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Contextual facilitators for learning activities involving technology in higher education: The C♭-model

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ABSTRACT

We propose a model of *contextual facilitators for learning activities involving technology* (in short: C♭-model) for both on-site and distance learning environments in higher education. The C♭-model aims at systematizing research on digital teaching and learning and offers a roadmap for future research to understand the complex dynamic of factors that lead to successful digital teaching and learning in higher education via suitable learning activities. First, we introduce students' learning outcomes as central benchmarks of teaching and learning with digital technologies in higher education. Second, we want to focus on a major proximal factor for students' learning outcomes and thus apply a learning activities perspective. Learning activities involving digital technologies reflect cognitive processes of students when using digital technologies and are causally connected with students' learning outcomes. Third, we highlight several contextual facilitators for learning activities involving technology in the C♭-model: learning opportunities that result from higher education teachers' instructional use of technology and students' self-arranged learning opportunities involving digital technologies. Apart from these proximal facilitators, we include more distal factors, namely, higher education teachers' knowledge, skills, and attitudes toward digital technology; higher education teachers' qualification; students' and teachers' digital technology equipment; and institutional, organizational, and administrative factors.

1. Introduction

Teaching and learning with digital technologies has changed education in general and specifically higher education in many ways. Digital technologies can promote new ways of learning and can effectively contribute to the successful acquisition of knowledge and skills, especially those needed in today's world (Hamilton et al., 2016; Puentedura, 2006). Digital technologies offer opportunities to support and enhance on-site learning (e.g., by visually representing complex procedures with digital presentations or by using audience response systems; Chien et al., 2016; Hunsu et al., 2016) and they allow for technology-enhanced distance learning (e.g., Surma & Kirschner, 2020). Whereas approaches such as blended learning and inverted classrooms (Låg & Sæle, 2019; Owston, 2013; Strelan et al., 2020) combine on-site and distance learning, other approaches focus on distance learning settings such as massive open online courses (MOOCs; Zhu et al., 2018). The use of digital technology for teaching and learning has been discussed for decades (see Tamim et al., 2011), but it has moved into the focus of broader public and political attention due to the COVID-19 pandemic (Seufert et al., 2021). During the COVID-19 pandemic, a temporary shift to distance teaching and learning occurred. This led to teaching formats such as emergency remote teaching (Hodges et al., 2020) or modifications of existing concepts such as online inverted classrooms (Tolks et al., 2020). Under these circumstances, with the COVID-19 pandemic entering the stage, institutions of higher education have faced a stress test with respect to their readiness for teaching and learning with digital technology: Higher education teachers need to successfully plan and implement digital teaching; students need to successfully make use of digital learning opportunities; and both teachers and students need an infrastructural, institutional, and organizational environment that is conducive to digital teaching and learning (see Liu et al., 2020).

In this article, we propose a model which is intended to help systematically capturing an overall picture of teaching and learning with digital technology in higher education and address the complex dynamic of factors that influence successful student learning. To this purpose, we want to apply a truly educational perspective by focusing on student learning activities with digital technologies. These learning activities are conceptualized as being causally connected to student learning (Chi &

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Wylie, 2014). We propose a model of *contextual facilitators for learning activities involving technology*. This model helps to systematize existing research and to plan for new research on the proximal and distal factors (Seidel & Shavelson, 2007) that influence students' learning activities in digitally supported learning environments. We focus on factors which are related to digital technologies and which can be influenced by the main stakeholders of higher education (i.e., students, higher education teachers, and administration). The resulting model can be seen as a roadmap for future research on teaching and learning in higher education and it can also be useful in (organizational) change processes with respect to the professional development of higher education teachers, curriculum development, as well as the design and evaluation of digitalization strategies for institutions of higher education.

2. A learning activities perspective on teaching and learning with digital technology

Several frameworks and models of digital teaching and learning in (higher) education have been developed which strive to explain the relevant conditions of success for higher education in a digital world. Before introducing our suggested learning activities perspective on teaching and learning with digital technology, we will have a look at existing models in K-12 education and higher education.

There have been attempts to create models of digital technology integration in the school context, such as the *will skill tool* model (Knezek et al., 2003). This model postulates that teachers' attitudes, teachers' skills, and the available infrastructure will influence digital technology classroom integration. Petko (2012) suggested an update to the model to account for teachers' constructivist beliefs. Knezek and Christensen (2016) built upon this idea and included teaching styles in their model to predict technology integration. The resulting model explains a substantial amount of variance in technology integration (Knezek & Christensen, 2016). However, although the model includes students' achievement as an outcome of technology integration, it does not strive to elaborate on the mechanisms through which technology integration might result in student achievement. In addition, the model focuses on home and classroom access to technology as an important institutional factor and places less emphasis on other institutional and organizational factors of influence such as institutional strategies and support structures for technology integration.

In the context of higher education, Liu et al. (2020) identified factors that are related to the adaption of learning technologies via a systematic review. Liu et al. (2020) applied a meta-narrative approach (see Greenhalgh et al., 2004) in their review of 131 articles. Based on their review the authors derived a conceptual framework which focusses on the adoption of learning technologies by higher education teachers. The framework consists of the main themes *learning technology*, *academic staff*, *context,* and *influencing adaption*. In the framework, *learning technology*, *academic staff*, and *context* are reciprocally connected. *Influencing adaption*, which incorporates different kinds of institutional strategies, affects the other three factors (Liu et al., 2020). However, whereas the framework is more comprehensive with regard to institutional and organizational factors, it does not cover students' achievement as the main outcome of higher education from an educational perspective.

In a systematic review of 619 articles, Martin et al. (2020) analyzed different themes that have been investigated in research about online teaching and learning. The review mostly builds on research from higher education. The authors assign the different themes to different levels of a framework that includes three levels: the *learner level*, the *course and instructor level*, and the *organizational level*. The learner level is nested in the course and instructor level. The course and instructor level is nested in the organizational level, emphasizing the interrelations between each level. The different levels include several sublevels such as learners' engagement and characteristics (learner level), course technologies and facilitation (course and instructor level), and institutional support (organizational level; Martin et al., 2020). However, the model does not explicitly address the specificity of interrelations between different levels and sublevels and does not account for learning that can take place outside the organized courses and lectures. Further, the framework does not include information about the mechanisms through which students' learning is or can be effectively fostered in online learning.

This brief overview shows that there have been efforts to develop frameworks to conceptualize teaching and learning with digital technology in both higher education and K-12 education (Knezek & Christensen, 2016; Liu et al., 2020; Martin et al., 2020). However, more comprehensive models on teaching and learning with digital technology that include proximal as well as distal factors are lacking. Especially proximal factors to student learning outcomes (e.g., the learning activities students engage in) have not been explicitly included in existing models. We argue that the integration of proximal and distal factors can help to better explain the relationships between technology integration and learning outcomes as well as to specify the roles that different factors play in the successful integration of digital technology in higher education. Our model includes an integrative framework for various lines of research, such as (1) cognitive research on learning processes enabled through or supported by digital technologies (Chi & Wylie, 2014; Vogel et al., 2017); (2) research on skills and attitudes for using digital technologies in schools and higher education (Fraillon et al., 2019; Lachner et al., 2019; OECD, 2012; Sailer et al., 2017; 2018; Vuorikari et al., 2016); (3) research on organizational development directed toward digital innovation (Gräsel et al., 2020; Owston, 2013); and (4) tool-centered research that builds on cognitive perspectives and focuses on the effects of a specific tool or technology-enhanced scenario (Chernikova et al., 2020; Låg & Sæle, 2019).

Thus, we offer a starting point to integrate these lines of research and incorporate teachers' and students' perspectives and central factors that empirical research has identified as factors that facilitate or hinder successful digital teaching and learning. By doing so, we aim to broaden the focus on teachers' use of technology in their teaching to include the ways in which students engage with it. And this is reflected by their visible learning activities when they are engaged with digital technology. Thus, we take into account the types of learning activities that are afforded to students by digital learning opportunities (Chi & Wylie, 2014). These types of learning activities are central to the model as they differ in the strength of their relationships with students' different learning outcomes (e.g., knowledge retention or skill development). Therefore, the proposed model comprises *contextual facilitators for learning activities involving technology*, which can be abbreviated with "CFLAT". C-flat is a musical note that is written as "C♭". We refer to the model as the C♭-model because the allusion to music takes up the idea of successful learning and instruction as an orchestration and arrangement of learning activities (see Kollar & Fischer, 2013). The C♭-model is depicted in Fig. 1.

In the following sections, we introduce the components of the C♭-model and discuss empirical research on the different aspects. As we focus on successful student learning with digital technologies in the C♭-model, we will start our illustration with students' knowledge, skills, and attitudes as desired learning outcomes of higher education (see Section 2.1). After that, the components will be illustrated in decreasing proximity to these desired student learning outcomes. The most proximal factor to students' knowledge, skills, and attitudes in the C♭-model are students' learning activities involving digital technology (see Section 2.2). These take the center stage in the in the C♭-model. Potential contextual facilitators for these students' learning activities involving digital technologies are higher education teachers' technology use and particularly the learning opportunities teachers provide for their students (see Section 2.3). However, student learning activities will frequently result from learning opportunities that the students find or create for themselves (see Section 2.4). The use of digital technology by teachers in higher education might be influenced by their knowledge, skills, and attitudes (see Section 2.5); by the qualification they have

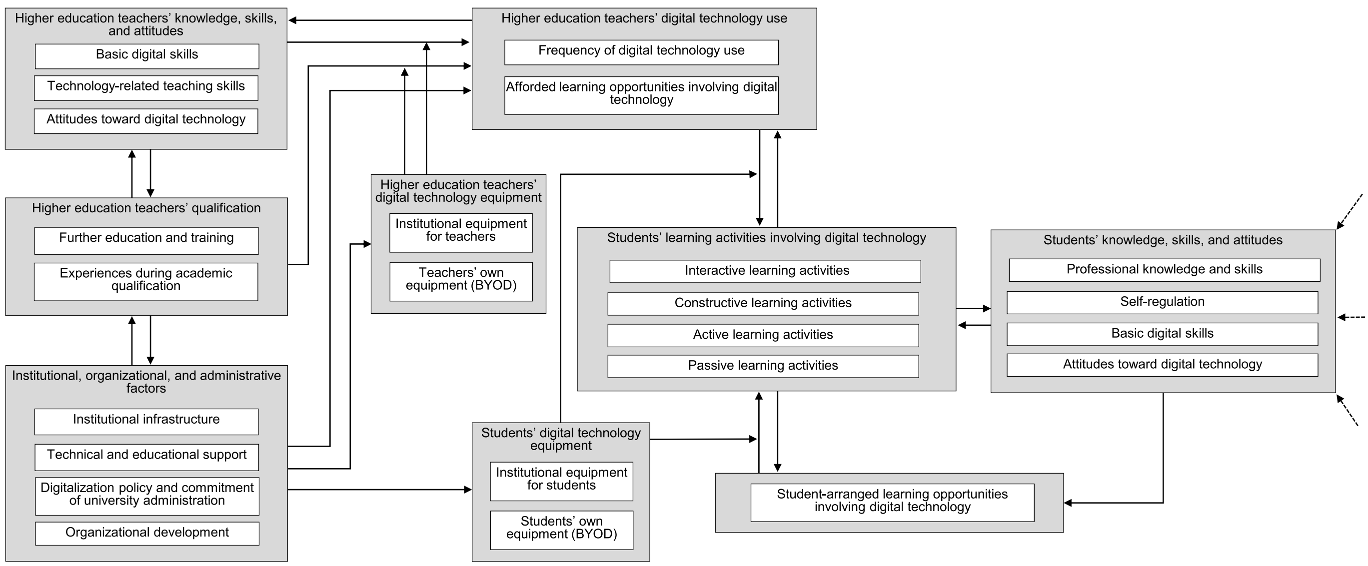

Fig. 1. The C♭-model for both on-site and distance learning environments in higher education. The arrows roughly indicate assumed influences and their direction. Students' learning activities involving digital technology are central in the model and have reciprocal relationships with students' knowledge, skills, and attitudes; student-arranged learning opportunities involving digital technology; and higher education teachers' digital technology use. The latter is influenced by higher education teachers' knowledge, skills, and attitudes; higher education teachers' qualification regarding teaching and learning with digital technologies; and institutional, organizational, and administrative factors relating to teaching and learning with digital technologies. Students' and higher education teachers' digital technology equipment are assumed to be moderators in the model.

received (see Section 2.6); and by institutional, organizational, and administrative factors (see Section 2.8). The digital technology equipment that students and higher education teachers use is a necessary but not sufficient factor for successful teaching and learning with digital technologies and is thus assumed to play a moderating role in students' learning activities and teachers' technology use (see Section 2.7).

2.1. Students' knowledge, skills, and attitudes as prerequisites for and outcomes of learning with digital technology

A major rationale for including technologies in higher education teaching has been to facilitate the understanding of domain-specific concepts (e.g. Höffler & Leutner, 2007; Merchant et al., 2014) and the advancement of domain-specific or cross-domain professional skills (e.g. Chernikova et al., 2020; Cook et al., 2011). Furthermore, the success of higher education studies as well as later continuing education systematically depends on the capacities of an individual for self-regulation (e.g. Schneider & Preckel, 2017). Self-regulation is crucial when reading extensive bodies of literature to prepare for exams or when participating in asynchronous online courses (Broadbent & Poon, 2015).

Partially driven by national agendas for digital transformation, an additional focus with respect to the outcomes of higher education has emerged: the advancement of students' digital competences (e.g. Bond et al., 2018). Concepts of digital competences typically include basic knowledge and skills, or digital literacy, but also students' attitudes towards digital technology, as there is evidence for the positive relationship of students' attitudes with the use of technologies for learning (e.g. Al-Emran et al., 2016; Farjon et al., 2019).

The C♭-model hence includes professional knowledge and skills (Section 2.1.1), self-regulation (Section 2.1.2), basic digital skills (Section 2.1.3), and attitudes toward digital technology (Section 2.1.4). With professional knowledge and skills, higher education prepares students for tasks (e.g., reasoning, problem-solving, creating, decision-making) in selected fields on the basis of domain-specific theories, concepts, and methods of academic disciplines. With respect to basic digital skills and self-regulation, higher education is supposed to deepen and enhance students' general education. We suggest these three broad sets of knowledge and skills as a heuristic, cross-domain categorization. However, we are aware of the extensive discourse on what important learning outcomes in higher education are, how they are or should be measured, and how they need to be conceptualized differently across disciplines, institutions, or countries (see Michelsen et al., 2017).

2.1.1. Students' professional knowledge and skills

Higher education is aimed at supporting the advancement of the knowledge and skills that are instrumental for performing effectively on certain types of problems in professional fields. Professional knowledge and skills include (a) conceptual and methodological knowledge and (b) skills for a specific subject matter (Förtsch et al., 2018). Nowadays, these will inevitably also include the knowledge and skills that are related to subject-specific aspects of digital technologies (e.g., on digital humanities, e.g., Gold, 2012). The advancement of these subject-specific professional skills is clearly a core goal of many programs of study in higher education.

2.1.2. Self-regulation of students

We propose a broad interactionist perspective on self-regulation (Prinz, 2012). We suggest that self-regulation entails skills that enable students to develop and pursue goals, make decisions, act and reflect individually and together with others, and participate in social and political deliberation in accordance with values and in a manner that is responsive to environmental constraints and affordances. In higher education, incoming students have typically already developed the basic capacity for self-regulation with respect to their executive functions (inhibition, cognitive flexibility, working memory; Diamond & Lee, 2011) and their self-regulation skills (Robson et al., 2020). Building on this basic capacity for self-regulation, there are more advanced strategies for learning and social interaction (e.g., academic help-seeking; Aleven et al., 2003) that enable individuals to advance their education in directions that are not determined solely by the teachers and course content in a specific educational context (Bransford & Schwartz, 1999).

2.1.3. Students' basic digital skills

Basic digital skills are skills that enable the use of computer software for writing, calculating, and finding information on the Internet, for producing textual and audio-visual digital media (e.g., tutorial videos), as well as for communicating and collaborating with others online (Carretero et al., 2017; Fraillon et al., 2014). In addition, some frameworks expand the scope of what is considered as basic digital skills under the label of 21st Century digital skills (e.g., van Laar et al., 2017) by further including, for example, the use of digital technologies to protect oneself and others from the potential hazards that come with digital technologies, or to engage in critical thinking about technology (Digital Campus of Bavaria research group, 2017). Critical thinking may include the evaluation of the credibility of sources and the ability to reflect on the possible functions and impacts of digital technologies (Sailer et al., 2021). Educational policies typically position primary and secondary schools and their teachers as those responsible for teaching these capacities to students (e.g., Caena & Redecker, 2019). However, research has clearly shown that we are currently far from a homogeneous level of education with respect to basic digital skills in K-12 (Fraillon et al., 2019), and it seems likely that many students at the threshold of entering higher education are starting off with low levels of these basic digital skills.

2.1.4. Students' attitudes toward digital technology

Further, we suggest including attitudes toward digital technology as being a main driver for engaging in learning activities involving digital technology (Al-Emran et al., 2016; Farjon et al., 2019). Generally, attitudes are defined as negatively to positively valenced evaluations of a topic, person, or event (Heddy et al., 2017). Specifically, attitudes toward digital technology refer to negatively to positively valenced evaluations of the use of digital technology. Attitudes toward digital technology are important for determining whether or not students will engage in learning with digital technologies; it seems likely that the use of technology during higher education for learning can affect attitudes toward digital technology in a positive way (Al-Emran et al., 2016; Teo et al., 2008).

In the C♭-model, this ensemble of students' knowledge, skills, and attitudes introduced in Section 2.1.1, 2.1.2, 2.1.3, and 2.1.4 plays two essential roles in higher education. First, these sets of knowledge and skills are considered main outcomes of higher education. Students are expected to learn and are assessed with respect to the degree to which they have successfully learned these skills during their university studies. Higher education institutions can be evaluated against their success in facilitating their students' learning of these sets of knowledge and skills. Second, this ensemble of students' knowledge, skills, and attitudes is likely to be a crucial prerequisite for successful learning in digital environments: The capacity of learners to effectively make use of digital technologies to engage in different kinds of learning activities in a certain subject crucially depends on what they have already learned and what they are able to employ to enhance new learning (i.e. their prior knowledge; Bransford & Schwartz, 1999). In addition, learning critically depends on learners' self-regulation, that is, whether they are able to pursue learning goals over a period of several weeks, whether they are able to discuss open questions with peers, or whether they can find academic support in other ways if necessary. Eventually, successful participation in education is considered to crucially depend on learners' basic digital skills in retrieving information from the Internet, communicating, collaborating, and solving problems, and using (or not using) specific technologies for their own learning (Digital Campus of Bavaria research group, 2017; van Laar et al., 2017). In Fig. 1, this double functions of students' knowledge, skills, and attitudes as outcomes of the successful engagement in learning activities and, at the same time, as prerequisites to engage in such learning activities are represented by the arrows leading *to* them from students' learning activities and the arrow leading *from* them *to* students' learning activities. The additional arrows pointing toward students' knowledge, skills, and attitudes symbolize other potential influences such as student characteristics that are not included in our model (see Schneider & Preckel, 2017).

2.2. Students' learning activities involving digital technology

Fostering students' knowledge and skills in higher education through technology does not primarily depend on the type of technology used or how often technology is used. Rather, it depends on *how* technology is used by the students themselves and how they are cognitively stimulated by and engage with it (Chien et al., 2016; Tamim et al., 2011; Wekerle et al., 2020). Student learning activities reflect how students use digital technology, and they are strongly connected to students' cognitive engagement in learning (Chi & Wylie, 2014). Cognitive engagement can be defined as a student's investment of cognitive effort in learning (Chi et al., 2018). Learning (i.e., stable changes in the representations of attitudes, knowledge, and skills in students' long-term memories) is more likely to happen if it relies on the active cognitive processing of information (Wouters et al., 2008). The ICAP (Interactive, Constructive, Active, and Passive learning activities) framework is a systematic approach that builds upon and specifies such a notion of active learning. It differentiates four types of learning activities that indicate different levels of cognitive engagement which have differential benefits for learning (Chi, 2009; Chi & Wylie, 2014; Menekse et al., 2013; Wekerle et al., 2020). More specifically, the different learning activities are related to different cognitive processes which in turn cause transformations in the learner's knowledge structures. Four core cognitive processes are *storing, activating, linking,* and *inferring* (Chi et al., 2018). In contrast to these cognitive processes, learning activities can be directly observed in a learning context and can be categorized into *passive*, *active*, *constructive*, and *interactive* activities (Chi, 2009). The C♭-model includes these four types of student learning activities involving digital technologies:

Passive learning activities involving digital technology imply that students are not exploring or manipulating the environment. They lack an observable physical activity, which is the case, for example, when students follow a digital presentation by an instructor, or students are watching an explanatory video online without taking notes. During passive learning activities, students are likely to engage in cognitive processes that are related to *storing* the presented information (Chi, 2009). Students can retrieve and use the stored information, especially if adequate context is provided. Storing of new information might be adequate for some learning contexts in which learning in an isolated way is sufficient. For example, such passive learning activities can be efficient for the acquisition of simple procedures, which include sequential steps, or for the recall of information in a test (Chi et al., 2018).

Active learning activities involving digital technology include overt actions or the physical manipulation of learning materials performed by the students, but there is no generation of information that is not already present in the learning material. Examples of active learning activities that involve digital technology include taking digital notes, highlighting or copying-and-pasting parts of a text, and taking an online quiz. While engaging in active learning activities, students' prior knowledge is likely to be *activated*, and new knowledge can be *linked* and *stored* with the activated prior knowledge (Chi & Wylie, 2014). Due to the activation of prior knowledge, new information can be assimilated or embedded in existing knowledge structures thus strengthening the new knowledge structure and making retrieval easier. To sum up, active (i.e. manipulative) engagement increases the probability of the cognitive processes *storing*, *activating*, and *linking* and can be efficient in many learning contexts (Chi et al., 2018), for example for the long term storage of a set of interrelated concepts in a certain academic field (e.g. history or biology).

Constructive learning activities involving digital technology refer to situations when students produce content and ideas that go beyond the learning material or when they solve problems and apply the learning material to another context (Chi et al., 2018). Thus, constructive learning activities are generative in nature. Engaging in a simulated learning environment and solving problems or generally creating digital content are examples of constructive learning activities involving digital technology. Engaging in constructive learning activities is likely to lead to the generation of new knowledge by *inferring* from *activated* prior knowledge or by *inferring* from prior knowledge *linked* with new information from the instructional material. Further, it includes the *storing* of new inferred knowledge. Thus, constructive (i.e. generative) engagement includes all four types of cognitive processes mentioned above (i.e. storing, activating, linking, inferring; Chi, 2009; Chi et al., 2018). This type of engagement can be particularly effective for creating elaborate and interrelated knowledge structures that are necessary components of complex skills, for example complex problem-solving in a domain.

Interactive learning activities involving digital technology have to be constructive in nature in the first place, but go beyond constructive learning activities in that they involve the co-construction of knowledge. Thus, the term *interactive* refers to interactions between two or more peers, and the contributions of each individual student must build upon each other (Chi et al., 2018). Co-constructive interactions between peers and teachers are included as well. Interactive learning activities can typically arise in discussions and argumentations in an online forum or peer-assessment activities on storyboards for the creation of explanatory videos. With regard to cognitive processes, interactive (i.e. collaborative) engagement increases the probability of the whole set of cognitive processes outlined above, namely *storing*, *activating*, *linking*, and *inferring*. However, during interactive learning activities, students can not only infer from their own knowledge (i.e. *infer-from-own*) but as well from information articulated by collaboration partners (i.e. *infer-from-other*). This highlights the potential of interactive engagement for the generation of innovative knowledge and ideas that results in enriched knowledge structures for all collaborating students (Chi et al., 2018; Chi & Wylie, 2014). Inferring and further processing of the results of inferences are likely to facilitate the development of complex socio-cognitive skills such as argumentation.

According to the ICAP framework, cognitive processes become increasingly sophisticated as students move from passive to interactive learning activities. Thus, learning activities show stronger relationships with students' domain-specific knowledge and skills when activities are characterized as active (vs. passive), constructive (vs. active), and interactive (vs. constructive; Chi & Wylie, 2014). However, as the different learning activities bear connections to somewhat different cognitive processes, they are relevant and suitable for different learning goals in different phases of learning and instruction. For students' acquisition of declarative knowledge, activation of prior knowledge, linking new information with prior knowledge, and storing the new information are the relevant cognitive processes. Thus, active and passive learning activities that reflect these cognitive processes and that are on the lower end of the learning activities taxonomy might be sufficient. However, for students' skill development, constructive and interactive learning activities are necessary as they increase the probability of processes of inferring new knowledge. In view of their potential to initiate different cognitive processes, it seems plausible to hypothesize a careful orchestration of all four types of learning activities in on-site and distance learning with digital technology so that these activities can be effective for producing successful and sustainable learning.

In the C♭-model, we assume that student learning activities that indicate students' cognitive processes are proximal factors for students' learning outcomes (i.e., the advancement of students' knowledge and skills). Further, we outline contextual facilitators for these learning activities involving technologies in the C♭-model. A Proximal contextual facilitator to students' learning activities is the use of digital technology in higher education through the learning opportunities that the teachers create (see Section 2.3) and learning opportunities that students arrange or create themselves (see section 2.4).

2.3. Higher education teachers' digital technology use

We assume that the *frequency* of digital technology use (see Section 2.3.1) as well as *how* technology is used to afford different types of learning opportunities (see Section 2.3.2) affect student learning activities with digital technology. However, we assume that the latter is more closely linked to the learning activities students engage in.

2.3.1. Higher education teachers' frequency of digital technology use

Research has often focused on how often (higher education) teachers use digital technologies in their teaching. The frequency of digital technology use by higher education teachers might be related to certain learning activities of students: It is important for students to experience the use of digital technology in general as well as to see their teachers acting as role models for technology use (Carpenter et al., 2020; Instefjord & Munthe, 2017). Large-scale studies have indicated that the general use of digital technology by teachers in higher education is rather high but that these teachers often fail to provide learning opportunities that go beyond digital presentations (Marcelo et al., 2015; Newman et al., 2018; Sailer et al., 2018; Schmid et al., 2017). With regard to the effectiveness of teachers' use of technology in higher education for students' learning, the question of *how* technology is applied therefore seems more important than *how often* it is used.

2.3.2. Higher education teachers' afforded learning opportunities involving digital technology

We highlight the *learning opportunities afforded by higher education teachers* in the C♭-model and assume that they are strongly connected to different student learning activities. The nature of the learning opportunities can make certain student learning activities more likely to happen. Whereas digital presentations or video lectures without (planned) interactions with or between students do not facilitate students to actively engage with the learning material or with peers, other instructional approaches do so by directly affording learning opportunities that make students more likely to engage in active, constructive, and interactive learning activities. Learning opportunities that include the exercise and practice of learning content, such as audience response systems (Chien et al., 2016; Hunsu et al., 2016) or quiz-based gamified interventions (Bai et al., 2020; Sailer & Homner, 2020), can activate students' prior knowledge and help them connect new knowledge with it. The nature of such learning opportunities mostly emphasizes active learning activities. Meta-analyses on the use of specific tools such as audience response systems or gamification have shown small-to medium-sized effects on learning (Bai et al., 2020; Chien et al., 2016; Hunsu et al., 2016; Sailer & Homner, 2020).

Learning opportunities that include students' problem solving (e.g., in authentic online simulations; Chernikova et al., 2020), or the creation of artefacts in virtual worlds (e.g., in serious games; Clark et al., 2016; Wouters et al., 2013) focus on cognitive processes that involve the inference of new knowledge and transfer. Learning opportunities that include problem solving and generative processes afford students constructive learning activities—and in the case of collaboration in such settings, even interactive learning activities. Meta-analytic results on simulation-based learning have shown large effects on learning (Chernikova et al., 2020), and meta-analyses on game-based learning have shown small-to medium-sized effects on learning depending on the type of learning activities involved (Clark et al., 2016; Wouters et al., 2013).

Learning opportunities that refer to collaborative problem solving or reasoning in technology-rich environments (Radkowitsch et al., 2020; Vogel et al., 2017) as well as learning opportunities that facilitate mutual engagement in inquiry activities within digital environments (Donnelly et al., 2014; Lazonder & Harmsen, 2016) allow for the co-creation of new knowledge. Such learning opportunities can offer students interactive learning activities, which not only have the potential to foster professional learning but at the same time may contribute to advancing self-regulation, including collaboration skills. However, interactive learning activities are challenging to initiate and need to be guided by teachers, tutors, or computers in online environments (Lazonder & Harmsen, 2016). Meta-analyses have shown that computer-supported collaborative learning approaches have small effects on learning and large effects on collaboration skills and self-regulation (Radkowitsch et al., 2020; Vogel et al., 2017).

Thus, we argue in the C♭-model that students' learning activities are stimulated but not determined by their teachers' use of technology in their higher education courses (Margaryan et al., 2011). Therefore, students' learning activities involving digital technology should not be taken for granted only because teachers try to initiate them. Teachers can provide learning opportunities to students; however, these are just opportunities. Students' engagement with these learning opportunities depend on learning prerequisites like prior knowledge or interest (Helmke & Weinert, 1997; Seidel, 2014). Students' prerequisites for engaging in specific learning activities (e.g., constructive and interactive learning activities that might require higher levels of self-regulation skills and basic digital skills) have to be considered, too (see Section 2.1). Besides this, guidance in complex learning environments is crucial for learning (Lazonder & Harmsen, 2016)—especially when prior knowledge is low (Kiesewetter et al., 2020; Kirschner et al., 2006).

In addition to learning opportunities provided by higher education teachers, students might also search for or create their own learning opportunities involving digital technology. We highlight this in the next Section (2.4).

2.4. Student-arranged learning opportunities

Even if higher education teachers do not succeed in providing a fruitful set of instructional affordances with digital technology, students might arrange their own learning opportunities by either searching for existing (online) learning opportunities or creating their own learning opportunities involving digital technologies. In that case, the learning activities that students engage in are influenced by the type of self-arranged learning opportunities.

Students can use and take advantage of already existing learning opportunities that are shared online and that are not mandatory or supported by the teacher of a higher education course: Students might use online video-sharing platforms like *YouTube* as independent informal learning environments to search for explanation videos (Tan, 2013). Student-arranged learning opportunities arising from online video-sharing platforms are likely to be primarily connected to passive and possibly active learning activities as they focus on the provision of videos. However, by sharing the opportunity and enable interaction and discussion around the content with other viewers, engagement in constructive and interactive learning activities is also possible (see Chi & Wylie, 2014). Other existing (online) resources might be simulation environments (see Chernikova et al., 2020), serious games (see Wouters et al., 2013), or a quiz on the course material (see Bai et al., 2020) that are available online and more strongly emphasize or even require active, constructive, and interactive learning activities.

Further, learning resources can be exchanged within informal online communities with peers that might also include discussions about them (Tan, 2013). Such informal online communities are often established in social networks such as *Facebook* (Charlton et al., 2009; Madge et al., 2009). Besides the exchange of learning resources, social networks can be used by students to informally organize academic activities such as group work (Charlton et al., 2009) and thus become informal educational networks (Madge et al., 2009; Sackey et al., 2015). In informal educational networks students have the possibility of arranging learning opportunities by themselves that also allow for advanced collaborative activities (e.g. the co-construction of a shared digital mind-map about a certain topic that is characterized by its interactive nature; see Chi & Wylie, 2014).

Social networks, e.g. *Facebook* or *Twitter*, also open up possibilities for online discussions and in argumentation about a certain topic of a course (Puhl et al., 2015). However, most social networks tend to be broadcast tools with flat-structured discussions that might impede argumentation. Thus, critical voices conclude that most social network services might not be well-suited for knowledge construction via discussion and argumentation (Kirschner, 2015b).

Nonetheless, students might still engage in the full range of learning activities, depending on certain prerequisites that help them search or create (online) learning opportunities: To self-arrange or to self-organize their own learning opportunities requires students to have advanced self-regulation skills (Jansen et al., 2020). Similar to the learning opportunities afforded by higher education teachers, these self-arranged learning opportunities are more or less likely to result in certain student learning activities involving digital technologies (see Chi, 2009). Further, finding external (online) learning opportunities or creating them requires students to have basic digital skills (Sailer et al., 2021). Therefore, the C♭-model highlights the influence of students' skills on self-arranged learning opportunities. In addition, students need to have access to the respective equipment to actually take advantage of such opportunities. Students' digital technology equipment might therefore moderate the relationship between self-arranged learning opportunities and learning activities involving digital technology (see Section 2.7).

We emphasize in the C♭-model that self-arranged learning opportunities as well as learning opportunities provided by higher education teachers are considered to be important contextual facilitators of student learning activities involving digital technologies. In the next sections, we introduce factors related to higher education teachers' digital technology use during teaching. These factors can function as contextual facilitators as well, however, they are more distal to students' learning activities as their effect on student learning activities is mediated via higher education teachers' digital technology. Those more distal contextual facilitators are higher education teachers' knowledge, skills, and attitudes (Section 2.5), measures of teachers' qualification (Section 2.6), and institutional, organizational, and administrative factors (Section 2.8).

2.5. Higher education teachers' knowledge, skills, and attitudes

To successfully implement and carry out digital technology use while teaching on-site or in distance learning, higher education teachers need a set of skills and attitudes with regard to digital technology. On the basis of research from teacher education, the broader school context, and higher education, we suggest that basic digital skills (see Section 2.5.1) and technology-related teaching skills (see Section 2.5.2) are core components of digitally literate higher education teachers (Digital Campus of Bavaria research group, 2017; Krumsvik, 2011). Based on models of teachers' competences, it is not only different types of professional knowledge and skills but diverse motivational aspects which are of relevance for teaching (Baumert et al., 2010). Thus, we also include attitudes toward digital technology (see Section 2.5.3) that might influence higher education teachers' digital technology use as well (Christensen & Knezek, 2017).

2.5.1. Higher education teachers' basic digital skills

Higher education teachers need basic digital skills, just like their students, or rather, just like anybody else in a digital world (Carretero et al., 2017; see Section 2.1). These skills are the basic part of a more complex range of skills that (higher education) teachers need in order to teach with digital technology (Knezek & Christensen, 2016; Krumsvik, 2011). As higher education is supposed to also contribute to deepening and enhancing students' general education, basic digital skills constitute a central higher education learning outcome that prepares students for future learning (Bransford & Schwartz, 1999). It seems plausible to assume that higher education teachers require at least the same set and degree of skills that they seek to foster in their students (Digital Campus of Bavaria research group, 2017). Research has shown that basic digital skills might indeed affect the digital technology use of higher education teachers (Liu et al., 2020). Whereas a lack of such skills can be a barrier to the use of digital technologies in teaching (Chitiyo & Harmon, 2009), higher levels of digital skills positively affect the use of advanced features in online course design (Buchanan et al., 2013). However, although basic digital skills are necessary, they are not sufficient for a teacher's ability to provide the full scope of learning opportunities to students (Sailer et al., 2021); this might be especially true for opportunities to engage in constructive and interactive learning activities.

2.5.2. Higher education teachers' technology-related teaching skills

For higher education teachers to effectively use technology in their on-site and distance teaching, *technology-related teaching skills* might be crucial (see Seufert et al., 2021). A precondition for higher education teachers to be able to effectively use digital technology to foster student learning is that the teachers must know how digital technology can be used to do so (Chien et al., 2016; Tamim et al., 2011; Wekerle et al., 2020). This knowledge has been operationalized and investigated in the context of pre- and in-service teacher education through the use of the TPACK (Technological Pedagogical Content Knowledge) model (Mishra & Koehler, 2006; Seufert et al., 2021). TPACK extends the perspective presented by Shulman (1986), who postulated that teachers need pedagogical knowledge (PK), content knowledge (CK), and pedagogical content knowledge (PCK), which is formed at the intersection of the other two. Mishra and Koehler (2006) extended Shulman's (1986) model by adding a fourth factor called technological knowledge (TK). Additionally, at the intersections of the different core knowledge areas (PK, CK, and TK), there are four hybrid components known as pedagogical content knowledge (PCK; see Shulman, 1986), technological pedagogical knowledge (TPK), technological content knowledge (TCK), and technological pedagogical content knowledge (TPCK; Mishra & Koehler, 2006; Schmid et al., 2020). Some lines of TPACK research have moved beyond teachers' *knowledge* to explore other more comprehensive concepts (Petko, 2020). For instance, there is the notion of skills for teaching with digital technology that puts a stronger focus on what teachers need *to be able to* do with technology in teaching settings (Digital Campus of Bavaria research group, 2017; Kelly & McAnear, 2002). Technology-related teaching skills have been suggested as the combination and integration of conceptual knowledge facets and action-oriented knowledge facets (Sailer et al., 2021). Conceptual knowledge facets refer to knowledge about (scientifically based) models and frameworks that link digital technologies and successful teaching and learning. Action-oriented knowledge facets refer to putting these conceptual knowledge facets into action (Sailer et al., 2021). Research from the school context highlights the idea that technology-related teaching skills in different phases of teaching with digital technologies (e.g., planning, implementing, evaluating, and sharing; Ertmer & Ottenbreit-Leftwich, 2010; Digital Campus of Bavaria research group, 2017; Zimmerman & Campillo, 2003) are necessary for fostering a broad range of student learning activities. In fact, they are especially relevant for fostering constructive and interactive learning activities (Sailer et al., 2021). However, research on higher education teachers' technology-related teaching skills and TPACK is scarce (Wekerle et al., 2020). The focus of TPACK research is on in- or pre-service school teachers (see Seufert et al., 2021). In the C♭-model, we assume that technology-related teaching skills are crucial for higher education teachers' technology use as well.

2.5.3. Higher education teachers' attitudes toward digital technology

Besides higher education teachers' knowledge and skills, their attitudes toward digital technology are important to consider as well (Kirschner, 2015a; van Merriënboer & Kirschner, 2017). These attitudes are often correlated with higher education teachers' knowledge and skills regarding digital technology (Scherer et al., 2018). In line with students' attitudes, higher education teachers' attitudes toward digital technology also refer to a negatively to positively valenced evaluation of the use of digital technology in teaching and in support of student learning (see Heddy et al., 2017). Research from teacher education has indicated that higher education teachers' attitudes indirectly affect their use of technology in teaching: Attitudes influence knowledge of technology integration, which affects technology use in teaching (Taimalu & Luik, 2019). Research on in- and pre-service teachers' technology use has indicated that attitudes toward teaching with digital technologies affect how often teachers use technology (see Scherer et al., 2019). Further, findings regarding learning opportunities offered by teachers are ambiguous. There is some evidence that positive attitudes are associated with higher quality of technology use (Backfisch et al., 2021). However, other studies that included both technology-related teaching skills and attitudes in their statistical models found that positive attitudes are only related to affording students passive learning activities, not to other learning activities that include different forms of student activation (Sailer et al., 2021). On the other hand, negative attitudes can impede the use of technology in teaching (Hew & Brush, 2007). Related research has argued that higher education teachers' lack of interest in digital learning can hinder innovation (Schneckenberg, 2009). However, others have pointed to more complex relationships between attitudes toward technology and the use of technology during teaching by claiming that having positive attitudes toward digital technology does not necessarily lead to more or better integration of technology in the classroom (Belland, 2009).

In the C♭-model, we assume that skills and attitudes are important for higher education teachers' use of technology. However, the relationship of teachers' skills and attitudes with teachers' use of technology might be reciprocal as higher education teachers can also learn from their own digital technology use (García & Roblin, 2008). This requires higher education teachers to engage in critical reflection about their own teaching (Ling & MacKenzie, 2001), which takes us to the qualification of higher education teachers as a contextual facilitator in the C♭-model: Higher education teachers' skills, at least in part, result from their participation in training and formal education.

2.6. Qualification of higher education teachers

Qualification of higher education teachers can refer to the provision of and participation in training programs (see Section 2.6.1) as well as to experiences during academic qualification of higher education teachers (see Section 2.6.2).

2.6.1. Further education and training

To ensure that higher education teachers have the skills needed to effectively use advanced technology in their teaching, formal staff development and quality assurance processes are relevant (Newland & Handley, 2016). Especially for distance education, specific training in the use of online learning environments can help higher education teachers make the most of such environments with regard to their students' learning (Owens, 2012). This relationship might be mediated by higher education teachers' skills and attitudes, which can be addressed in further education and training. Research has shown that online training programs for technology-related teaching skills can be successful in fostering these skills in teachers (Rienties et al., 2013). Training can also be part of an informal learning process in the form of self-study formats as well as exchange, support, and co-design with colleagues (Gast et al., 2017; King, 2002).

2.6.2. Experiences during academic qualification

The use of technology in higher education is likely to influence students' skills and attitudes but also the use of technology after their own higher education (Voogt & McKenney, 2017). Teachers in higher education are role models—especially for people who later enter into the teaching profession themselves (Carpenter et al., 2020; Instefjord & Munthe, 2017). Thus, for teachers in higher education, their experience during their own studies as well as during the early phases of their academic careers can have an impact on the way they will later use digital technology themselves in their teaching.

In the C♭-model, the qualification of academic staff is connected to higher education teachers' knowledge, skills, and attitudes as well as to institutional, organizational, and administrative factors (Bond et al., 2018). On the one hand, qualification measures can result in more advanced skills (Rienties et al., 2013), and further improving from an advanced skill level requires more sophisticated training opportunities. Besides this, positive attitudes toward technology can result in a greater willingness to participate in further education with regard to digital technology. On the other hand, institutional, organizational, and administrative factors (see Section 2.8) are connected to the types and amounts of additional educational opportunities and requirements that are present (Liu et al., 2020).

2.7. Students' and higher education teachers' digital technology equipment

Although the implementation of digital technologies in higher education depends on numerous factors beyond merely equipping students and teachers in higher education with hardware, it has been shown that the level of access to technology can, for instance, influence how often technology is used during teaching and how many technology-enhanced learning opportunities higher education teachers afford (Agbonlahor, 2006; Liu et al., 2020; Reid, 2014). Research from the context of secondary schools also shows that teachers generally report higher frequencies of digital technology use when there were fewer limitations of resources, e.g. digital technology equipment (Fraillon et al., 2014). However, the amount of resources invested in educational technologies is not related to improved student achievement in reading, mathematics or science (OECD, 2015). Thus, even though the availability of digital technologies for teachers and students can be seen as a prerequisite for teaching and learning with digital technologies, especially in case of distance teaching and learning, it is no guarantee of its effective use for student learning (Considine et al., 2009; Fraillon et al., 2014). Based on these findings, we assume the availability of digital technology equipment for teachers and students is a necessary but not sufficient factor when it comes to student learning activities involving digital technologies.

Further, in many parts of the world students' digital technology equipment ownership is becoming more or less ubiquitous (Sundgren, 2017). Thus, *bring your own device* (BYOD) concepts are used in higher education at large scale. However, the success of BYOD concepts depends on the actual devices that students can afford and whether or not they can afford such devices at all (Sundgren, 2017). Even if we take into account that a relatively large number of higher education students make use of their own personal technological devices (e.g., notebooks, tablets) for learning (Cassidy et al., 2014; Sailer et al., 2018), the provision of technology by institutions is likely to make a difference and address important barriers to the use of technology in higher education teaching and learning as it sets technological standards, strengthens reliability, and enables the use of advanced applications (Reid, 2014). BYOD concepts rely on the precondition that students' or teachers' own technology equipment is sufficient for the intended learning activities and purposes (Sundgren, 2017) and that enough technical support is available for these devices (see Gikas & Grant, 2013).

In the C♭-model, we emphasize that availability of digital technology equipment is no guarantee for effective student learning (Considine et al., 2009). However, we are aware that equipment itself is a precondition for technology being used. Thus, we assume that higher education teachers' digital technology equipment might moderate the relationship between higher education teachers' knowledge, skills, and attitudes on the one hand, and their use of digital technology in classrooms on the other hand. Similarly, this might apply to the relation between higher education teachers' qualification and their digital technology use. High levels of knowledge, skills, and attitudes as well as a high level of participation in qualification measures can result in actual digital technology use only as long as the digital technology is available at all. In a similar way, students' digital technology equipment is conceptualized as having a moderating influence in the C♭-model on the connection between learning opportunities, which are either provided by the teacher or student-arranged, and the learning activities involving digital technologies. In that sense, digital technology equipment is a necessary, but not a sufficient factor for teachers' technology use and students' learning activities involving digital technologies (see Sailer et al., 2018).

It is a question of main concern not only with regard to costs or general considerations of digitalization policies but to the actual use of technology in teaching and learning whether institutions of higher education should develop and implement digitalization strategies that involve equipping faculty and students with institutional technology or rather BYOD concepts. Thus, we assume that institutional, organizational, and administrative factors (see Section 2.8) influence the equipment that students and teachers have at their disposal.

2.8. Institutional, organizational, and administrative factors

The use of technology in higher education to enable specific learning activities is not only a matter of interaction between higher education teachers and students. Teaching and learning in institutions of higher education are situated in an institutional and administrative context that has its own factors of influence—some that might advance specific uses of digital technology and some that might impede them or even make them impossible (Agbonlahor, 2006; Schneckenberg, 2009). Indeed, as technology changes teaching and learning in higher education, successful implementation will also greatly depend on general structural and organizational factors of institutions of higher education such as faculty autonomy or the relative unimportance of teaching in academia as a whole (Liu et al., 2020; Schneckenberg, 2009). Thus, although there is a need for more research on organizational-level topics (Martin et al., 2020), it has been argued that the successful implementation of digital technology in an educational context might depend on the combination of personal and institutional factors (Agbonlahor, 2006; Gräsel et al., 2020; Liu et al., 2020; Schneckenberg, 2009).

With respect to this aspect, the C♭-model accentuates four factors that are considered to play major roles in higher education teachers' use of digital technology and thus student learning activities, namely, institutional infrastructure (see Section 2.8.1), technical and educational support (see Section 2.8.2), digitalization policy and the commitment of a university's administration (see Section 2.8.3), and organizational development (see Section 2.8.4). In the following sections, we discuss these factors in the order of their decreasing proximity to the actual teaching and learning that takes place in institutions of higher education.

2.8.1. Institutional infrastructure

It has been asserted that digitalization policies rather than technologies themselves enable institutions of higher education to harness digitalization (Orr et al., 2018). However, *without* a basic (threshold) level of digital infrastructure on-site and online (e.g., equipping rooms with technology, on-site access to the Internet, or availability of an online learning management system), teaching and learning at universities are unlikely to unlock the potential that technology offers for teaching and learning (Jorgensen et al., 2018). Also, from a learning activity perspective, with the progress from passive and active to constructive and interactive learning opportunities, the demand for a more advanced technological infrastructure is also likely to increase as higher education teachers afford increasingly rich and complex learning opportunities with constructive or interactive learning activities that require a robust and up-to-date digital infrastructure (Liu et al., 2020).

2.8.2. Technical and educational support

However, technological infrastructure *alone* is not considered sufficient for advancing digital teaching and learning if it is not accompanied by an adequate support system for the teachers in institutions of higher education (Garrison & Vaughan, 2013; Gräsel et al., 2020; Mercader & Gairín, 2020; Reid, 2014). Such a support system can address the technological aspect (i.e., it can support technology use in teaching and learning situations), as even higher education teachers with high basic digital skills will not be able to solve all the problems that can and will arise in their teaching (Garrison & Vaughan, 2013; Reid, 2014). However, the educational aspect of support for higher education teachers—that is, to provide educational assistance for questions about the planning, development, and implementation of digital learning opportunities on the basis of scientific evidence—might be important as well (Digital Campus of Bavaria research group, 2017; Gräsel et al., 2020).

Technical support is important for students as well, especially when relying on BYOD concepts in higher education. A lack of adequate support for students can lead to frustration (Gikas & Grant, 2013).

2.8.3. Digitalization policy and commitment of university administration

As we move from more proximal to more distal factors of influence, more general institutional and administrative parameters come into view, namely, whether institutions of higher education have a clear and coherent digitalization policy at all and the extent to which they are committed to it (Czerniewicz & Brown, 2009; Garrison & Vaughan, 2013; Mercader & Gairín, 2020). A deliberate digitalization strategy has been assumed to play an important role in institutions of education before (Gräsel et al., 2020; Orr et al., 2018). However, empirical research on the proportion of institutions that have indeed systematically developed and implemented such strategies and the effects of having implemented a strategy have provided only inconclusive results so far (Mercader & Gairín, 2020; Orr et al., 2018; Sailer et al., 2018; Schneckenberg, 2009). In addition to the formal development of a digitalization strategy, institutional support has been shown to be an important factor in the successful implementation of digital technology in higher education (Reid, 2014), and so has the establishment of an organizational and social climate in which technology is a positive contributor to faculty's institutional status (Agbonlahor, 2006; Schneckenberg, 2009). These findings suggest that digitalization strategies are more effective when they address institutions of higher education as complex organizations in a process of transformation and thus go beyond the mere adding on of technology to an otherwise unchanged teaching and learning routine (Orr et al., 2018). Thus, the digital transformation of institutions of higher education seems more likely to meet with substantial success when it is embedded in an overarching process of organizational development that addresses several or even all institutional levels. This is also why, in the C♭-model, we have included the commitment of university administrations as an indicator of and factor in the implementation of such a comprehensive digitalization strategy.

2.8.4. Organizational development

Institutions of higher education can be considered learning institutions if they are to harness digital technologies to their best potential (Gräsel et al., 2020). As such, any strategic initiative that strives to contribute to change in teaching and learning on the level of the learning activities seems more likely to be effective if it addresses different organizational levels of governance and administration, teaching and learning, academic life and student participation, and different stakeholders' perspectives (Czerniewicz & Brown, 2009; Liu et al., 2020; Reid, 2014; Schneckenberg, 2009). This is all the more so because of two reasons: First, the different stakeholders in higher education rely on a much higher degree of autonomy in their professional decisions—especially academic teachers in comparison to teachers in primary or secondary education (Liu et al., 2020; Reid, 2014; Schneckenberg, 2009). Second, the different factors of influence outlined in this section bear complex interrelationships between each other so that, for example, when institutions provide further education in the field of technology-enhanced teaching, this might result in growing demands on technological equipment, which, if met, might generate new types of learning opportunities (see Puentedura, 2006; Sailer et al., 2018).

In the C♭-model, we assume that institutional, organizational, and administrative factors are related to the digital technology equipment of students and teachers either by providing such devices or by offering support for personal devices (see Gikas & Grant, 2013; Reid, 2014). Further, institutional, organization, and administrative factors might influence the way teachers use technology as they include digitalization strategies that may or may not emphasize technology use in general. These strategies may also suggest prioritizing certain learning activities involving digital technologies over others (Orr et al., 2018).

3. Conclusion

3.1. The C♭-model for on-site and distance learning environments in higher education

Research on digital teaching and learning in higher education in the past has taken into consideration various contextual factors and often focused on frequency of teachers' technology use as the main success criterion of technology integration. In contrast, the C♭-model proposes to shift the focus to students' learning activities involving digital technology. Thus, it introduces a clear goal orientation by suggesting that students' learning outcomes are the most important benchmark of successful technology integration in higher education. Learning outcomes, according to the ICAP framework, are directly and causally related to students' visible learning activities (Chi, 2009; Chi & Wylie, 2014). And these are most typically facilitated by instructional affordances by teachers of higher education – affordances provided on the basis of their own set of knowledge, skills and attitudes in a larger institutional context. Thus, the C♭-model concentrates on the most proximal facilitators of learning outcomes that is students' learning activities in an instructional setting and includes contextual facilitators of students' learning activities involving digital technologies. What is more, the C♭-model suggests relationships between them – even if the specification of these relationships is still somewhat coarse at this point. By doing so, the C♭-model qualifies not only as a general framework, but as a model in a stricter and more ambitious sense. To date, only part of the complex (inter-)relationships between different facilitating factors have been subject of systematic research, thus opening up manifold starting points for future research.

3.2. Limitations of the C♭-model

The C♭-model focusses on student learning outcomes as the main goal of teaching and learning with digital technologies. The learning activities and the contextual facilitators presented in the context of the C♭-model present proximal and distal factors that are related to those student learning outcomes. The focus of the model lies on factors which are related to digital technologies and which can be influenced by stakeholders of higher education. However, for students' achievement in higher education other factors like students' characteristics (e.g. intelligence, personality characteristics) and instructional variables (e.g. meaningful learning and assessment) that are not explicitly related to digital technologies are influential as well (Schneider & Preckel, 2017). Such variables are out of the scope of our model. It is an open question how well technology integration has to be aligned to other relevant factors that influence student learning.

Further, we emphasized a perspective on learning activities to include learning processes in our model. Nevertheless, micro-processes, such as guidance and scaffolding with digital technology, are less visible in the C♭-model than the focused learning activities involving technology and contextual facilitators. However, we tried to emphasize the importance of supporting, scaffolding, and guiding students during learning with technology. We are aware that certain learning activities involving digital technologies require students' elaborated prior skills (e.g. basic digital skills or self-regulation skills) and guidance by teachers or the digital learning environment itself (e.g. by intelligent tutoring systems) in case these prior skills are missing (see Kiesewetter et al., 2020; Kirschner et al., 2006).

Not every aspect and every proposed relation in the C♭-model is equally well investigated yet. As a consequence, there are relations specified in the model which are less evidence-based than others. More specifically, the roles of digital technology equipment as moderators have not been explicitly investigated in empirical research yet. Further, the role of institutional, organization, and administrative factors has not been explored systematically in empirical research yet. In addition, some findings originate from the school context, particularly those regarding teachers' knowledge, skills, and attitudes. These concepts and their relations need empirical investigation in the context of higher education. Generally, we encourage empirical testing of the C♭-model despite its proposed complexity and its limitations. Such research might rely on self-assessments and survey methodologies; however, it could provide answers to the questions which contextual facilitators have the most direct impact and thus, how and in what order contextual facilitators can be addressed to initiate change in higher education institutions (for an empirical investigation of the C♭-model see Lohr et al., 2021).

3.3. Future research based on the C♭-model

Some of the open theoretical and empirical questions for research include:

(1) Role(s) of technology and the interaction of institutional and student-owned digital technology equipment. At this point, it seems trivial to say that digital technology is probably not the most important factor in the C♭-model, at least not the one to start with. However, technology is crucial anyway. In the literature, there have been different suggestions about the role that digital technology plays in teaching and learning. Some suggestions concern the amount of technology that is necessary to advance teaching and learning (e.g., the threshold model; see Sailer et al., 2018). Some address the degree to which technology is really changing processes substantially (e.g. SAMR; Puentedura, 2006). Still others theorize on the interrelation of technological and pedagogical progress (Co-Evolution). At this point, it seems likely that there will not be one technology model that outperforms all the others. Rather, it seems plausible to assume that these models are valid under certain, yet unknown conditions. An investigation of these conditions makes sense once a common frame of reference is used, including— most importantly—learning activities and outcome measures related to student learning. The C♭-model proposed in this article may qualify as such a joint conceptual foundation. A threshold model, for example, seems valid to some extent if we observe a higher frequency of technology use in the university classroom and a broader spectrum of learning activities afforded by technology from a certain relatively low level of equipment that does not change substantially when more technology is added. A different set of open questions with respect to the role of digital technology is related to the fact that many students increasingly rely on their own technology in order to follow courses and engage in self-regulated learning (Sundgren, 2017). It seems plausible that BYOD can be effective, but it is also rather obvious that there can be circumstances under which BYOD will facilitate social injustice. Therefore, more important questions are related to the conditions under which BYOD can be effectively employed to facilitate participation in beneficial learning activities. For example, open questions include how flexible platforms can be developed as part of the equipment owned by the university that can integrate the different technologies that students use, and how these platforms can support students' interaction in real time, in hybrid learning environments, and without violating privacy regulations. Another question is which models of loaned digital technology equipment can contribute to avoiding social injustice with respect to learning activities and outcomes.

(2) A co-evolution of learning activities, pedagogies, and technology? Learning activities seem to be among the best predictors of learning outcomes available to date because engaging in certain learning activities makes different kinds of cognitive processes more likely to happen. As laid out in Section 2.2, engaging in active, constructive, and interactive rather than passive activities is suggested to afford better learning outcomes (Chi & Wylie, 2014). This raises two questions with regard to the use of technology in higher education. First, it has to be considered that learning activities that include students' actions (i.e. active, constructive, and interactive learning activities) are more challenging for higher education teachers to implement in their courses. This leads to the question whether well-arranged settings affording mainly passive learning activities could possibly be more effective regarding students' learning than poorly implemented settings which call for students' actions (see Stegmann, 2020). Especially students' constructive and interactive learning activities with digital technology require teachers to carefully guide and scaffold their learning process and thus demand more advanced technology-related teaching skills. Second, is it plausible to assume that digital learning environments include only constructive and interactive activities? Probably not. Even for the most effective online discussions, there is a time when listening to a new argument is helpful and can facilitate learning. It seems reasonable to assume that different blends of learning activities or different sequences of activities over time have different effects on learning as well. Watching an explanatory video that elaborates on a complex process may be useful before engaging in problem-solving activities. There are different pedagogies that orchestrate learning activities (e.g., around inquiry or problem-solving). It seems plausible to assume that digital technologies can be used to make certain patterns of learning activities more likely to occur. However, at the same time, it seems possible that pedagogies and patterns of learning activities co-evolve with new types of digital technology (see Chien et al., 2016; Hunsu et al., 2016). We see both the one-directional "enhancement" mechanism as well as the bi-directional co-evolution mechanism as plausible but under-investigated hypotheses.

(3) The interplay of skills and attitudes of teachers and students. Many higher education teachers may have decent basic digital skills. We argued in Section 2.5 that these basic skills are necessary but not sufficient for initiating student learning activities with digital technologies. They are not sufficient mainly because they do not include knowledge about learning activities and the specific use of technology to help others learn. There are many open conceptual and empirical questions resulting from this assumption, including the following: How are basic digital skills and technology-related teaching skills connected, and how do they co-develop over time in higher education teachers? What is the relative importance of basic digital skills and technology-related teaching skills of higher education teachers for explaining and predicting the type, combination, or sequence of learning activities they try to stimulate in their students? Is the relative importance (i.e., the explanatory and predictive power) of technology-related teaching skills higher when students' basic digital skills and their self-regulation are less advanced? What are the conditions under which programs to facilitate digital teaching skills are effective?

(4) On the importance of institutional strategy and change. Although there is some debate on the relative importance of institutional commitment for effective digital teaching and learning, there appears to be a consensus that such a strategy for change is

important (see Orr et al., 2018). We therefore suggest that a more important question would be: Under what conditions are higher education strategies for digital teaching and learning effective with respect to students' learning activities and learning outcomes? Referring to the C♭-model, we can expect that a strategy will be more effective when it focuses on learning activities, technology-related teaching skills, and attitudes, on student skills as prerequisites, and on technology that supports students' engagement in effective learning activities. Another line of research questions could address the approach that is applied to bring about organizational change (e.g., through professional learning communities) and the participatory roles of higher education teachers, students, and experts on organizational change as well as experts on digital teaching and learning in developing an institutional strategy. In addition, questions about the conditions for effective implementation seem important, including aspects such as incentivizing, communicating, and monitoring goals and instruments.

The digital transformation poses considerable challenges not only to people but to organizations as a whole and not least of all to institutions of higher education. Institutions of higher education also seem to be particularly apt to face this challenge because they are inherently learning organizations, at least much more so than, for example, institutions of primary and secondary education or organizations outside the educational system. The reason for this is that institutions of higher education have a specific public mandate to offer both research *and* teaching. On account of this double mandate, they observe and describe current societal transformations (e.g., digitalization), and by doing so, they generate the very knowledge that enables societies to react adequately to these transformations. However, if we truly want to understand the complex dynamic of factors that lead to successful digital teaching and learning in institutions of higher education via suitable learning activities, we have to try to capture an overall picture of teaching and learning with technology in higher education. In this view, C♭-model can be seen as a roadmap for future research to do so.

Author contribution

Michael Sailer, Conceptualization, Funding acquisition, Visualization, Writing – original draft, Writing – review & editing. Florian Schultz-Pernice, Conceptualization, Writing – original draft, Writing – review & editing. Frank Fischer, Conceptualization, Funding acquisition, Writing – original draft, Writing – review & editing.

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