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Research paper

Teachers’ technology use for teaching: Comparing two explanatory mechanisms

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HIGHLIGHTS

- We propose a synergism of two perspectives on teachers' technology use.
- Technology integration comprises quantitative and qualitative aspects.
- Direct *and* indirect relations between motivation and technology use exist.
- A model integrating a concurrent and cascade mechanism fits the data best.
- TPACK self-efficacy is critical for successful technology integration.

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ABSTRACT

Although integrating technologies for teaching has received much attention, research demonstrated that teachers rarely use technologies likely because of low levels of technology-related motivation. Theories on teacher motivation such as Expectancy-Value Theory and Technology Acceptance models differ in how they conceive the influence of motivation on technology integration. To investigate these conflicting assumptions, we conducted a survey study within one-to-one technology-enhanced schools with $N = 524$ in-service teachers. Findings from structural equation modeling showed that rather than being mutually exclusive, the two perspectives should be integrated to inform research and practitioners about the implication of teacher motivation for technology integration.

1. Introduction

Teaching with technologies is advocated within the political as well as the scientific debate (Fraillon et al., 2019; OECD, 2015). In these discussions the potential of technologies to promote distinct teaching and learning processes as well as the necessity of technology integration in schools to develop students' 21st century skills are stressed. Besides the availability of infrastructure (Drossel et al., 2017), research showed that teachers' motivational beliefs are boundary conditions of their technology integration (Backfisch, Lachner, Hische, Loose, & Scheiter, 2020; Scherer, Siddiq, & Tondeur, 2019; Taimalu & Luik, 2019; Teo, 2011). Particularly teachers’ self-efficacy beliefs towards using technologies for teaching and perceived utility of educational technologies were identified as crucial motivational sources (e.g., Backfisch et al., 2020; Scherer et al., 2019; van Braak et al., 2004; Fraillon et al., 2019; Wozney et al., 2006).

However, the exact nature regarding the relationships and mechanisms among teachers' motivational beliefs (i.e., self-efficacy, perceived utility) and technology integration are yet unclear. For instance, classical motivational belief models (e.g., expectancy-value theory, EVT, Eccles & Wigfield, 2002) assume a concurrent mechanism with direct effects of self-efficacy *and* utility-value on

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technology integration (Taimalu & Luik, 2019). Alternatively, technology acceptance models (TAM, Scherer et al., 2019; Marangunić & Granić, 2015) propose a cascade mechanism: First, external variables, such as teachers' self-efficacy, are assumed to be related to their perceived utility of educational technology. Second, teachers' utility is assumed to be related to their technology integration (for investigations of this cascaded mechanism, see Al-Azawei et al., 2017; Mayer & Girwidz, 2019; Sánchez-Prieto et al., 2017; Wong et al., 2012). Therefore, according to this cascade mechanism self-efficacy is only indirectly related to technology integration via the perceived utility-value of technology integration. To disentangle these two alternative assumptions (concurrent versus cascade mechanism of teacher motivation), we tested them empirically by using survey data of in-service teachers ($N = 524$). All teachers were teaching in a municipality in Norway where classrooms were fully equipped with technical infrastructure. We performed structural equation modeling to investigate concurrent and cascade associations of teachers' self-efficacy and their utility-value on their technology integration. As technology integration in the classroom aims at facilitating students' learning processes as well as heightening their digital literacy, we used measures both for the frequency of in-class technology use during teaching and teachers' emphasis on developing students' digital literacy as potential proxies for technology integration (Siddiq, Scherer, & Tondeur, 2016). This procedure enabled broad and deep insights in the nature of relationships between teacher motivation and technology integration.

2. Literature review

2.1. Technology integration and use

Technology integration refers to teachers' use of technologies during teaching in school which can a) facilitate teaching and learning processes with digital media, and b) support students' domain-general digital literacy to participate in a digitalized society (OECD, 2015). Research has demonstrated distinct potentials of educational technology for scaffolding teaching processes, such as learning from multimedia (Moreno & Mayer, 2007; Renkl & Scheiter, 2017) and on-time adaptive learning support (Aleven & Koedinger, 2002; Lachner, Burkhart, & Nückles, 2017; Ma et al., 2014; Zhu & Urhahne, 2018). Moreover, technology integration should scaffold students' development of technology-related 21st century skills (i.e., *digital literacy*) which include not only the use of technologies but also the ability to use them conscientiously and critically reflect upon its possible consequences and risks (Fraillon et al., 2014). Therefore, teachers should put emphasis on developing students' digital literacy when inviting students to engage in digital learning activities during domain-specific teaching. For instance, if the teacher asks the students to make an explanatory video for a domain-specific topic, teachers should educate students about copyright and personal rights so that students can administer copyright rules to their own digital products (DigCompEdu, Redecker & Punie, 2017; Norwegian Directorate for Education and Training, 2012).

Teachers, however, need appropriate infrastructure to be able to teach with technologies and to promote students' digital literacy. There is an increasing number of governmental one-to-one initiatives across countries which typically provide teachers and students with their own digital devices (Fleischer, 2012). These initiatives are sought to be effective in supporting technology integration and therefore should work as a catalyst for change of daily school practice (Beauchamp et al., 2015; Keane & Keane, 2019; Liu & Milrad, 2010).

Besides appropriate infrastructure, there are further prevailing boundary conditions that constrain technology use in schools (Farjon et al., 2019; Knezek & Christensen, 2016; Petko, 2012). The International Computer and Information Literacy Study (ICILS) 2013 examined boundary conditions for in-class technology use in schools and its effect on students' computer and information literacy (CIL) across different countries. For this purpose, not only students but also teachers were surveyed to assess their experiences and confidence in using technologies as well as their value beliefs towards teaching with technologies. Additionally, data on school characteristics and general technical equipment at schools was collected (Fraillon et al., 2014). The ICILS results suggested that appropriate technological equipment of schools alone is not sufficient for technology integration as the frequency of technology integration was not necessarily related to the level of technical infrastructure in schools of the respective country (Drossel et al., 2017). Therefore, other factors than the mere availability of technologies might be prerequisite for technology integration, such as teachers' professional knowledge and motivation (Mishra & Koehler, 2006; Scherer & Teo, 2019; Scherer, Tondeur, & Siddiq, 2017).

2.2. Teacher motivation

One of the main boundary conditions for technology integration found to be is teachers' motivation (Backfisch et al., 2020; Scherer et al., 2019; Barton & Dexter, 2019; Ertmer et al., 2012; Taimalu & Luik, 2019; Wozney et al., 2006). In general, motivation refers to internal states that make humans "wanting change", therefore, motivation "energizes, directs and sustains behavior" (Reeve, 2016, p. 31). Research on determinants of generic teaching quality found that various aspects of teachers' motivational beliefs such as teaching enthusiasm, goal orientation, and self-efficacy beliefs are important (Kunter et al., 2013; Tschannen-Moran & Hoy, 2007). However, whether and how different aspects of teacher motivation interact and (differently) explain their technology integration is yet unclear. This may be due to the lack of a comprehensive framework describing the antecedents of technology integration - in fact, most research on technology integration was based on divergent, mostly independent lines of theoretical assumptions. These theoretical assumptions derive from either Expectancy-Value Theory (*EVT*, Eccles & Wigfield, 2002) or Technology Acceptance Models (*TAM*, Davis, 1989; Teo, 2011). Both approaches make different assumptions regarding the underlying mechanisms of teacher motivation on technology integration. Most prominently, research investigating the relations between individual generic motivational beliefs and associated behavior were summarized in the EVT. As core concepts, EVT focuses on an individual's expectancy of coping with a task (i.e., the self-efficacy and confidence in one's skills), and the value beliefs associated with the task (i.e., the perceived added value and usefulness of the task). These value beliefs are commonly differentiated into four categories: costs (as possible negative consequences of a task), intrinsic value (as an affective value component), attainment value (as the personal importance of doing well in a task), and most importantly, utility-value (Gaspard, 2015, pp. 1–195). Therefore, according to EVT, both self-efficacy and utility-value concurrently determine the choice, persistence, and achievement within the task (i.e., technology integration).

Besides general motivational beliefs research, which has been increasingly adopted in the context of technology integration, there are specific models for describing teachers' behavioral intentions to integrate technologies and the frequency of technology use in the classroom (e.g., the Unified Theory of Acceptance and Use of Technology UTAUT, Venkatesh et al., 2003; Technology Acceptance Model TAM, Davis, 1989; Scherer & Teo, 2019; for an overview, see Taherdoost, 2018). As a core assumption, the TAM assumes a cascaded mechanism of direct and indirect effects of motivational variables and additional external variables such as social norms, facilitating conditions and computer self-efficacy on the behavioral intention to use technologies (Scherer et al., 2019; Marangunić & Granić, 2015). Self-efficacy beliefs are associated with attitudes toward computers and perceived usefulness, and these attitudes, in turn, affect the intentions to use technologies which, finally, affect the use of technologies.

Even though EVT and the TAM differ in their assumed mechanisms, they intersect regarding the considered aspects of motivational beliefs: *Self-efficacy beliefs,* which represent an individual's confidence in teaching with technologies, and *utility-value* of teaching with technologies, which represents the individual's perceived usefulness of integrating technologies into teaching. Therefore, the investigation of these two aspects of teachers' motivational beliefs allows to model the core mechanisms of EVT and TAM.

2.2.1. Self-efficacy

Self-efficacy beliefs refer to an individual's confidence in successfully accomplishing a distinct task (Bandura, 2010; Barton & Dexter, 2019; Marsh et al., 2019). To assess this self-efficacy, individuals are asked to judge their perceived knowledge for example based on mastery or vicarious experiences (e.g., previous experiences during teaching with technologies, Tschannen-Moran & Hoy, 2007). In line with the different knowledge components needed to accomplish a distinct task, “the efficacy belief system is not a global trait but a differentiated set of self-beliefs linked to distinct realms of functioning” (Bandura, 2006, p. 306). Accordingly, individuals might be confident regarding one distinct realm of a task, but less confident regarding another sub-task. Especially regarding complex tasks, such as teaching with technologies, this multidimensionality is apparent: Teachers need diverse sub-skills and knowledge components to successfully integrate technologies into their teaching (Herring et al., 2016). The TPACK framework by Mishra and Koehler (2006) conceptualizes these subskills of teachers' professional knowledge regarding technology integration during teaching. In the TPACK framework, it is postulated that to successfully adopt technologies, teachers need to have technological knowledge (TK), and to integrate it with their professional knowledge of teaching (content knowledge [CK], pedagogical knowledge [PK], and pedagogical content knowledge [PCK]). This knowledge integration then ideally leads to embedded knowledge components: technological pedagogical knowledge (TPK as knowledge about how to embed technologies into pedagogical methods); technological content knowledge (TCK as knowledge about how to deliver content with technologies); and technological pedagogical content knowledge (TPACK as knowledge on how to teach certain content with technologies in a pedagogical sound way). Scherer et al. (2017) investigated the factorial structure and measurement invariance of TPACK captured with a self-assessment questionnaire in a sample of $N = 665$ pre-service teachers. The authors found that the specific TK dimension stands out among the different dimensions of the TPACK framework, as it was less related to the other T-dimensions (i.e., TPK, TCK, TPCK). Contrarily the TPK, TCK and TPCK were highly related. Furthermore, the authors emphasized that besides these specific dimensions, there is an underlying, general TPACK factor, on how to use technologies in the classroom which potentially influences all specific T-dimensions. This general TPACK factor should be considered when depicting the different specific dimensions of teachers' knowledge and associated self-efficacy for technology-enhanced teaching (Scherer et al., 2017).

Previous research mainly relied on teachers' self-assessments and confidence in doing different tasks associated with the specific skills of the TPACK framework (Fisser et al., 2015). One prominent example is the questionnaire by Schmidt et al. (2009) that asks teachers to indicate their confidence in doing distinct tasks (e.g., “I can choose technologies that enhance what and how I teach.“). Accordingly, these self-evaluations of knowledge are discussed as rather depicting self-efficacy beliefs than available knowledge (see Lachner, Backfisch, & Stürmer, 2019; Scherer et al., 2017; Fisser et al., 2015; Kopcha et al., 2014; Krauskopf & Forssell, 2013, pp. 2190–2197; Petko, 2020; Willermark, 2018, for critical discussions of TPACK self-report measures). For example, if teachers indicate that they are highly confident in choosing technologies that enhance what and how they teach it cannot be granted that this is the case in reality. In general, research that investigated the relation of teachers' self-efficacy and their actual technology integration showed a positive relationship (Chuang et al., 2015; Fraillon et al., 2019; Scherer, Siddiq, & Teo, 2015). However, the multidimensional structure of teachers’ self-efficacy beliefs has mostly been neglected in these studies.

2.2.2. Perceived utility-value

In addition to teachers' self-efficacy expectations in their ability to teach with technologies, value beliefs are considered a crucial barrier regarding technology integration. Particularly their utility-value of teaching with technologies showed to be an important aspect (Backfisch et al., 2020; Scherer et al., 2017; Taimalu & Luik, 2019). Utility-value describes the degree to which teachers perceive an added value of using and/or integrating technologies into their teaching and therefore perceive them as useful for their teaching. The notion of perceived usefulness frequently used in TAM research (since Davis, 1989) resembles the utility-value construct from EVT research. For example, teachers might perceive technologies as useful, as their use enables individual and adaptive learning activities and therefore might enhance students’ learning as well as their digital literacy (Backfisch et al., 2020). Higher levels of utility-value might prompt teachers to integrate technologies more often during their teaching (Backfisch et al., 2020; Scherer et al., 2015; Wozney et al., 2006).

2.3. Relations between self-efficacy, utility-value, and technology integration

2.3.1. Concurrent mechanism

The EVT considers self-efficacy and value beliefs to be side-by-side constructs that both have a simultaneous direct effect on behavior (i.e., *concurrent mechanism* of motivation on behavior, see Fig. 1A).

A first empirical illustration of these assumptions with regard to teachers' technology integration can be found in the study by Wozney et al. (2006). In a cross-sectional study with 764 primary and secondary teachers, the authors investigated the relations of self-efficacy and perceived utility-value on technology integration. In line with EVT, the authors found that both, self-efficacy and utility-value were directly related to frequency of technology use. However, this theory-conform pattern could rarely be replicated in further studies. For instance, Taimalu and Luik (2019) examined the impact of the motivation of teacher educators ($N = 54$) on their technology integration by means of a questionnaire. The authors showed that only technology-related self-efficacy had a direct effect on technology integration, but not utility-value beliefs. Contrarily, Backfisch et al. (2020) investigated the relations of teacher motivation and quality of technology integration in a lesson-planning scenario. Here, Backfisch et al. found that perceived utility-value, but not self-efficacy predicted the quality of technology-enhanced lesson plans (see Backfisch, Lachner, Stürmer, & Scheiter, 2021 for similar findings). Therefore, the

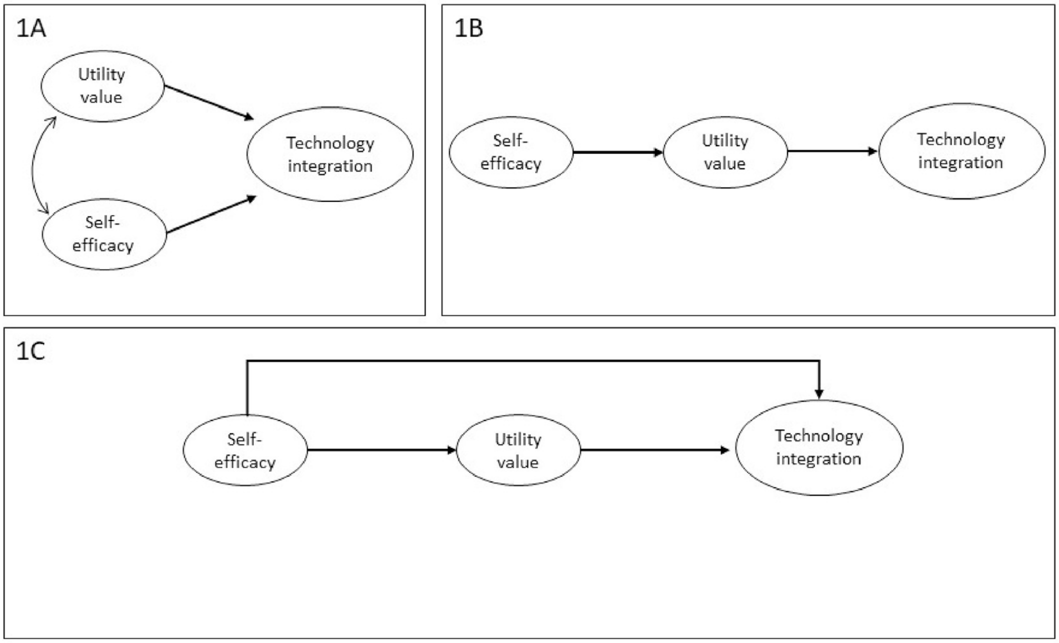

Fig. 1. Schematic representation of concurrent mechanism based on EVT (1A), cascade mechanism model based on TAM (1B) and integration model considering both mechanisms (1C).

extent to which teachers' utility-value and self-efficacy directly influence their technology integration in a concurrent mechanism is still an open issue.

2.3.2. Cascade mechanism

In contrast to the assumed direct effects of self-efficacy and utility-value on technology integration, TAM assumes a cascaded mechanism (*cascade mechanism* Scherer & Teo, 2019; Teo, 2011, see Fig. 1B).

Scherer et al. (2019) tested such a cascade mechanism of teacher motivation on technology integration by means of a meta-analytic structural equation model, based on 114 studies. In line with TAM, they found that teacher motivation followed a cascade mechanism where, first, self-efficacy was linked to the core variables of the TAM such as utility beliefs, and, second, utility beliefs were linked to the behavioral intention and technology integration. However, it has to be noted that in many primary studies within the TAM framework the direct link between use intentions and actual use was missing (Nistor, 2014; Scherer et al., 2019). For example, Teo (2009) examined direct relations of pre-service teacher motivation and behavioral intention and found direct links of, both, self-efficacy and utility-value on their behavioral intention to use technologies. However, the Author did not investigate potential relations with the actual technology integration. In line with EVT, Scherer et al. (2019) conclude that teachers' self-efficacy should be further investigated in terms of direct relations of self-efficacy and technology integration as it possibly serves as a direct barrier or enabler for their behavior.

2.3.3. Two worlds apart?

Overall, the derived mechanisms of teacher motivation and technology integration informed by the EVT and the TAM differ in their proposed relations of motivational beliefs on technology integration (concurrent vs. cascade mechanisms). At the same time, both theoretical considerations refer, among other variables, to the same explanatory components of motivational beliefs as core variables: self-efficacy and perceived utility-value. Therefore, the investigation of those two crucial components of teacher motivation enables to investigate and contrast the divergent mechanisms proposed by the TAM and EVT.

Regarding research on technology integration, the combination of EVT and TAM can expand the field of research as EVT, in contrast to the TAM, particularly focusses on the persistence and performance in a task. Therefore, EVT goes beyond the mere behavioral intention which is addressed in studies following the TAM framework. Following EVT it is apparent that research has to examine how teachers' use technologies to foster distinct teaching and learning processes as well as to support students' digital literacy (see also Siddiq et al., 2016). Recently, Ranellucci et al. (2020) also combined TAM and EVT to investigate the relation of pre-service teachers' motivation ($N = 249$) and their intention to use technologies. Ranellucci et al. could not find a significant relation of self-efficacy beliefs and behavioral intention, but only a significant relation of utility-value and behavioral intention. Against this background, a major benefit of integrating EVT and TAM might not only be the specification of concrete mechanisms of value beliefs and self-efficacy, but, following EVT, also the direct investigation of teachers' behavior (i.e., technology use) and not only their behavioral intention.

Regarding teacher education, the combination of EVT and TAM can provide a guideline for more comprehensive professional development courses as following either of the theoretical models induce different design principles and goals. Teacher education courses following the TAM framework might mainly focus on fostering teachers' value beliefs and fostering their behavioral intention to use technologies during teaching. These courses might primarily show the benefit and value of using technologies during teaching and engage the teachers to think of concrete scenarios in which they could use technologies in their teaching to heighten their behavioral intention to use technologies. In contrast, courses following the EVT would focus on fostering, both, value beliefs and self-efficacy of using technologies for teaching with the goal of promoting teachers' persistence and performance in teaching with technologies. These courses might not only show the benefit of using technologies but also offer possibilities to try out technology-enhanced teaching to advance teachers' self-efficacy in using technologies. Additionally, teachers might be encouraged to design technology-based lessons to improve their performance in teaching with technologies (e.g., micro-teachings; Grossman & McDonald, 2008; Lee & Lee, 2014; Seidel, 2006). A synergism of EVT and the TAM might highlight the significant role of value beliefs based on the TAM and simultaneously shifts the focus towards the question of how technologies are integrated and the important role of teachers' efficacy beliefs informed by EVT.

To sum up, there are mixed results and blind spots in both lines of theoretical reasoning which may require an integrated perspective yielding a synergism of both lines of research. The integration of the concurrent and cascade mechanism would lead to a model which not only assumes direct relations of teachers' self-efficacy and utility-value on technology integration but would also acknowledge a cascade mechanism of self-efficacy and utility-value, see Fig. 1C. Therefore, it is suggested that rather than being mutually exclusive, the relation between teacher motivation and technology integration may both constitute paths of concurrent and cascade mechanisms. Bringing together these two mechanisms will advance the field of research as well as teacher education as it may clear up possible divergent practices and identify synergies.

3. Present study

3.1. Objective of the study

The objective of the study was to examine the mechanisms of teachers' motivation and their use of technologies for teaching and learning in a differentiated way, that is, differentiating between different proposed mechanisms based on EVT and TAM. The two theories build on two diverging assumptions about mechanisms of different aspects of teacher motivation for technology integration: assuming either a concurrent mechanism following EVT; or a cascaded mechanism which defines a distinct sequence of relations based on TAM.I If one strictly followed the mechanisms proposed by EVT, one would neglect a cascaded trend from self-efficacy on value beliefs, whereas following TAM might underestimate the significance of self-efficacy and its direct impact on teachers' technology use during teaching. Nevertheless, the two research strands consider the same aspects of teacher motivation as core concepts: self-efficacy and value beliefs. The investigation of those two core concepts were in the focus of the present study and enabled to examine and to statistically contrast the core mechanisms of EVT and TAM.

Moreover, EVT and TAM differ in the conceptualization of outcome measures: Whereas EVT focuses on the performance and persistence within a task and therefore rather on qualitative indicators, TAM focuses on the behavioral intention of using technologies and the frequency of its use. To represent both theories, we investigated the level of technology integration by means of two complementary measures: first, the frequency of teachers' technology integration by their technology use regarding different activities and, second, the emphasis teachers put on developing students' digital skills as a measure regarding the quality and intensity of technology integration. Therefore, the present study allowed to investigate the predictive power of teacher motivation for different aspects of technology integration as it is particularly demanded in research following the TAM (Scherer & Teo, 2019; Nistor, 2014; Šumak et al., 2011).

To this end, the aim of the present study was to investigate the extent to which teachers' self-efficacy and value beliefs could explain their technology use during teaching. The findings will comprehensively inform research and educational practice regarding the underlying mechanisms of teacher motivation on technology integration. This way, blind spots of either theory in the context of technology-rich environments can be avoided. Given that our study focuses on one-to-one classrooms, without potential bias by additional external barriers such as lack of infrastructure (Ertmer et al., 2012), the present study allows to draw some conclusions relevant for subsequent one-to-one initiatives and for prospective teacher education when classrooms are comprehensively equipped with technical infrastructure.

3.2. Context of the study

The present study was conducted within a governmental initiative in a medium-sized municipality in Norway. The municipality is responsible for 24 schools which vary in terms of the number of students and the students' socio-economic background (Tømte et al., 2019). Prior to the present initiative, the schools only had limited access to technologies with only stationary computers, and/or shared laptops. However, in general, the ICIL study 2013 showed that Norwegian students are well equipped when it comes to technology access at their homes: Most of the students have their own smartphones, and access to tablets and computers at home (Ottestad et al., 2014). Within the present initiative all 16 primary and 8 lower secondary schools (grades 1–10, age of students: 6–16 years) in the municipality were equipped with individual technological devices for every teacher and every student (i.e., tablets or laptops). Additionally, all participating teachers were enrolled in a professional development program. The present survey was conducted in 2017 at the start of the governmental initiative, meaning that all participating teachers already taught in actual one-to-one-classrooms. However, they were likely to possess relatively low levels of professional knowledge for technology integration given the little experience they had yet acquired with technology-based teaching.

3.3. Research questions

The context of the study allowed us to disentangle the divergent mechanisms (i.e., concurrent vs. cascade mechanism) of motivational beliefs on technology integration, as we had a unique technology rich research environment without external barriers such as lacking infrastructure. We operationalized technology integration, both in terms of the mere frequency of in-class technology use (*Research Question 1*), but also teachers' emphasis on developing students' digital literacy which rather represents the intensity of technology use (*Research Question 2*). Besides testing concurrent versus cascade mechanisms, we explored the possible synergism between concurrent and cascade mechanisms in an integrated model, see Fig. 1. Specifically, we addressed the following research questions (RQs):

RQ 1: To what extent do teachers' TPACK self-efficacy and utility-value explain variation in the frequency of in-class technology use in (a) a *concurrent mechanism*, (b) a *cascade mechanism*, and (c) an *integrated mechanism*?

RQ 2**:** To what extent do teachers' TPACK self-efficacy and utility-value explain variation in the emphasis teachers put on developing students' digital literacy in (a) a *concurrent mechanism*, (b) a *cascade mechanism*, and (c) an *integrated mechanism*?

4. Method

4.1. Sample

All teachers ($N = 730$) who were part of the initiative received an invitation via e-mail with a link to the online survey. The participation in the survey was voluntarily and anonymous. $N_{initial} = 717$ teachers (98% participation rate) gave their consent to participate in the study and started to fill in the survey. The whole procedure was approved by the Norwegian Centre for Research Data.

We excluded the data from 193 teachers, because either their responses on the TPACK self-efficacy or the utility-value scales were completely missing and/or these teachers were not fully certified (e.g., librarians, assistant teachers). The final sample of the present study consisted of $N = 524$ fully certified in-service teachers (age: $M = 45.25$ years, $SD = 11.05$ years, teaching experience: $M = 14.97$ years, $SD = 10.24$ years). The teachers were equally distributed across grades and subjects taught ($n = 340$ primary school teachers (grades 1–7), $n = 184$ secondary school teachers (grades 8–10), see Table A1 in Appendix for exact numbers.

4.2. Measures

An overview and examples of all measures applied can be found in Table 1. For the descriptive statistics and scale properties (e.g., mean, reliability, skewness) of our measures see Table 2. All constructs that assessed the motivational beliefs as well as technology integration were represented as latent (unobserved) variables (Kline, 2016), see the Supplementary Material and the syntax.

4.3. Data analyses

4.3.1. Model estimation and evaluation

All manifest indicators of the latent variables were approximately normally distributed (see Table 2). To evaluate the fit of the structural equation models, we referred to established guidelines for an acceptable fit (i.e., CFI $\geq$ 0.95, TLI $\geq$ 0.95, RMSEA $\leq$ 0.08, and SRMR $\leq$ 0.10; Hu & Bentler, 1999; Kline, 2016). However, especially for complex factor structures with nested factors, these guidelines should not be considered as strict cut-off criteria, because they have been validated mainly for correlated-traits factor models (Marsh et al., 2004). As suggested by Scherer et al. (2017), we represented the factor structure of TPACK self-efficacy by a nested-factor model -specifically, we specified a bifactor-(S-1) measurement model (Eid et al., 2017). This bifactor structure of TPACK self-efficacy consisted of one general factor (indicated by all TPACK self-efficacy item responses) and four specific factors (each indicated by the specific items of the four TPACK dimensions TPK, TCK, TPCK, and TK). In this model, the specific factors co-vary, and one reference factor is chosen based on theoretical and conceptual reasoning (Eid et al., 2017; see Fig. 2). We choose the Technological Knowledge (TK) factor as the reference, because it was found to co-vary less with all other TPACK-factors in previous studies (e.g., Scherer et al., 2017). As a consequence of setting this reference, all other specific factors represent the deviations from what is captured by the TK items. For a more detailed explanation of this procedure and the reasoning behind the interpretation of the resultant factors see Eid et al. (2017).

Additionally, we compared competing models by means of chi-square difference testing and by evaluating the differences in the goodness-of-fit indices next to the overall fit of the models. This was possible, as the two different models (concurrent and cascade mechanism models) differed in only one parameter (Kline, 2016)—the direct effect of self-efficacy on technology integration that only exists in the concurrent mechanism model. All models were specified and estimated using the R package *lavaan* (Rosseel, 2012).

4.3.2. Item parceling

Given that the models used to represent the constructs and their relations contained many parameters (due to the number of constructs involved and the bifactor structure) relative to the restricted sample size ($N = 524$), we used item parceling to effectively reduce the number of model parameters and, ultimately, describe the relations between motivational beliefs and technology integration with a more parsimonious model. Furthermore, statistical power and reliability are gained (Little et al, 2002, 2013; Rieger et al., 2019). We followed suggestions by Little et al. (2013) and built the item parcels summarized in a 'super-item' through averaging the item response scores based on factor loadings of each item. First, the item with the highest factor loadings was selected; second, the one with the lowest factor loading was selected. These two

Table 1
Overview of applied measures.

Measures	Assessment	Examples	# items	Scale	Source
TPACK self-efficacy assessed on four different dimensions:	Teachers were asked to indicate their confidence in fulfilling tasks on the different dimensions of TPACK.		12	0 (*strongly disagree*) to 3 (*strongly agree*)	Tondeur, Scherer, Siddiq, & Baran, 2017 based on Schmidt et al., 2009
TPCK self-efficacy		I can teach lessons that appropriately combine technologies, literacy, and teaching approaches.			
TCK self-efficacy		I can choose ICT applications that support lessons a subject domain.			
TPK self-efficacy		I can choose technologies that enhance the teaching approaches for a lesson.			
TK self-efficacy		I can learn technology easily.			
Utility value of educational technologies	Teachers were asked to indicate their agreement to statements regarding the value of educational technologies.	Using technologies in school helps students work at a level appropriate to their learning needs.	8	0 (*strongly disagree*) to 3 (*strongly agree*)	Fraillon et al. (2014)
Frequency of in-class technology use	Teachers were asked to indicate how often they used technologies for different classroom scenarios.	I used technologies for presenting information through direct class instruction. I used technologies for providing feedback to students.	11	0 (*never*) to 3 (*in every or almost every lesson*)	Fraillon et al., 2014; Siddiq et al., 2016
Emphasis on developing students' digital literacy	Teachers were asked to rate the degree to which they emphasized the development of digital literacy skills in their teaching.	Evaluating the credibility of digital information. Exploring a range of digital resources when searching for information.	14	0 (*no emphasis*) to 3 (*strong emphasis)*	Fraillon et al., 2014; Siddiq et al., 2016

Table 2
Descriptive statistics and scale properties.

Scale	*M*	*SD*	*N*	*Mdn*	*Min*	*Max*	Skewness	Kurtosis	*SE*	α
Utility value	2.073	.376	475	2.000	0.88	3.00	-.289	-.395	.017	.818
TPCK self-efficacy	1.811	.564	455	2.000	0.00	3.00	-.275	1.181	.027	.896
TCK self-efficacy	2.118	.531	484	2.000	0.00	3.00	-.154	1.341	.024	.924
TPK self-efficacy	1.803	.498	473	1.750	0.00	3.00	-.037	-.997	.023	.827
TK self-efficacy	1.682	.618	464	1.714	0.00	3.00	-.192	-.072	.029	.920
Frequency of technology use	1.105	.503	429	1.000	0.00	3.00	-.796	1.208	.024	.876
Teachers' emphasis on developing digital literacy	1.582	.712	426	1.712	0.00	2.93	-.687	-.167	.034	.948

Note. TPCK = Technological pedagogical content knowledge, TCK = Technological content knowledge, TPK = Technological pedagogical knowledge, TK = Technological knowledge; α = Cronbach's alpha.

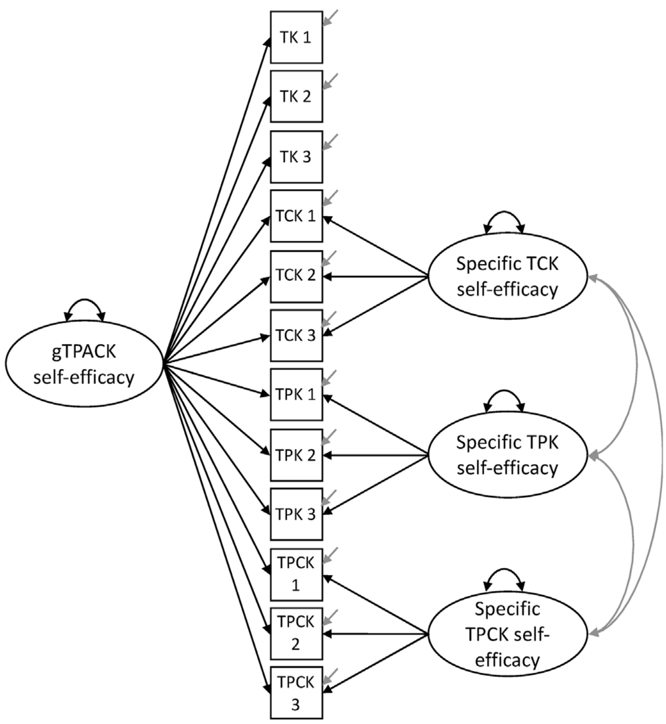

Fig. 2. Bifactor (S-1) structure of teachers' TPACK self-efficacy.

items were then averaged, and a new variable (i.e., the item parcel) was created representing the mean responses across the two chosen items (see also Little et al., 2002). This procedure was then repeated for the next parcel. We built three parcels for each scale (Little et al., 2013; Matsunaga, 2008),. Therefore, two to five items were averaged into one parcel depending on the number of items of the scale. This approach allowed to reduce the number of model parameters and simultaneously retain the relation among the structural parameters (Little et al., 2013). Moreover, this procedure allowed to avoid arbitrary item-item residual covariances, and, simultaneously improve model fit and convergence (Little et al., 2013; Matsunaga, 2008). Simulataneously, we acknowledge that the use of item parcels is not unproblematic, especially when testing for the invariance of model parameters across groups (Marsh et al., 2013). We therefore compared the results of our analyses between the models with item responses and item parcels as indicators of the latent variables (see Supplementary Material).

4.3.3. Handling missing data

As the in-service teachers ($N = 524$) participated in the study on a voluntarily basis in addition to their daily obligations, missing data occurred. In total, 6% of the item responses were missing. Given that no pattern of missingness surfaced, we assumed a missing-at-random mechanism and performed full-information-maximum-likelihood (FIML) estimation. This procedure takes into account all available information (i.e., also participants with missing values) when estimating the model parameters (Enders, 2010).

4.3.4. Measurement models of teacher motivation

First, we specified and estimated the measurement models for TPACK self-efficacy and utility-value. For *TPACK self-efficacy* and the item parcels as indicators, we first specified a correlated-traits model distinguishing between the four TPACK aspects as separate but correlated factors to depict the multidimensionality of teachers' TPACK self-efficacy (TCK, TPK, TPCK, and TK). The model exhibited an acceptable fit to the data, χ^2 (48) = 107.504, p < .001, RMSEA = 0.050, 90% CI RMSEA = [0.037, 0.062], CFI = 0.989, TLI = 0.985, SRMR = 0.025. Factor loadings in this model were high and ranged between 0.82 and 0.96. However, the correlations among some of the factors were high $\rho = 0.87$ (between the TCK and TPCK factor). Second, we specified the bifactor (S-1) model and obtained a well-fitting measurement model, χ^2 (42) = 79.230, p < .001, RMSEA = 0.042, 90% CI RMSEA = [0.028, 0.056], CFI = 0.993, TLI = 0.989, SRMR = 0.019. The general factor as well as its specific dimensions could be identified statistically through significant factor loadings (see Supplementary Material). Comparing the correlated-traits and bifactor (S-1) models showed the preference of the latter over the former, $\Delta\chi^2$ (6) = 28.275, p < .001, ΔCFI = 0.004, ΔRMSEA = −0.008, ΔSRMR = −0.006. We therefore accepted the bifactor (S-1) model as a representation of TPACK self-efficacy in all subsequent analyses.

For *utility-value*, we created three item parcels—hence, the final measurement model exhibited an exact fit to the data without any degrees of freedom in the model (for more details on this general observation, please refer to Kline, 2016).

5. Results

5.1. Preliminary analyses

5.1.1. Descriptive statistics and scale reliabilities

First, we examined the descriptive statistics, characteristics of distributions, and reliability for each scale (see Table 2). Teachers' frequency of in-class technology use showed mediocre means indicating that teachers rather integrated technologies on average ‘in some’ to ‘in most lessons’ with huge differences among them as indicated by a high standard deviation. As the item distributions and scale distributions were neither severely skewed nor biased by ceiling effects, models that assume normally distributed latent variables could be specified. Cronbach's alpha showed acceptable to excellent reliabilities of the scales after one modification in the TPK scale (one item was deleted which was related to the self-efficacy of applying strategies which were learned during teacher education on how to teach with technologies).

The bivariate correlations showed that all investigated constructs were significantly correlated except for teachers' utility-value and the emphasis they put on developing students' digital literacy (see Table 3). Given the high correlations between the specific factors in the TPACK self-efficacy measurement model (ranging between $\rho = 0.53$ and $\rho = 0.77$; see Supplementary Material), which may bias the structural parameters (i.e., path coefficients) in the subsequent models, we examined multicollinearity. The resultant variance inflation factors for each of the specific TPACK factors, the general TPACK factor, and utility-value ranged between 1.22 and 3.28, indicating multicollinearity did not severely bias the structural parameters (criterion: VIF < 5; Thompson et al., 2017).

5.2. RQ 1: Teacher motivation and frequency of technology use

5.2.1. RQ 1a: Concurrent mechanism of teacher motivation on the frequency of technology use

First, we examined the concurrent mechanism of TPACK self-efficacy and utility-value on frequency of in-class technology use. Therefore, we implemented the bifactor (S-1) model of TPACK self-efficacy and the measurement model of utility-value as separate predictors of the frequency of technology use (see Fig. 3). The model fit was excellent, χ^2 (114) = 153.431, $p = .008$, CFI = 0.994, TLI = 0.992, RMSEA = 0.026, 90% CI RMSEA [0.014, 0.036], SRMR = 0.021. We found that self-efficacy of technology-enhanced teaching (general TPACK self-efficacy: $\beta = 0.514$, $SE = 0.083$, $p < .001$, specific TPK self-efficacy, $\beta = 0.324$, $SE = 0.155$, $p = .036$) as well as their utility-value ($\beta = 0.147$, $SE = 0.073$, $p = .044$) were directly related to the frequency of technology use. The two predictors explained 22.5% of the variance in technology use. This finding indicates that as assumed by the EVT, self-efficacy *and* utility-value both were concurrently (i.e., directly) related to the frequency of in-class technology use.

5.2.2. RQ 1b: Cascade mechanism of teachers' motivation on the frequency of technology use

To model the cascade mechanism proposed in the TAM, we only allowed for the cascaded/indirect effect of TPACK self-efficacy on technology use via their utility-value (i.e., self-efficacy → utility-value → frequency of technology use, Fig. 4). The indirect effects were estimated by using 100 bootstrap samples. This model also showed the hypothesized path, following a cascade with a significant positive relation between self-efficacy of technology-enhanced teaching and utility-value towards technology use (general TPACK self-efficacy: $\beta = .482$, $SE = 0.063$, $p < .001$; specific TPK: $\beta = 0.217$, $SE = 0.098$, $p = .027$). Utility-value ($\beta = 0.431$, $SE = 0.077$, $p < .001$) was also positively related to the frequency of technology use. Additional mediation analysis revealed that this cascaded (indirect) effect was indeed significant (general TPACK self-efficacy: $a \times b = 0.208$, bootstrapped $SE = .049$, $p < .001$, specific TPK self-efficacy: $a \times b = 0.094$, bootstrapped $SE = .054$, $p = .080$). The total effect was $\beta = 0.289$, bootstrapped $SE = .074$, $p < .001$. The overall model fit was reasonable (χ^2 [118] = 208.976, $p < .001$, CFI = 0.987, TLI = 0.983, RMSEA = 0.038, 90% CI RMSEA [0.030, 0.047], SRMR = 0.086), and 11.1% of the variance in technology use were explained. Thus, our analyses also showed evidence for the cascade mechanism model based on the technology-acceptance model (TAM); yet, with a poorer model fit than the concurrent mechanism model, $\Delta\chi^2$ (4) = 55.545, ΔCFI = −0.007, ΔRMSEA = 0.012, ΔSRMR = 0.065.

5.2.3. RQ 1c: Integrated perspective

The previous analyses provided evidence supporting the fit of both the concurrent and the cascade mechanism models. However, the overall model fit of the concurrent mechanism model (informed by EVT) was significantly better than for the cascade mechanism model (informed by TAM).Including the direct effects of TPACK self-efficacy on technology use was key to improving model fit. However, part of the variance of the frequency of technology use was still explained by an indirect effect of self-efficacy via utility-value. Therefore, we built an integrated model encompassing direct and indirect paths of self-efficacy on the frequency of technology use and direct paths of utility-value on the frequency of technology use (see Fig. 1C for a schematic overview). This integrated model enabled us to see whether the indirect effect of self-efficacy via utility-value remained significant after allowing for the direct relation between self-efficacy and technology use. The direct relations between utility-value ($\beta = 0.147$, $SE = 0.073$, $p = .044$) and technology use as well as the direct relations between TPACK self-efficacy and technology use were statistically significant (general TPACK self-efficacy: $\beta = 0.514$, $SE = 0.083$, $p < .001$, TPK self-efficacy: $\beta = 0.324$, $SE = 0.155$, $p = .036$). An additional mediation analysis showed that the general TPACK self-efficacy still had an indirect effect ($\beta = 0.068$, bootstrapped $SE = .037$, $p = .068$) on technology use (see Fig. 5). The integrated model had an excellent fit, which was, due to the same covariance-matrix of the two models, exactly the same as the model fit of the concurrent model, χ^2 (114) = 153.431, $p = .008$, CFI = 0.994, TLI = 0.992, RMSEA = 0.026, 90% CI RMSEA [0.014, 0.036], SRMR = 0.021. Overall, 22.5% of the variance in technology use were explained.

The integrated model did not only consider a relation between self-efficacy and utility-value, but also encompassed the direction of the relation of self-efficacy and utility-value following a cascaded trend. Additional nesting and equivalence testing (NET, Bentler & Satorra, 2010) showed that the integrated model had the equivalent complexity as the concurrent model (see Supplementary Material).

As an exploratory analysis, we investigated differential effects of teacher motivation on different type of technology use (teacher-vs. student-centered usages). These analyses showed that for student-centered technology usages especially teachers' TPK self-efficacy

Table 3
Bivariate Correlations among the Measures.

	1	2	3	4	5	6
1 Frequency of technology use	1.00					
2 Teachers' emphasis on developing students' digital literacy	.564**	–				
3 Utility value	.249**	.099				
4 TCK self-efficacy	.300**	.218**	.276**			
5 TPK self-efficacy	.404**	.293**	.311**	.618**		
6 TPCK self-efficacy	.372**	.275**	.366**	.650**	.758**	
7 TK self-efficacy	.400**	.295**	.380**	.550**	.587**	.597**

**$p < .001$.

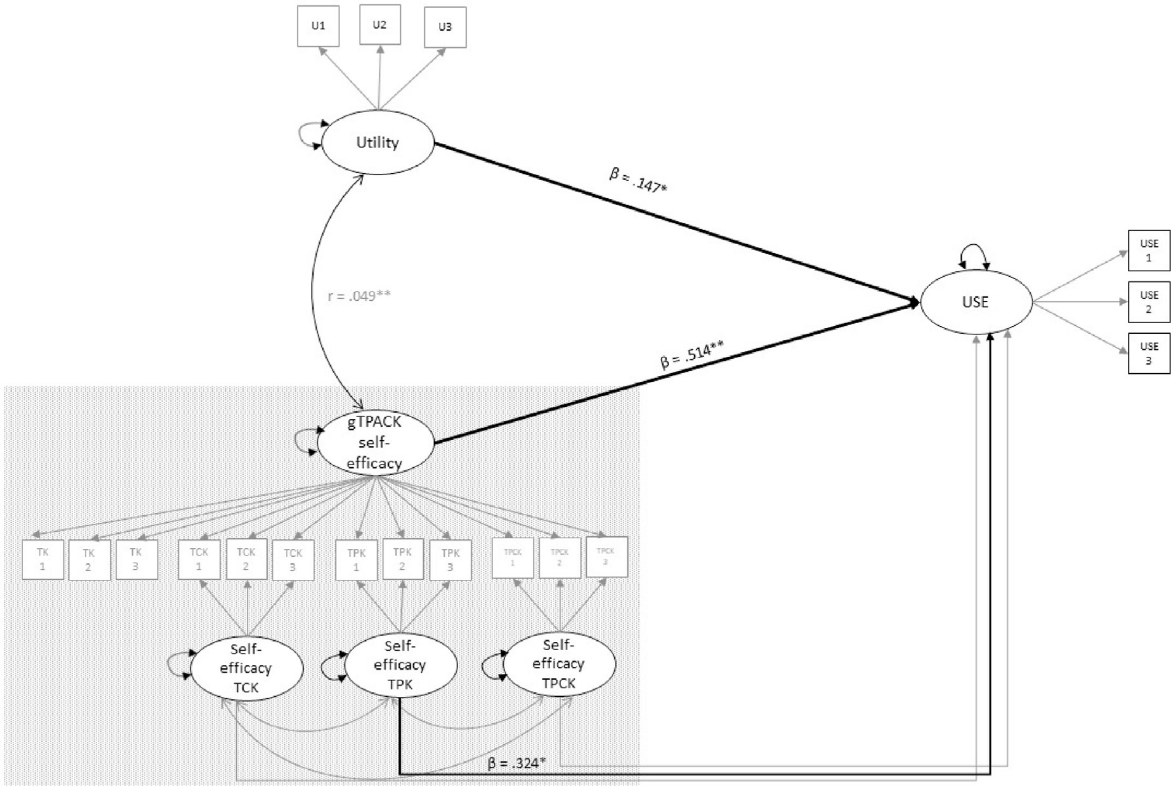

Fig. 3. Concurrent Mechanism Model of Teachers' Self-Efficacy and Utility Value on Frequency of Technology Use. *Note.* Bold lines represent statistically significant paths. The measurement model of TPACK self-efficacy is shaded in grey. *$p < .05$, **$p < .01$.

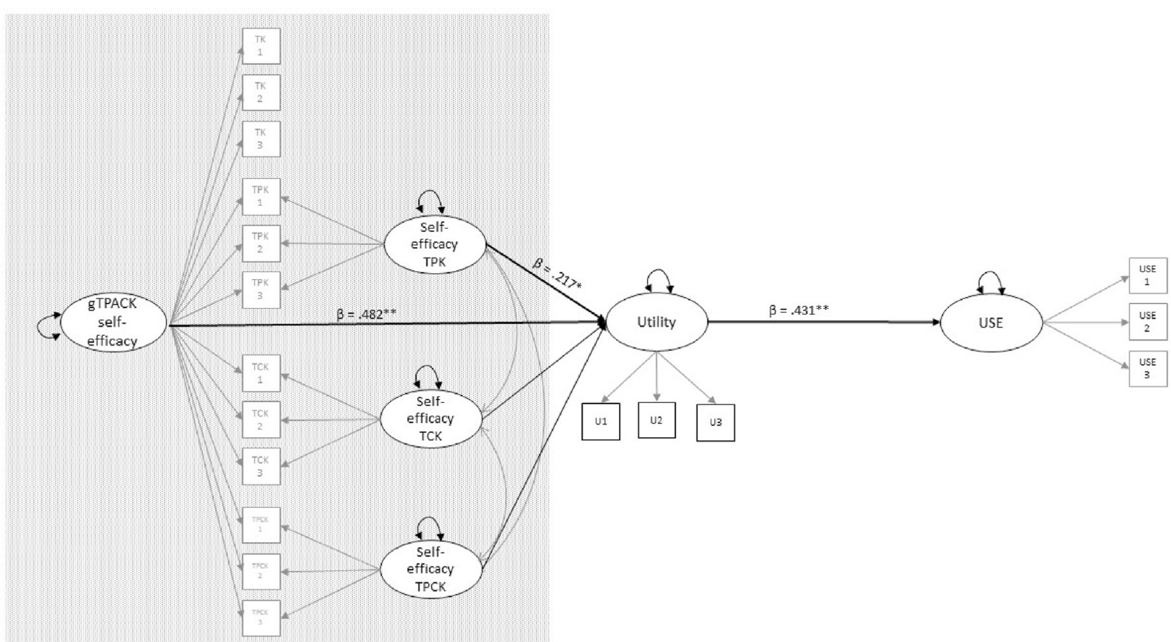

Fig. 4. Cascade mechanism model of teachers' self-efficacy and utility value on frequency of technology use. *Note.* Bold lines represent statistically significant paths. The measurement model of TPACK self-efficacy is shaded in grey. *$p < .05$, **$p < .01$.

was crucial, whereas it played a subordinate role in teacher-centered applications. However, these findings should be treated with caution, because the frequencies of different types of usages were highly correlated (see Supplementary Material).

Overall, our findings showed that both hypotheses on the mechanisms of relations between TPACK self-efficacy, utility-value, and the frequency of technology use could be supported. The model comparisons indicated that a direct relation between TPACK self-

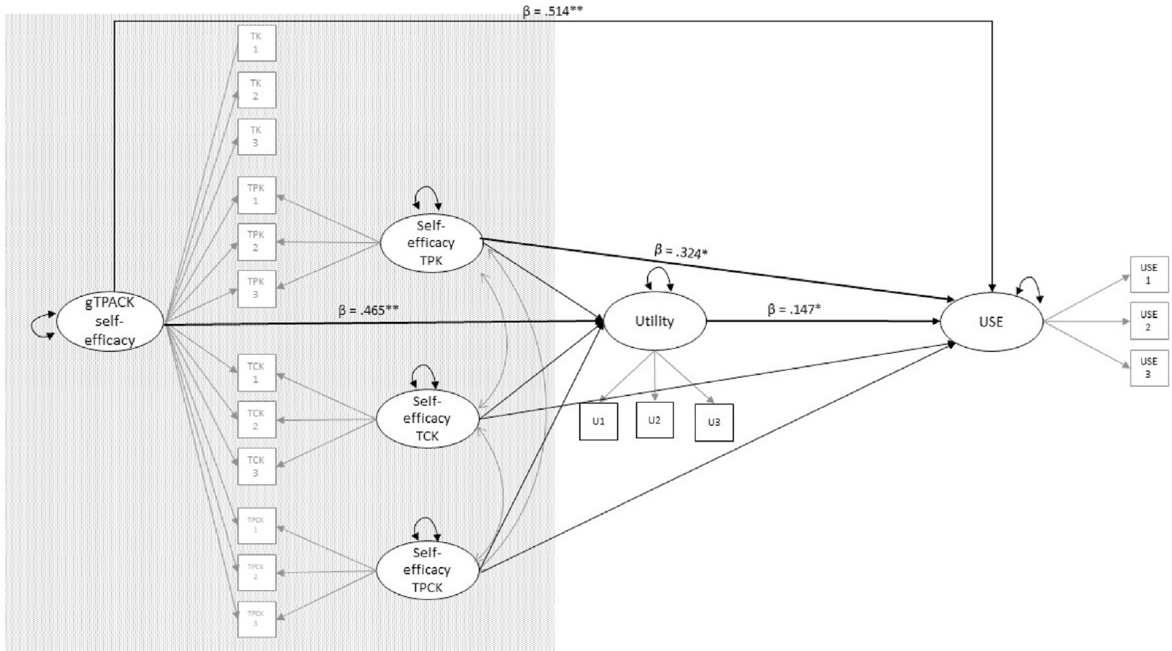

Fig. 5. Integrated model of teachers' self-efficacy and utility value on frequency of technology use. *Note.* Bold lines represent statistically significant paths. The measurement model of TPACK self-efficacy is shaded in grey. $^{*}p < .05$, $^{**}p < .01$.

efficacy and technology existed—this observation suggests that self-efficacy cannot only be considered an external variable which operates indirectly through utility-value (as proposed in the TAM) but is also a variable with a direct explanatory connection to technology use.

5.3. RQ 2: Teacher motivation and emphasis on developing students' digital literacy

5.3.1. RQ 2a: Concurrent effect mechanism of motivation on emphasis

Regarding teachers' emphasis on developing students' digital literacy as outcome variable the analysis showed that only the direct paths of TPACK self-efficacy on emphasis was significant (see Fig. 6). General TPACK self-efficacy ($\beta = 0.633$, $SE = 0.122$, $p < .001$) and TPK ($\beta = 0.459$, $SE = 0.234$, $p = .050$) were significantly related to teachers' emphasis on developing students' digital literacy, while no significant direct effect of utility-value on their emphasis was obtained ($\beta = -0.042$, $SE = 0.110$, $p = .701$). The model fit was very good, χ^2 (114) = 165.323, $p = .001$, CFI = 0.993, TLI = 0.991, RMSEA = 0.029, 90% CI RMSEA [0.019, 0.039], SRMR = 0.026. This analysis indicated that self-efficacy of teaching with technology was directly related to the emphasis teachers' put on developing their students' digital literacy—however, their utility-value was not. Therefore, the assumed concurrent mechanism informed by the EVT could only be partly confirmed. Overall, 11.6% of the variance in the outcome variable could be explained.

5.3.2. RQ 2b: Cascade effect mechanism of motivation on emphasis

To model the cascade mechanism proposed in the TAM, we only allowed for the indirect effect of TPACK self-efficacy on their emphasis on developing students' digital literacy (see Fig. 7). Again, the general TPACK self-efficacy factor and the specific TPK factor were positively related to utility-value (general TPACK self-efficacy: $\beta = 0.473$, $SE = 0.060$, $p < .001$; specific TPK self-efficacy: $\beta = 0.214$, $SE = 0.118$, $p = .069$). Furthermore, perceived utility ($\beta = 0.307$, $SE = 0.096$, $p = .001$) was positively related to the emphasis teachers put on developing students' digital literacy skills. An additional mediation analysis showed that this cascaded effect was significant (general TPACK self-efficacy: $\beta = 0.145$, bootstrapped $SE = .053$, $p = .006$). The total effect was $\beta = 0.202$ (bootstrapped $SE = .071$, $p = .005$). The model fit was slightly worse than in the concurrent model, χ^2 (118) = 204.032, $p < .001$; CFI = 0.988, RMSEA = 0.037, 90% CI RMSEA [0.029, 0.046], SRMR = 0.084, suggesting that it is important to consider the direct effects of TPACK self-efficacy on the emphasis they put on developing students' digital literacy, which are proposed in the EVT. Overall, 2.5% of the variance in teachers' emphasis could be explained, while 21.8% of the variance in utility-value was explained.

5.3.3. RQ 2c: Integrated perspective

Again, already the evaluation of the overall model fit indicated that the concurrent mechanism model represented the data better than the cascade mechanism model. This was also supported by means of chi-square difference testing as it showed a significant better fit for the concurrent mechanism model, $\Delta\chi^2$ (4) = 38.709, p < .001, ΔCFI = −0.005, ΔRMSEA = 0.008, ΔSRMR = 0.058. Additionally, we build an integrated model encompassing direct and indirect effects of self-efficacy and direct effects of utility-value on the emphasis of developing students' digital literacy (see Fig. 1C for a schematic overview; see Fig. 8 for the detailed model parameters). In line with the considerable better model fit of the concurrent model, the model fit of the integrated model was very good χ^2 (114) = 165.323, $p = .001$; CFI = 0.993, RMSEA = 0.029, 90% CI RMSEA [0.019, 0.039], SRMR = 0.026. Both models were equally complex (Bentler & Satorra, 2010). The model showed direct relations between self-efficacy for technology-enhanced teaching and the emphasis on developing students' digital literacy (general TPACK self-efficacy: $\beta = 0.633$, $SE = 0.122$, $p < .001$, specific TPK self-efficacy: $\beta = 0.459$, $SE = 0.234$, $p = .050$). Additionally, general TPACK self-efficacy was related to the utility-value ($\beta = 0.465$, $SE = 0.060$, $p < .001$). However, there were no indirect effects of

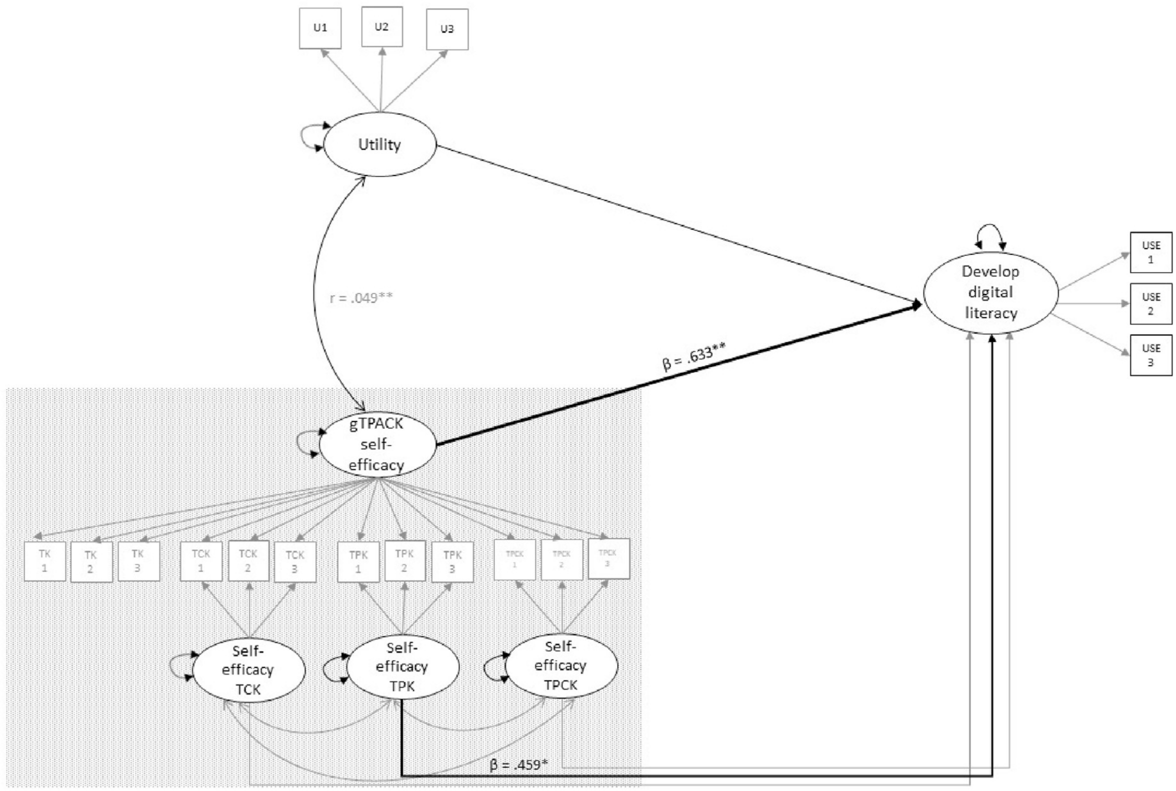

Fig. 6. Concurrent Mechanism Model of Teachers' Self-efficacy and Utility Value on Teachers' Emphasis on developing Students' Digital Literacy. *Note.* Bold lines represent statistically significant paths. The measurement model of TPACK self-efficacy is shaded in grey. *$p < .05$, **$p < .01$.

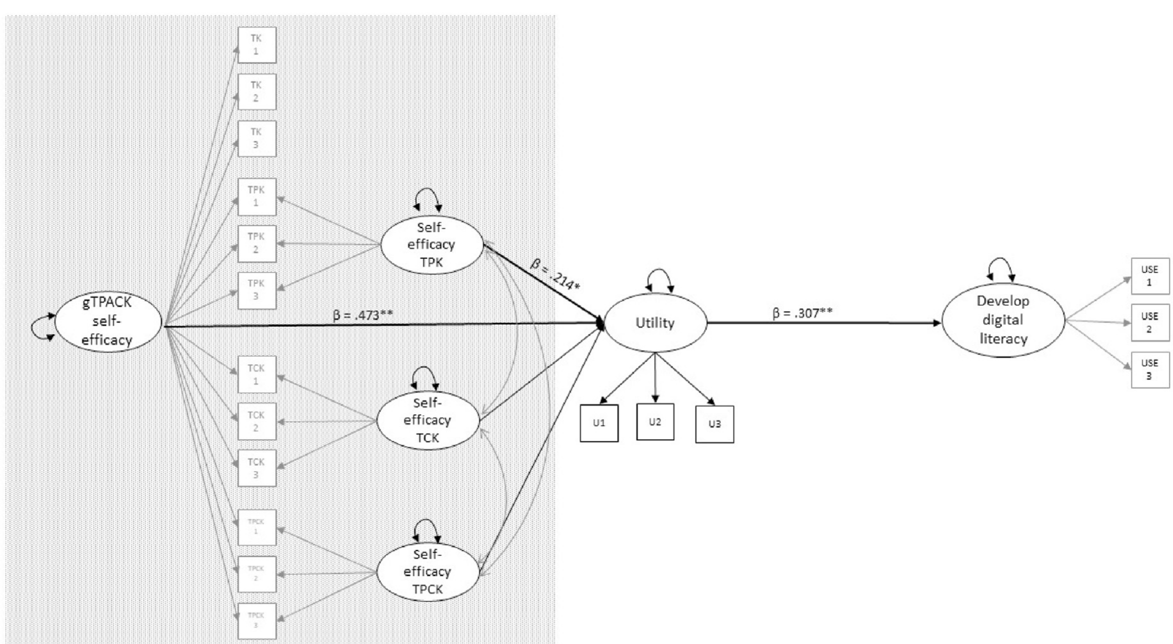

Fig. 7. Cascade Mechanism Model of Teachers' Self-Efficacy and Utility Value on Teachers' Emphasis on developing Students' Digital Literacy. *Note.* Bold lines represent statistically significant paths. The measurement model of TPACK self-efficacy is shaded in grey. *$p < .05$, **$p < .01$.

self-efficacy on teachers' emphasis on developing students' digital literacy and, in line with that, no significant total effect (see Supplementary Material). This model resulted in a variance explanation of 11.5% in the final outcome variable and 21.2% in utility-value.

Overall, the present findings give as one of the first studies valuable insights on the constituents of the emphasis teachers put on developing students' digital literacy. The analysis suggests that self-efficacy is directly related to their emphasis and therefore most

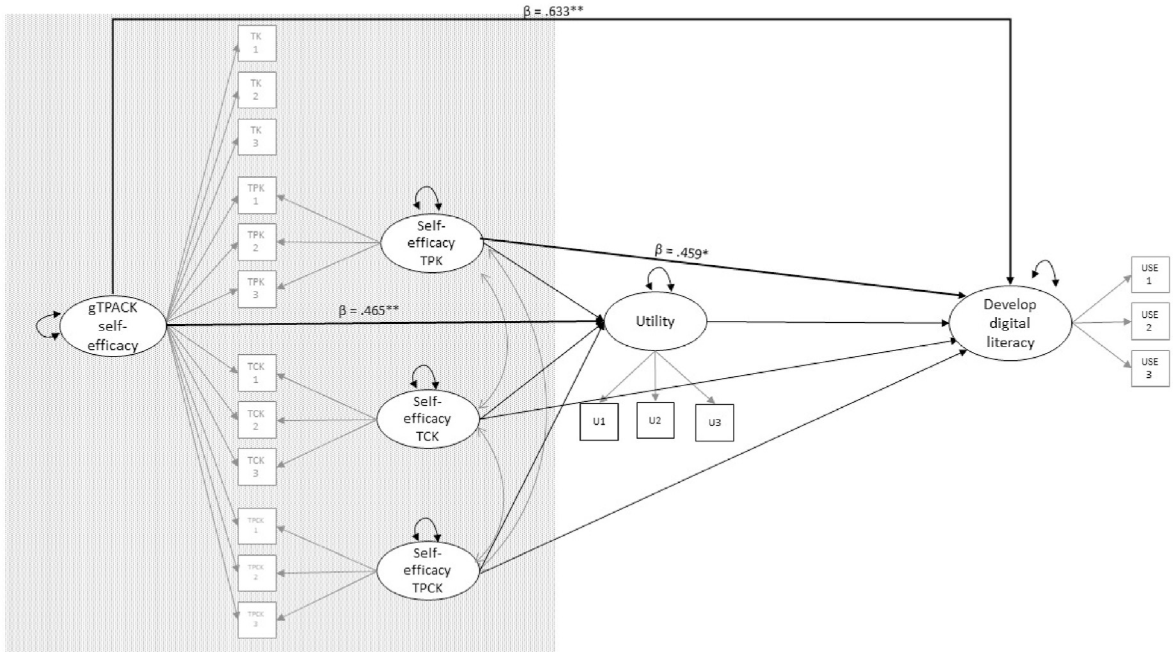

Fig. 8. Integrated Model of Teachers' Self-Efficacy and Utility Value on Teachers' Emphasis on developing Students' Digital Literacy. *Note.* Bold lines represent statistically significant paths. The measurement model of TPACK self-efficacy is shaded in grey. *$p < .05$, **$p < .01$.

important whereas their utility-value is not. In addition, there were no indirect relations of self-efficacy and teachers' emphasis.

6. Discussion

The present study investigated the relations between teacher motivation and their technology integration in a unique technology-rich environment. More precisely, we investigated the predictive power and concrete mechanisms of self-efficacy and value beliefs as determinants of technology integration. We followed two divergent theoretical perspectives which either assumed (a) a concurrent mechanism of TPACK self-efficacy and utility-value informed by EVT; or (b) a cascade mechanism following TAM. Instead of measuring technology use only by items assessing the frequency of using *specific software or technological devices*, we measured this variable by items assessing the frequency of technology use for *specific instructional activities and the emphasis* placed on fostering digital skills. These measurements offer a skills-development and a multiple-measures perspective on technology use (Bebell et al., 2004) and more adequately reflect the focus of EVT on persistence and performance in tasks as outcome measure (Eccles & Wigfield, 2002). In sum, the present study expands the current field of research on technology integration regarding two aspects: First, we highlighted the crucial role of self-efficacy beliefs as central and direct determinant of technology integration. Second, we directly investigated teachers' technology integration in the classroom by its frequency and emphasis towards developing students' digital literacy. With this approach, we followed recent demands within TAM research to further investigate the role of self-efficacy beliefs and to examine teachers' technology use directly rather than just their behavioral intention to use it (Scherer & Teo, 2019; Nistor, 2014; Šumak et al., 2011).

Regarding the frequency of in-class technology use, structural equation modelling revealed that the concurrent and the cascade model represented the data well. Based on additional model comparison tests, we found that an integrated model encompassing direct and indirect relations of self-efficacy, utility-value and the frequency of technology use may best represent our data. Therefore, when teachers get started with using technologies for teaching, self-efficacy may have a direct effect and an indirect effect via utility-value on their frequency of technology use.

Regarding teachers' emphasis on developing students' digital literacy, however, only TPACK self-efficacy was predictive. This suggests that for distinct (complex) teaching activities such as improving students' digital literacy skills it might be more important that teachers feel confident to implement these teaching activities. As such, these findings suggest that teachers' self-efficacy might be more than an external variable, as it has direct effects on their technology integration.

Additionally, the representation of TPACK self-efficacy in a bifactorial measurement model allowed us to disentangle differential effects of the different components of technology-related self-efficacy on their technology integration. This analysis showed that besides the relation of teachers' general self-efficacy regarding technology-enhanced teaching their self-efficacy of being able to integrate technologies in their pedagogical approaches (i.e., TPK self-efficacy) played a crucial role.

By focusing our study on one-to-one classrooms without potential bias from additional external barriers such as lack of infrastructure (Ertmer et al., 2012), we could investigate the 'net' effect of teacher motivation on technology integration. The findings of our study are not only generalizable to the plethora of one-to-one initiatives around the globe, but also to the technology-rich future where technical infrastructure will be readily available at schools.

6.1. Theoretical and methodological contributions and implications

From a theoretical point of view, the present study extends current research that is conducted informed by assumption based on the EVT and the TAM framework. Our findings rather corroborate an integrated perspective on teacher motivation and technology integration, at least for the frequency of in-class technology use. This finding may resolve potential differences between previous studies (Backfisch et al., 2020, 2021; Scherer et al., 2019; Taimalu & Luik, 2019; Wozney et al., 2006), as the integrated perspective suggests that direct and indirect relations of teacher motivation and technology integration may co-exist. Based on these analyses and in line with suggestions by Scherer et al. (2019), in research on technology integration, self-efficacy should be taken more into account. Our findings indicate that self-efficacy is not only highly related to core TAM variables, such as perceived utility, but also directly influences the frequency of technology use and emphasis on developing students' digital literacy. Therefore, our findings suggest that the EVT and the TAM are not mutually exclusive to understand the relation between teacher motivation and technology integration. Hence, an integrated perspective should be adopted when investigating teachers' technology integration for fostering teaching and learning processes. This integrated perspective considers previous work of, both, research focusing on relations of motivational beliefs and individuals' behavior (e.g., EVT; Eccles & Wigfield, 2002) and research focusing on technology use and identifying potential boundary conditions for its use (e.g., TAM Scherer & Teo, 2019; Scherer et al., 2019). Consequently, research that follows the reasoning of motivational beliefs theory should also take into account that there are cascade effects and relations of teachers' self-efficacy and their attitudes about technologies. In the field of student motivation this lack of considering intervening effects of self-efficacy and utility-value has been currently discussed (e.g., Nagengast et al., 2011; Trautwein et al., 2012), and should be transferred to research investigating direct relations of teacher motivation and their technology integration.

In addition, it might be useful for future research that follows the TAM reasoning to also consider direct relations of self-efficacy and technology integration. Our analyses suggested that, in contrast to traditional TAM approaches (Davis, 1989; Marangunić & Granić, 2015), self-efficacy might be more than an external variable that determines only attitudes and therefore only indirectly influences the use of technologies. Accordingly, modeling approaches should reflect that teachers' self-efficacy is an internal variable of their belief system (Bandura, 2010). Consequently, the TAM should be extended and adopted to highlight the significance of self-efficacy beliefs for actual behavior.

An unexpected finding was that only self-efficacy, but not utility-value was related to teachers' emphasis on students' digital literacy. This finding stands in contrast to previous studies, which demonstrated that the perceived utility was decisive for related yet distinct quality indicators, such as technology exploitation, or general teaching quality (e.g., Backfisch et al., 2020, 2021). The unexpected pattern can be explained in three ways:

First, the applied outcome measure was focused on the development of students' digital literacy and not, as in the studies by Backfisch et al. (2020, 2021) on subject-specific technology-enhanced teaching quality. Therefore, it might be the case that teachers need high utility-value to implement technology in a pedagogical meaningful manner; however, particularly, their self-efficacy might lead them to put emphasis on developing students' digital literacy. High self-efficacy beliefs might enable teachers to serve as role models in consciously using technologies and considering potential risks of technology use during teaching. Therefore, teachers with high self-efficacy might be able to, both, technologically enrich their domain-specific teaching and concurrently elaborate and discuss with students the potential impact of its use on a meta-level (Tondeur, Scherer, Siddiq, & Baran, 2020).

Second, in the present study we assessed teachers' utility-value based on their perceived added value of introducing technologies related to students' academic performance and motivation. However, the recently published study by Backfisch et al. (2020), additionally assessed utility-value based on teachers' perception of the societal relevance of teaching with technologies to respond to society's changing needs which likely corresponds to the emphasis teachers' put on developing students' digital literacy. This should be further investigated in future studies.

Third, we only applied self-reports, which may restrict the validity of our findings. Therefore, our findings should be replicated with more direct measures, such as classroom observations and recordings of classroom situations (see e.g., Koh et al., 2014).

Finally, from a methodological perspective, a further contribution of our study is the assessment of self-efficacy for teaching with technologies in a very fine-grained manner based on the TPACK self-assessment questionnaire by Schmidt et al. (2009). This allowed us to apply bifactor (1-S)-models (Eid et al., 2017), which modeled self-efficacy on different dimensions, and simultaneously allowed to model general technology-related self-efficacy. Therefore, we were able to represent the complex and multidimensional structure of the different dimensions of self-efficacy and to disentangle differential relations of the subdimensions with technology integration. Such approaches may help to better understand potential effects of teacher motivation on technology integration (Scherer et al., 2019).

6.2. Practical contributions and implications

From a practical point of view, it is particularly interesting that even (or especially) in this technology-rich environment (i.e., one-to-one classrooms) teacher motivation was a crucial boundary condition for technology integration. This finding showed that technological infrastructure is only a necessary but not sufficient conditions for teachers' technology integration (see also Drossel et al., 2017). Therefore, policy makers and teacher educators should consider teacher motivation when introducing (governmental) initiatives for enhancing technical infrastructure at schools. Precisely, both the concurrent and cascade relations of teachers' motivational beliefs and their technology integration should be considered. Furthermore, teacher educators and teachers themselves should be aware that both, their beliefs about the self-efficacy and utility-value of educational technologies, influence the amount and quality of technology integration.

Particularly within teacher education, self-efficacy of teaching with technologies should be promoted as a crucial determinant for the use of technologies. Overall, the present study can help to bridge the gap between the two worlds of theoretical reasoning, which could also inform the design and implementation of future effective teacher education programs for technology-enhanced teaching. The findings of the present study propose that teacher education courses should focus on both, teachers' self-efficacy of using technologies for teaching and their value beliefs of educational technologies with the goal of promoting teachers' performance and persistence of using technologies for teaching. Teachers' self-efficacy could be enhanced by providing opportunities to try out teaching with technologies; simultaneously, their utility-value could be advanced by highlighting the added value of teaching with technologies (for first insights on the importance of comprehensive teacher trainings for technology-enhanced teaching, see Howard et al., 2021). Furthermore, our study did not only investigate motivational determinants for the mere frequency of in-class technology use, but also as one of the first studies, the relation of teacher motivation and their emphasis on developing students' digital literacy.

For teacher educators, it is particularly important that the self-efficacy of integrating technologies in a pedagogical meaningful way (i.e., TPK self-efficacy) plays an outstanding role. Teacher education programs should not only address technological knowledge on how to handle technologies, but integrate this technological knowledge with pedagogical methods and technology-enhanced teaching practices. This could be achieved by providing pre-service teachers with guided opportunities to use educational technologies already in early phases of teacher education (Grossman & McDonald, 2008; Lee & Lee, 2014; Seidel, 2006). Additionally, it might be crucial to provide teachers with technology-enriched teaching material that already meaningfully integrates technologies and pedagogies to also allow teachers with low TPK self-efficacy to meaningfully integrate technologies into their teaching.

6.3. Limitations and future directions

The present study is a first attempt to integrate and investigate the predictive power of divergent research that is either informed by EVT or the TAM. Both are two prominent theoretical approaches to model relations between teacher motivation and their technology use during teaching. However, we only considered the core mechanisms and only the intersecting variables of EVT and the TAM to be able to test and contrast the different core mechanisms. In addition, both theories account for further variables (Flake et al., 2015; Scherer et al., 2019), which may further constrain teachers' technology integration. We encourage researchers to investigate additional variables in future studies to test the extended model in a more comprehensive manner. Additionally, future studies should investigate the relation of teachers' self-reported TPACK and their self-efficacy ratings for example in meta-analytical approaches to examine potential drawbacks of using self-report TPACK questionnaires as knowledge measure (e.g., in terms of jingle-jangle fallacies, Gonzalez et al., 2020).

Also a closer look should be adopted with regard to teachers' technology integration. It would be interesting to replicate the findings of the current study with data based on teachers' actual technology use during teaching, and to apply more direct measures of teaching quality. Furthermore, more differentiated analyses regarding subjects taught etc. would be worth to investigate in future studies with bigger sample sizes. Another limitation of the current study refers to the sample of teachers of only one technology-rich municipality in Norway. It could be investigated to what extent the findings of the present study are transferable to classrooms which are less well equipped with technologies than the classrooms in the current study or educational systems in which technological innovativeness in general is not that valued (Eickelmann, 2011). Simultaneously, also due to the current pandemic, technical infrastructure in schools will become more readily available in the upcoming years and therefore the findings of the present study will be relevant and applicable beyond specific initiatives.

To conclude, the main idea of the present study was to integrate two predominantly apart worlds to outline a comprehensive and integrated picture of teacher motivation and technology integration. The findings suggest that researchers of both fields can learn from each other to conclusively inform practice, policy makers and teacher educators. As such, future teachers should be supported in developing the necessary motivational prerequisites to effectively integrate technology in their teaching.

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Appendix ASupplementary data

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