	Yes
	Technical and educational support	Yes
Self-assessed basic digital skills	Self-assessed technology-related teaching skills	No
	Institutional Equipment	No
	Technical and educational support	Yes
Self-assessed technology-related teaching skills	Institutional Equipment	No
	Technical and educational support	No
Institutional Equipment	Technical and educational support	No
Online course	Seminar	No
	Lecture	Yes
Seminar	Lecture	Yes

Note. Yes means $p < .05$, which indicates that there is a difference in relevance between the two compared variables for level of initiated digital learning activity. No means $p > .05$, which indicates that there is difference in relevance.

skills as the second strongest correlation and self-assessed technology-related teaching skills as the third strongest correlation were not statistically different from each other in their associations with level of initiated digital learning activities ($p > .05$). Both of these correlations were not stronger than any of the others except that self-assessed basic digital skills was significantly more strongly correlated with the level of initiated digital learning activities than technical and educational support ($p < .05$). Institutional equipment and technical and educational support were not different from one another regarding their relevance for the level of initiated digital learning activities ($p > .05$).

To address RQ5, we looked at correlations between the three teaching setting variables lecture, seminar, and online course with the level of initiated digital learning activities and compared them with one another. Standardized correlations of the three types of teaching settings with the level of initiated digital learning activities are shown in Fig. 2. Differences are shown in Table 5. The results showed that both teaching an online course ($r = 0.147^{**}$) and teaching a seminar ($r = 0.125^{**}$) were significantly and positively related to the level of initiated digital learning activities, whereas teaching a lecture was not ($r = -0.024$).

Whereas both teaching an online course and teaching a seminar were significantly more strongly correlated with the level of initiated digital learning activities than teaching a lecture was ($p < .05$), they did not differ from one another in their relevance for level of initiated digital learning activities ($p > .05$). Therefore, these results supported H5, as we found differences in the relevance of teaching settings for the level of initiated digital learning activities.

5. Discussion

Higher education teachers reported that, on average, they initiated a mixture of digital learning activities rather than just one type of digital learning activity. However, this mixture was not balanced: Higher education teachers initiated passive digital learning activities more often than active digital learning activities, active more often than constructive, and constructive more often than interactive digital learning activities (P > A > C > I). These results support H1. Our finding that higher education teachers initiated passive digital learning activities most often is in line with results from several other studies (Marcelo-García et al., 2015; Schmid et al., 2017). The findings strengthen the position that higher education teachers use digital technology predominantly for passive and active digital learning activities and less often for constructive and interactive digital learning activities, in which digital technology could better fulfill the potential it has for teaching and learning (Tamim et al., 2011).

The results of our study regarding RQ2 suggest that we need to be more careful about making general statements about higher education teachers' use of digital technologies to initiate learning activities, as there seem to be different approaches to digitally supported teaching. With regard to teacher-initiated level of digital learning activities, we were able to identify three distinct levels, namely low, moderate, and high levels. These levels could be characterized as following: About one third of our sample initiated digital learning activities at a low level. They sometimes used digital technologies to initiate passive digital learning activities, which were most likely to be digitally supported presentations or video/audio presentations. Therefore, we suggest naming them *powerpointers*, as a powerpoint presentation is a prototypical way of teaching for this level.

We named higher education teachers in Cluster 2 *clickerers*. They initiated digital learning activities at a moderate level. The term clickerers alludes to higher education teachers implementation of audience-response systems that typically involve students' active learning activities (see Chien et al., 2016), which can be seen as a prototypical way of how teachers are using digital technology at this level. In this cluster, higher education teachers reported to frequently use digital technologies to support their teaching. However, they did so with a limited range of digital learning activities, namely, passive and active, indicating that they made use of films and audio presentations, as well as digital presentations similar to the powerpointers in Cluster 1. However, different from the powerpointers, the clickerers also made frequent use of technology to engage their students in active digital learning activities that could include activities such as answering closed factual knowledge questions in audience response systems, digital quizzes, or digital worksheets. In the third cluster, there was a more or less balanced distribution of digital learning activities that were initiated, and thus we suggest that these higher education teachers be called the *digital pros*. They initiated digital learning activities at a high level. They reported using technology to initiate or support students' problem solving, idea generation, and evaluative positioning, and they reported doing this for both individuals alone and in socially interactive settings. Thus, H2 received partial support as we hypothesized that we would find that teachers initiated digital learning activities at four levels. We did not find a level in which higher education teachers mostly initiated passive, active, and constructive digital learning activities. However, finding that teachers initiated digital learning activities at three levels instead of four still seems reasonable as constructive and interactive digital learning activities share certain characteristics. According to the ICAP framework, interactive digital learning activities are foremost constructive digital learning activities but additionally include the aspect of co-inferring knowledge with others and co-creating contents and ideas with others (Chi, 2009; Chi & Wylie, 2014).

Furthermore, the clusters point towards a possibility to further extend the C♭-model (Sailer et al., 2021). The digital learning activities that were initiated do not seem to be independent of each other, at least not from the higher education teachers' point of view. We found interesting patterns of co-occurrences that suggest that constructive and interactive digital learning activities hardly occur without passive and active digital learning activities also being initiated by the same higher education teacher. This patterns of co-occurrences were also present in several other studies (Marcelo-García et al., 2015; Schmid et al., 2017; Wekerle et al., 2020). We cannot infer possible sequences from these types of data, but it seems practically plausible that some passive and active digital learning activities precede constructive or interactive digital learning activities. By contrast, passive and active digital learning activities can easily occur without constructive or interactive digital learning activities. It is unclear whether or to what extent powerpointers advance to become clickerers or digital pros, as well as whether there are reversed sequences, or whether new clusters emerge with many more higher education teachers using digital technologies in their teaching every day. It is thus important to replicate this study to determine the stability of or possible changes in this typology.

The results also showed that the teaching settings (i.e., lecture, seminar, and online course) seemed to be associated with different levels of initiated digital learning activities, supporting H5. While the information that someone had taught a seminar or an online course was related to a higher level of initiated digital learning activities, the information that someone taught a lecture did not have a linear relation to the level at which learning activities were initiated. Whereas online courses might have the reputation as a format that lags behind face-to-face teaching, higher education teachers' teaching of an online course was positively correlated with the level of initiated digital learning activities. In addition, this correlation was not different to that of teaching face-to-face seminars. This finding indicates that online courses might indeed be a setting for the initiation of a high level of digital learning activities. It has to be mentioned though that there can, of course, be variability in the teaching settings, depending on how exactly a course is designed, and higher or lower success can come from lectures, seminars and online courses.

Further, all five factors that were derived from the C♭-model, which are self-assessed basic digital skills, self-assessed technology-related teaching skills, digitalization policy and commitment of the university administration, technical and educational support, and institutional infrastructure, were positively correlated with the level of initiated digital learning activities as indicated by the three clusters. Thus, they supported H3.1, H3.2, H3.3, H3.4, and H3.5. This means that when when a higher education teacher is a clickerer or even a digital pro instead of a powerpointer, their status is positively related to the level of teachers' self-assessed basic digital skills and self-assessed technology-related teaching skills and highly developed university policy and commitment, institutional infrastructure, and support structures. However, the reader should keep in mind that our data were correlational and not causal in nature and that the criterion, the level of initiated digital learning activities, was quite specific (although we are convinced that it is the proper criterion). The pattern of findings can further contribute to addressing the question of the relative importance of the different personal and institutional factors. This study contributes to this discussion, first, by setting theoretically meaningful criteria, namely, initiated digital learning activities. Second, the pattern of results supports the claim that all of the personal and institutional factors in the underlying C♭-model are important for the level of initiated digital learning activities. Third, the results can help in evaluating the relative relevance of the personal and institutional factors. Results supported H4, as they showed differences in the relative relevance of personal and institutional factors. In our sample, the university's strategy was the most relevant institutional factor for a high level of initiated digital learning activities. However, looking at personal factors, both higher education teachers' self-assessed basic digital skills and self-assessed technology-related teaching skills were as relevant as the strategy of higher education institutions for a high level of initiated digital learning activities. While these results point towards the important role of the university's strategy and higher education teachers' skills for a more variable employment and a broader scope of digital learning activities – technical and educational support and a good institutional infrastructure are important as well for a high level of initiated digital learning activities. Digital teaching and learning will simply not work without accessible and fast WiFi, learning management systems and software for teaching and learning.

Overall, our statistical model explained a substantial amount of variance in levels of initiated digital learning activities. Different types of teaching settings, especially online courses and seminars can contribute to explaining variance, probably because they are associated with different conditions for teaching. Further, findings can be taken to support the validity of important relations hypothesized in the C♭-model (Sailer et al., 2021). However, there might be other possibly important factors missing in our statistical model, which could help to explain more variance. Some of this factors are already included in the C♭-model, such as students' knowledge, skills and attitudes as well as higher education teachers' and students' digital technology equipment (Sailer et al., 2021). Beyond factors included in the C♭-model, higher education teachers' general knowledge and expertise in teaching might also be additional factors that could help explain more variance.

5.1. Limitations and further research

The results from our study have some limitations that should be taken into consideration when interpreting the results and drawing conclusions. First, we conducted our study with higher education teachers situated in the context of German higher education. Thus, our results can probably not be fully generalized to other countries and their respective educational systems without further investigations. Second, after assessing model fit based on correlations, we were not able to carry out regression analyses as a further step, as our statistical model did not converge. This was due to high correlations between the three latent variables pertaining to institutional, organizational, and administrative factors, suggesting multicollinearity. Multicollinearity occurs when there is linear dependency between two or more predictors. However, parts of these dependencies are even suggested by the C♭-model, making correlation analyses the better choice. Further research could conduct experimental studies (e.g., field experiments) to causally test some of the relationships between personal and institutional factors and levels of initiated digital learning activities. Third, the study focused on the view of higher education teachers. It would have been interesting to additionally include students' data for comparison. This would be particularly interesting for measuring digital learning activities as there might be differences between the type of digital learning activity a higher education teacher intended to initiate and students' actual engagement in these learning activities (Chi & Wylie, 2014; Kirkwood, 2009). It would also be interesting to look into research on teacher identity (see Beauchamp & Thomas, 2009; van Lankveld et al., 2017) to further investigate teachers' intentions behind initiating a digital learning activity.

Fourth, our categorization of teaching settings (i.e. lecture, seminar, online course), was relatively broad and did not allow us to depict specific variations of the different teaching settings (such as asynchronous/synchronous learning approaches, blended learning approaches). However, we did measure more detailed aspects of the teaching settings (such as collaborative student learning) through assessing the four different types of initiated digital learning activities with the ICAP scenarios (see section 3.3.4). For instance, we measured collaborative learning through measuring interactive digital learning activities (of which collaborative student work is one of the main characteristics). Further research could explore how specific characteristics and conditions associated with the teaching settings, such as asynchronous/

synchronous learning, blended learning approaches or number of students, might benefit higher levels of initiated digital learning activities.

Fifth, our results were based on the self-reports of higher education teachers. One of the main advantages of using a self-report instrument was that we could administer it to a large sample (Demetriou et al., 2015), which is needed for complex statistical model analysis (Schumacker & Lomax, 2010). However, futures studies should try to collect objective data where possible, especially for higher education teachers' knowledge and skills. Sixth, based on our result that higher education teachers can be clustered into three levels on the basis of the digital learning activities they initiate, further research should test whether these three levels can be replicated across different countries and between different educational systems (e.g., schools) and time. Although the level of initiated digital learning activities can possibly be constant between different courses of a single higher education teacher, the levels are not meant to be stable teaching styles. They might vary depending on different teaching settings and different surrounding conditions, among them the Covid-19 pandemic, which broke out over a year after data collection. Besides the general need for replication of these different levels across different contexts, it has to be explored by further research to what extent the Covid-19 pandemic had an influence on the relations found in our data or if the pandemic has contributed to a shift (short-term and long-term) in the level of initiated digital learning activities. The Covid-19 pandemic has led to an abrupt change in digital teaching and learning in higher education, as higher education teachers quickly had to change from face-to face teaching to almost exclusively teaching courses online. One the one hand, the resulting sudden need for higher education teachers to deal with and rely heavily on digital technology to conduct their courses online might have reduced the number of powerpointers as online courses relate to higher levels of initiated learning activities (compared to lectures). On the other hand, as Hodges et al. (2020) point out, online teaching during the Covid-19 as an "emergency remote teaching" (p. 2) has little in common with the carefully planned and developed online courses, which took place before the Covid-19 pandemic. The sudden change, not enough time to prepare and overburdened support systems (Hodges et al., 2020), might have rather lead to higher education teachers initiating digital learning activities on the same level they did before.

Further, these results could be used as foundation of a progression model for higher education teachers during their practical teaching, moving from a powerpointer up to a clickerer or even digital pro. It would then be interesting to investigate how this progression could be facilitated. For instance, as our results showed that teachers' skills are relevant for becoming a digital pro, universities could invest in further education and training as means to foster teachers' progression.

5.2. Conclusions

In our study, we found three levels of teacher-initiated digital learning activities that occur in courses of higher education teachers, namely a low level (powerpointers), a moderate level (clickerers), and a high level (digital pros) of initiated digital learning activities. In addition, our study provided empirical evidence for the relevance of the contextual factors for teacher-initiated digital learning activities postulated by the C♭-model (Sailer et al., 2021). The investigated factors *digitalization policy and commitment of the university administration, institutional equipment, technical and educational* support*, self-assessed basic digital skills,* and *self-assessed technology-related teaching skills* explained a substantial amount of variance in teacher-initiated digital learning activities and can be seen as relevant parameters of digital teaching and learning in higher education. If we interpret the levels of initiated digital learning activities as context-dependent, changeable, and fluent, the factors from the C♭-model could help facilitate higher education teachers' progression towards using a broader scope of different digital learning activities. This might help to address a variety of learning goals and to facilitate learning activities that are theoretically associated with cognitive processes facilitating the transfer of knowledge.

Further, the results of our study can help to formulate hypotheses about the relative importance of the different factors proposed by the C♭-model and thus guide the practice of higher education to succeed in providing digital teaching and learning. A comprehensive approach to organizational development (as proposed by the C♭ model) addressing digitalization strategy, qualification of higher education teachers, as well as necessary equipment, infrastructure, and support is more likely to be accompanied with a broader variety of digital learning activities and the more frequent initiation of digital learning activities associated with the transfer of knowledge and skills (Chi and Wylie, 2014) than isolated measures that focus on technical equipment and teachers' skills alone.

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Declaration of competing interest

We have no conflicts of interest to disclose.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chb.2021.106715.

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