Frontline Learning Research
An official journal of EARLI

Frontline **L**earning **R**esearch Vol. 12 No. 1 (2024) 1 -15
ISSN 2295-3159

Towards an Integrated Perspective of Teachers' Technology Integration: A Preliminary Model and Future Research Directions

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Article received 26 September 2022 / Article revised 17 June 2023 / Accepted 5 December 2023 / Available online 11 January 2024

Abstract

Technology integration is regarded as a crucial and complex endeavour to enhance students' learning and prepare them to participate in a digital society. Although the research landscape on teachers' technology integration is vivid and stimulating, an analytical model which synthesises different strands of research to model antecedents (i.e., teachers' professional competences), processes and outcomes of technology integration in an integrated manner is missing. That said, previous research was often rather product-oriented and ignored potential effects on students' learning processes and their achievement. To fill this gap, in this paper, we outline a preliminary model, the TPTI-model (teachers' professional competence for technology integration), in which we deliberately link different research perspectives on teachers' professional competences, professional vision and students' learning (processes) to model technology integration during teaching. Based on the preliminary TPTI-model, we propose future research directions, which may allow to gain a better understanding of the teacher- and student-related conditions as well as processes of technology integration and their effects on students' learning.

Keywords: technology integration, professional competence, professional vision, technology-enhanced teaching, teaching quality

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1. Introduction

The digital transformation is one of the drastic challenges of the 21st century. As such, educational systems are required to continuously prepare students for a digitised society. For instance, in addition to other factors such as school administration or the availability of infrastructure, there is large consensus that teachers play a pivotal role in technology integration and preparing students for a digitally shaped future (Backfisch et al., 2020; Sailer et al., 2021). Despite the central role of technology integration for schooling, however, empirical research demonstrated that in many educational systems, teachers rarely adopt technology into teaching or only to substitute previous teaching processes (Backfisch, Lachner et al., 2021; Fraillon et al., 2020; Sailer et al., 2021). For instance, in the International Computer and Information Literacy Study (ICILS, Fraillon et al., 2020), teachers indicated that they use technology primarily for substituting conventional teaching activities such as presenting information to students. More innovative adoptions of technology were reported to a less pronounced extent (see also Antonietti et al., 2023; Fütterer, Hoch, et al., 2023, for recent findings).

From a research perspective, these findings are crucial as they pose the demanding questions, a) which boundary conditions determine teachers' technology integration, b) which teaching processes may account for an effective technology integration, and c) whether and how technology integration may contribute to students' learning processes and their achievement. The current research landscape on teachers' technology integration is very vivid and stimulating, as it both identified generic as well as specific boundary conditions of technology integration, such as professional knowledge, teacher motivation, and teacher beliefs (Backfisch, Lachner et al., 2021; Ertmer et al., 2012; Mishra & Koehler, 2006; Ottenbreit-Leftwich et al., 2010; Scherer et al., 2017, 2019). These boundary conditions, however, were rarely put into context of each other, and thus have been investigated mostly in a fragmented manner (see Backfisch et al., 2020, for a quasi-experimental approach tackling cognitive and motivational pre-requisites). A second limitation is that researchers often adopted a product-oriented perspective, as they most exclusively investigated only whether but not how teachers integrated technology (see Backfisch, Lachner et al., 2021; Bibi & Khan, 2017; Pierson, 2001, for more process-oriented approaches). Thus, it is largely an open question which teaching processes accounted for teachers' different qualities of technology integration. More importantly, the link between the quality of technology integration and the initiation of students' learning processes and achievement is largely missing. This type of research on granular processes is needed as it allows to model how the quality of technology integration develops and allow recommendations on how technology integration can adequately be fostered in teacher education. Against this background, we propose a preliminary model (see Figure 1), the TPTI-model (teachers' professional competence for technology integration) which aims to integrate antecedents (i.e., teachers' professional competences of technology integration) as well as provide suggestions for a cognitive perspective on a teacher's processes during technology integration that is linked to students' learning processes and achievement. To accomplish these goals, we applied generic models of teachers' professional competence and professional vision (Goodwin, 1994; Jarodzka et al., 2021; Kunter et al., 2013; Loewenberg Ball et al., 2008; Seidel & Stürmer, 2014; van Es & Sherin, 2002; Wolff et al., 2021) to model (meta-)cognitive teaching processes (i.e., noticing, reasoning, acting while integrating technology) which may be responsible for successful technology integration. By adopting the concept of teaching quality, we further linked these "teacher variables" to "student variables" to draw conceptual conclusions regarding effects of technology integration processes on learning processes.

To this end, we see this paper as potential food for thought to stimulate integrative research in the context of technology integration and provide additional perspectives on how to foster teachers' continuing professional development regarding technology integration (Fütterer, Scherer et al., 2023; König & Mulder, 2014; Vokatis & Zhang, 2016). Furthermore, this integrative perspective may also help typologise the different constructs of technology integration and prevent potential jingle-jangle fallacies (Marsh et al., 2019), which are erroneous assumptions that either two different constructs are the same, because the same term is used across research contexts (jingle-fallacy), or two constructs are supposed to be different, as they are labelled differently, but bear the identical construct (jangle-fallacies, see 2.1).

We want to clearly note that the current scope of this paper was to synthesise previously isolated research strands and propose a potential proposal for future research that builds on an integrated multi-method approach to model and measure antecedents, processes, and products of technology integration. To this end, the empirical validation of the preliminary TPTI-model has yet been missing in this paper. Rather, we see the proposed TPTI-model as a potential analytical starting point, 1) to deliberately link different perspectives on teachers' technology integration and, more importantly, 2) to take a look forward regarding potential future areas in the research field and to understand the effects of underlying processes.

That said, as models clearly aim to reduce real phenomena, and therefore warrant a parsimonious use of assumptions, our preliminary TPTI-model takes a distinct perspective regarding teachers' technology integration focusing on schooling. In this paper, we therefore primarily draw on formal learning processes at school, which preliminarily focus on subject-matter knowledge and skill acquisition. Nevertheless, we admit that the integration of other perspectives of learning, such as enculturation and participation, could be stimulating for future model iterations (Sfard, 1998; see also Dishon, 2022; Wegner & Nückles, 2015). At this stage of the model, however, a comprehensive consideration of these different perspectives and their delineation would go beyond this paper.

2. The Need for an Integrative Model of Teachers' Technology Integration

In this section, we outline the scientific need for an integrated model of teachers' technology integration, both from the perspective of potential boundary conditions of technology integration as well as process-models of technology integration (Niederhauser & Lindstrom, 2018).

2.1 The Need for Integrating Professional Competence as Antecedents of Technology Integration

In the context of technology integration, many different models and frameworks exist which accentuate different conditions of teachers' professional competence (Niederhauser & Lindstrom, 2018). First, most models emphasise teachers' cognitive pre-requisites as crucial boundary conditions. For instance, the prominent TPACK-framework (Mishra & Koehler, 2006) highlights the critical role of professional knowledge for technology integration. TPACK is rooted in general frameworks, such as the one by Shulman (1986), who proposed three knowledge components for professional teaching (see also Baumert et al., 2010; Hill et al., 2005; Kunter et al., 2013 for empirical applications): a) *content knowledge* (CK) constitutes teachers' subject-specific knowledge of the to-be-taught contents; b) *pedagogical knowledge* (PK) is operationalised as generic knowledge regarding the realisation of powerful teaching strategies to support students' learning (Baumert et al., 2010; Voss et al., 2011); and c) *pedagogical content knowledge* (PCK) is the intersection of content knowledge and pedagogical knowledge describing, content-specific teaching strategies and knowledge about students' (mis-)conceptions (Baumert et al., 2010; Hill et al., 2005; Shulman, 1986, 1987). Mishra and Koehler (2006) added technological knowledge (TK) as a further component in their framework which refers to knowledge about the functionalities and applications of technologies, which resulted in further intersections: a) *technological pedagogical knowledge* (TPK) as a generic dimension of technology understanding that support students' learning across contents (Koehler & Mishra, 2009; Scherer et al., 2017), b) *technological content knowledge* (TCK), as a dimension to apply technologies within a certain domain, and c) *technological pedagogical content knowledge* (TPACK) as a content-specific dimension to apply technologies for subject-matter teaching (Koehler & Mishra, 2009). In the last decade, several researchers suggested extensions to the TPACK-framework. For instance, Angeli and Valanides (2009) proposed a perspective on the development of TPACK and juxtaposed two different developmental processes (transformative versus integrative view). Whereas the transformative view suggests that TPACK is a separate and distinctive knowledge structure, which is developed over time via deliberate practice from other teacher knowledge structures, the integrative view suggests that TPACK is not a distinct knowledge structure. Instead, TPACK may be spontaneously constructed on the fly by integrating separated knowledge structures during the act of technology integration. Relatedly, in addition to these developmental processes, Mishra (2019) proposed a contextual knowledge component which highlights situational knowledge about the instructional context (Backfisch, Lachner et al., 2021; Brianza et al., 2022; Dishon, 2022; Lachner et al., 2019; Turner & Meyer, 2000), such as knowledge about how a school is functioning, or how organisational change can be enhanced to realise technology integration (see Angeli & Valanides, 2009, for related concepts).

Contrarily, technology-acceptance models (TAM, see Scherer et al., 2019; Teo, 2011) emphasise the role of teacher motivation as a fundamental basis to accept and integrate technology for teaching. In the TAM-model, the perceived usefulness and perceived ease-of-use constitute important motivational boundary conditions to successfully integrate technology (Teo, 2011). In this regard, Scherer et al (2019) synthesised findings from 114 studies which examined the relations between teacher motivation (i.e., perceived usefulness and ease of use of educational technologies) and the intention to use these technologies. Meta-analytic structural equation modelling showed that the perceived usefulness of educational technologies was the strongest predictor for the intention to use technologies. Relatedly, psychology-related approaches adapted generic models of expectancy-value theories (e.g., Backfisch, Lachner et al., 2021; Taimalu & Luik, 2019; Wozney et al., 2006) towards technology integration. Similarly, these models emphasise the role of perceived utility of technology integration and the teachers' self-efficacy as important boundary conditions. However, whereas TAM only proposes indirect effects of self-efficacy on teachers' intention to use technologies via perceived utility, expectancy-value theories imply direct effects of both self-efficacy and the perceived utility on the use of technologies. To investigate these differential assumptions of TAM and expectancy value theories, Backfisch, Scherer et al. (2021) analysed survey data of $N = 524$ in-service teachers who taught in fully technology-equipped schools, in which all students had their own tablet device for learning. Findings from structural equation modelling showed that both self-efficacy and perceived utility had direct and indirect effects on the frequency of technology use for different classroom scenarios. Therefore, the two theoretical perspectives should not be considered exclusive of each other but should be integrated to inform research and practitioners on the impact of teacher motivation on technology integration.

A related strand of research regards teacher beliefs and attitudes towards technology integration as further boundary conditions of technology integration (e.g., Ertmer et al., 2012; Farjon et al., 2019; Kim et al., 2013; Wilson, 2023). For example, Farjon et al. (2019) investigated the relationship between teachers' attitudes towards technology in general, in education, and attitudes towards the integration of technologies and their perceived level of technology integration ($N = 398$). The analyses showed that these attitudes were the strongest predictor for their technology integration, even more important than self-assessed skills and available tools. In these studies, the concept of teacher beliefs and teacher motivation has been used relatively inconsistently and comprises relatively stable beliefs for instance about one-self (e.g., self-efficacy) or about the value of technologies for teaching (Park & Ertmer, 2008) or also about generic epistemological beliefs (Kim et al., 2013). For example, Tondeur et al. (2017) used the term 'pedagogical beliefs' referring to the generic perceptions, premises, or propositions about teaching and learning in their qualitative synthesis. Their analysis of 14 selected studies showed that the relationship between pedagogical beliefs and technology use should be considered as bi-directional. This finding indicates that technology-use can be an enabler to change teaching approaches and associated pedagogical beliefs as well as the other way around, that certain pedagogical beliefs, such as constructivist beliefs, can be enablers for technology integration.

One desiderate regarding the antecedents of technology integration which emerges due to a plethora of different models is that these models emphasise different aspects of professional competences in isolation (e.g., knowledge versus motivation versus beliefs). Likewise, the different concepts are not exclusive enough so that, for instance, beliefs and attitudes may constitute motivational constructs or vice versa. This is not only a constraint of research on technology integration but is rather regarded as a research desiderate in general motivation psychology (see Murayama, 2021). Similarly, the overly excessive use of self-reports in teacher's technology integration for assessing professional knowledge may rather reflect the current level of self-efficacy regarding technology integration (see Backfisch et al., 2020; Lachner et al., 2021). Overall, these research practices may have contributed to the well-known phenomenon of jangle-fallacies (see Gonzalez et al., 2021), as almost identical constructs (e.g., TPACK, self-efficacy, beliefs) are different because they are labelled differently. These caveats require an integrative perspective of teachers' professional competence regarding technology integration (Baier et al., 2019; Baumert et al., 2010; Kunter et al., 2013, for examples on generic teaching). Commonly, professional competence is a multifaceted construct, which refers to clusters of cognitive and motivational pre-requisites but also metacognitive and self-regulatory conditions, which are to-date an underspecified area in the context of technology integration. These sub-facets are regarded to highly depend on each other and are at least conceptually treated in an integrated manner. Within these frameworks, professional competence is regarded to be learnable and malleable and a primary aim of teacher education.

2.2 The Need for Integrating a Process-oriented Perspective of Technology Integration

Another caveat of previous conceptualisations of technology integration is that they were relatively product-oriented and considered technology integration as the "endpoint" of applying technology, and thus, conceptualised the underlying processes of technology integration only to a limited extent. For instance, the Substitution Augmentation Modification Redefinition (SAMR)-model (Puentedura, 2006; see also Blundell et al., 2022, for a scoping review), conceptualises technology integration as a four-level hierarchical development from technology integration as a simple substitution of previous analogous approaches with no functional change, to redefinition, allowing teachers to apply technology for solving new tasks which could not be realised without technology (see also Hughes et al., 2006, for a related model). These approaches provide a sensible lens for analysing whether teachers are capable to exploit the potential technology (Backfisch, Lachner et al., 2021). At the same time, these approaches are less capable to model the underlying learning and teaching processes (Hamilton et al., 2016), emerging during technology integration. Therefore, it is important to consider whether and how technology can be integrated to enhance teaching quality, for instance, by providing challenging learning activities (i.e., cognitive activation), by supporting students' learning processes (i.e., supportive climate), and by enabling efficient classroom management (Baier et al., 2019; Fauth et al., 2014; Hugener et al., 2009; Kunter et al., 2013). That said, although previous technology integration models, such as SAMR, propose a developmental hierarchy of technology integration, the cognitive and developmental conditions and its effects on the process of professional technology integration are underspecified (Backfisch et al., 2020). A valuable approach could thus be to adopt and integrate process-oriented perspectives to model the underlying processes of teaching behaviour in the context of technology integration. For instance, early research in the context of teacher expertise (e.g., Berliner, 1986; Borko & Livingston, 1989; Leinhardt & Greeno, 1986, see also Jarodzka et al., 2021; Lachner et al., 2016, 2019, for recent approaches) adopted the expert-novice paradigm and contrasted the underlying behaviour processes of expert and novice teachers by using granular methods from cognitive psychology, such as think aloud protocols, clinical interviews, and concept mapping. These classic studies can be regarded as precursors of current research of professional vision, which explicitly focusses on the attentive processes of teacher behaviour predominantly during classroom instruction (e.g., Jarodzka et al., 2021; Lachner et al., 2016; Seidel & Stürmer, 2014; van Es & Sherin, 2002). Professional vision is regarded as the backbone of teacher behaviour, comprising the subprocesses to notice and interpret crucial events and interactions in the classroom as a prerequisite for enacting teaching. Interestingly, in his seminal ethnographic studies, Goodwin (1994) brought up a broader definition of professional vision, as it not only was restricted to on-the-fly events such as students' classroom interactions, but any professional practice, in which attention is a crucial prerequisite to realise complex practices by (collaboratively) applying tools, technologies, and artefacts. As such, in its original meaning, professional vision approaches may also be suited to describe the underlying processes of professional practices such as technology integration. These practices require the attentive processes including noticing and reasoning of the potential of educational technologies to successfully integrate them in the classroom for enhancing teaching quality. Considering these (meta-)cognitive processes could allow to model a process-oriented perspective on technology integration.

2.3 The Need for Relating Technology Integration with Teaching Quality and Student Achievement

A final desiderate of previous conceptualisations of technology integration was that it considered the underlying teaching and learning processes only to a limited extent, as most of the research relied on quantitative indicators of technology integration. For instance, in the context of technology integration, a central indicator is the mere frequency of technology integration during teaching (see e.g., Backfisch, Scherer et al., 2021; Fraillon et al., 2020). Although these findings give indications regarding the general use and saturation of technology in classrooms, these studies do not allow to provide insights into the quality of technology integration (see Backfisch, Lachner et al., 2021; Scherer et al., 2019; Voogt et al., 2013, for a critical consideration). Furthermore, research on TAM mainly focusses on the teachers' general acceptance and intention to use technology as a precursor for technology application. However, no assertions can be made whether the integration of these technologies contributed to effective or efficient classroom teaching. To this end, recent research has started to adopt generic indicators of teaching quality in the context of technology integration, for instance, to measure the quality of lesson plans (Backfisch et al., 2020; Schmid et al., 2021) or retrospective reports of teaching behaviour (Backfisch, Lachner et al., 2021). These models operationalised high levels of technology integration in terms of a) cognitive activation by presenting students with challenging technology-mediated activities, b) supportive climate, in which students receive adequate support to master their goals, and c) efficient classroom management to maximise time on task. However, whether these indicators really constitute high-quality of technology integration is an open issue. Relatedly, another limitation regards the fact that learning processes and associated outcomes were not related to the quality of technology integration. As technology integration can only be seen as an opportunity for student learning during classroom instruction, it is an open issue whether students use this potential for their learning. Applying conceptual models which explicitly model the process of teaching as input, and students' learning processes and outcomes as output which are mediated via the realised quality of technology integration, may therefore constitute a conceptual lens to better understand the complex interactions between teaching and technology-mediated learning processes (see Kunter et al., 2013 for applications in generic teaching).

3. An Integrative Conceptual Model of Teachers' Technology Integration

Based on generic models of teachers' professional competences (Kunter et al., 2013), professional vision (Goodwin, 1994; van Es & Sherin, 2002), and technology integration (Hughes et al., 2006; Puentedura. 2006), we developed a model of teachers' professional competence for technology integration (TPTI-model, see Figure 1). At the core of the TPTI-model, we propose that technology integration should be viewed as an enabler to enhance the process of teaching and therefore to increase teaching quality. As indicated by research on generic teaching quality, it can be assumed that overall teaching quality is not a stable construct, but rather depends on the situational context in which teaching takes place (Dishon, 2022). For instance, the availability of infrastructure (tablets, internet access) and time constraints could determine how technology can be implemented in the classroom to foster individual or collaborative learning processes (see Backfisch, Lachner et al., 2021, for empirical evidence). At the same time, dynamic characteristics of the class and students could also influence teaching quality (Zitzmann et al., 2022).

At the level of teaching processes, we consider teachers' professional competences for technology integration, as multi-dimensional antecedents comprising professional technology-related knowledge, motivational orientations, belief systems, and the level of self-regulation as core facets of professional competence (Baier et al., 2019; Kunter et al., 2013). The level of self-regulation is so far an underspecified facet of professional competence in the context of technology integration and regards teachers' cognitive, metacognitive, and affective-motivational abilities to monitor and control their teaching behaviours and habits (Kunter et al., 2013). These pre-requisites are regarded to interact with each other and serve as a crucial basis for the effective integration of technology.

The second part of the model accentuates teachers' underlying processes during technology integration, which are dependent on the particular level of professional competence (Seidel & Stürmer, 2014). Following common conceptions of professional vision (Jarodzka et al., 2021; Seidel & Stürmer, 2014; van Es & Sherin, 2002), in the TPTI-model, we model technology integration as an iterative and reciprocal three-step process. First, teachers have to notice the distinct potential of technology for improving teaching quality (e.g., multi-modality; manipulation of objects, visualisation). That said, noticing describes whether teachers are able to pay attention to the potential of technology that critically influence teaching and learning in classrooms, and as such, affect student learning in a positive or negative sense. Second, teachers are required to adequately reason about the use of technologies. Thus, teachers are required to apply evidence-based principles of technology-based teaching and learning to critically reflect on the integration of technology (Lachner et al., 2016; Seidel & Stürmer, 2014). These principles can both be derived from generic and subject-specific evidence. Third, teachers have to implement educational technologies in the classroom. Throughout these integration processes, teachers have to continuously monitor the underlying processes to regulate their current processes of technology integration.

Effectively implementing technologies during classroom teaching requires a considerable amount of deliberate teaching experience (e.g., Backfisch et al., 2020; Meschede et al., 2017). This teaching experience allows to automate technology integration routines and procedures, as well as organise knowledge around encountered teaching cases and experiences which may result in more elaborated and coherently organized knowledge structures (Krauss et al., 2008; Lachner et al., 2016; Pauli & Reusser, 2003; Putnam, 1987; Wolff et al., 2021). Putnam (1987) called this specific type of knowledge representations "curriculum scripts" (see also Wolff et al., 2021). Curriculum scripts refer to generalised knowledge structures a teacher has about distinct types of frequently encountered situations and teaching problems as well as their solutions. As such, curriculum scripts are higher-order knowledge structures which integrate episodic and professional knowledge and allow teachers to rapidly recognise meaningful patterns for technology integration and to make informed and flexible teaching decisions (Lachner et al., 2016; Putnam, 1987; Wolff et al., 2021). Again, these three-step processes are considered to be highly constrained by the situational context (Turner & Meyer, 2000), as, for instance, the availability of infrastructure and tools, but also the involved students with their prerequisites may constrain the activation of different curriculum scripts. We argue that these processes are highly dependent on each other, and can result in cyclical and reciprocal loops of noticing, reasoning, and acting processes, if teachers realise distinct metacognitive self-regulation strategies.

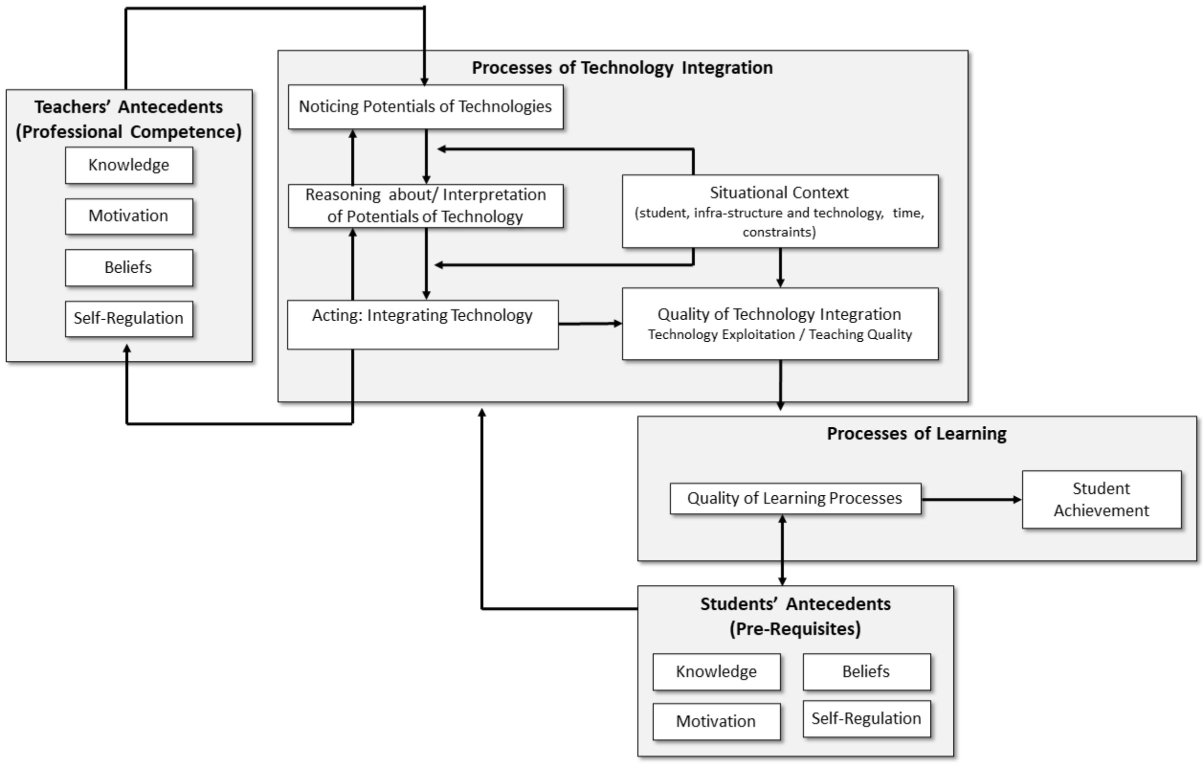

Figure 1: The TPTI-model of Teachers' Professional Competences for Technology Integration

At the level of learning processes, the provided technology-supported learning activities are seen as opportunities to learn that have to be utilised by students. Dependent on students' prerequisites, they can use these opportunities during teaching to realise germane processes of self-regulated learning, such as cognitive, metacognitive, and motivational-affective learning strategies (Nückles et al., 2020; Weinstein & Mayer, 1986). On the cognitive level, core cognitive processes include organisation and elaboration strategies (see Nückles et al., 2020; Weinstein & Mayer, 1986). Organisation strategies help students identify main concepts during teaching and establish relations between the to-be-learned concepts and structure the learning content in a meaningful way. Elaboration strategies help students integrate the previously encountered information into their prior knowledge, for instance, by drawing analogies or making examples. Both organisation and elaboration strategies have been discussed to enhance students' meaningful learning. On the metacognitive level, students' monitoring (of one's own understanding) and regulation of learning behaviour are regarded as further important processes to successfully enact meaningful cognitive processes. On a motivational level, metacognitive strategies not only regard cognitively oriented strategies, but also the monitoring and regulation of current motivational states, such as boredom or anxiety, that help to maintain successful learning. The realisation of deep-level learning processes should contribute to student achievement. As for professional competence, we argue that these processes are highly interwoven and depend on each other.

4. Directions for Future Research

In this article, we proposed a preliminary model (Fig. 1) which may guide future research for modelling and measuring teachers' technology integration. Therefore, the main goal of future research could be to empirically test the proposed relationships.

In a first attempt of such a research proposal, the development of measures of professional competence, professional vision, technology integration, and student achievement would be a central requirement. Objective assessments will be crucial in improving our understanding of the causal relationships of the proposed antecedents, potential processes, and outcomes of technology integration. The construction of objective test instruments is currently at the beginning (see Baier & Kunter, 2020; Drummond & Sweeney, 2017; Lachner et al., 2019, 2021 for exceptions), as most of the previous studies in the context of technology integration relied on self-reported knowledge assessments (Schmidt et al., 2009; e.g., "I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn."). Yet, it is still an open issue whether self-reports may validly capture the availability of professional knowledge. That is, even when these measures are substantially correlated, the level of judged performance may be higher or lower than the actual performance and prone to distinct cognitive biases. These biases may be even more pronounced for less experienced teachers, as they may tend to over-estimate their professional knowledge (Kruger & Dunning, 1999; see Aesaert et al., 2017). First attempts to measure teachers' technology-related professional knowledge have been made. For instance, Lachner et al. (2019) developed a TPK-test using multiple-choice questions for measuring conceptual and situational TPK (see also Baier & Kunter, 2020, for related approaches). The authors demonstrated that differences in TPK worked as a function of teacher expertise. Moreover, in another study, conceptual TPK was related to teachers' self-reported task differentiation during the Covid-19 pandemic (König et al., 2020). Together, the tests are a crucial basis to test relationships in the TPTI-model, however, still the psychometric properties have to be increased to obtain reliable judgments of teachers' professional knowledge. That said, measures that validly capture the level of technology integration and teaching quality in situ are needed (see Fütterer et al., 2022; Hammer et al., 2021 for first attempts) to investigate how professional knowledge affects technology integration and student achievement. To reduce the complexity during testing these interwoven relationships, we argue for a stepwise strategy that allows iterative refinements of the TPTI-model.

In a second and related attempt, we argue to test underlying cognitive and metacognitive processes during technology integration. For instance, think aloud protocols and video analyses in combination with cued retrospective reporting and/or eye-tracking (see Maatta et al., 2021; Wolff et al., 2016 for recent applications in generic teaching) could help to investigate whether and how these processes of noticing, reasoning, and acting may be responsible for different qualities of technology integration. For instance, eye-tracking could allow to analyse the attentive processes during lesson planning and help to understand which features teachers are focussing on when selecting technologies during teaching. Additionally, mobile eye-tracking systems in combination with video analyses could allow to simultaneously trace the attentive processes during technology integration in the classroom both from a student and a teacher perspective (see Jarodzka et al., 2021).

Given that the situational context plays a decisive role during technology integration, it makes sense to generalise the obtained findings to other teaching contexts (e.g., subject, class, and student characteristics), for instance by adopting a many-classes approach (Fyfe et al., 2021; see also Lachner et al., 2021 for recent applications). Many-classes approaches allow to explore patterns such as relations among antecedents and processes of technology integration across a variety of class contexts and educational implementations, subject areas, and students. As such, this approach allows to understand whether distinct relations are generalisable and/or whether findings are determined by distinct situational contexts (Fyfe et al., 2021).

A third attempt would be to closely investigate the interplay of the facets of teachers' professional competence. So far, these relationships have been investigated mainly in isolation. However, there is increasing agreement in educational psychology and teacher education that not only the availability of professional knowledge is important, but putting them in combination with motivational orientations, beliefs, and self-regulation abilities seems crucial (Kunter et al., 2013). That said, increasingly more research has been showing that not a single variable may account for different outcomes, such as teaching quality, but rather their combinations. These person-centred approaches find more and more ways in research on professional competence (e.g., Holzberger et al., 2019; Thommen et al., 2021), but have seldomly been used in the context of teachers' technology integration.

A fourth and final attempt would be to close the loop within the TPTI-model and relate the teaching and learning processes during technology integration towards student achievement. Investigating those relationships among teaching and learning processes during technology integration would help to uncover whether and how technology integration can contribute to students' learning and achievement in authentic classroom settings, which to date is still an open question in educational research. As for the processes, process analyses by means of advanced and sophisticated technologies such as eye-tracking or video analyses in combination with test data could help trace the effects of technology integration on students' learning (Goldberg et al., 2021; Haataja et al., 2021). That said, student achievement should not only be investigated from a cognitive perspective, but also include motivational orientations, belief systems, as well as self-regulation, as a multidimensional construct.

5. Conclusions and Discussion

Although there is increased interest from researchers and practitioners in how technology can be successfully integrated in the classroom, our knowledge of when and why technology integration promotes learning is still limited. In this theoretical contribution, we aimed to take a step toward filling this knowledge gap by proposing the TPTI-model, a preliminary model of teachers' technology integration, synthesising models of professional competence, professional vision, and the associated learning and teaching processes during technology integration. One of the clear limitations is that most of the relationships within the model have not yet been tested. We hope that this model may mark a stimulating research road map that can help move this relatively young but promising field of research forward to successfully delineate the underlying conditions of successful technology integration. That said, in future iterations of the model, it could be fruitful to consider additional forms of (informal) learning, such as problem solving, collaborative learning, or creative learning, and explore whether and how the TPTI-model may generalise to the development of such competences. In line with these suggestions, whether and how the TPTI-model may transfer to different educational stages, such as higher education, is another open issue (see Sailer et al., 2021). Together, we hope that the TPTI-model may provide a starting point for integrative research on the process of technology integration and guide ways to systematically analyse effective strategies for technology integration.

Keypoints

- Technology integration was predominantly treated in an isolated manner.
- We provide a comprehensive model which explicitly links teaching and learning processes during technology integration.
- Therefore, we bridge research from professional competence and professional vision.
- Additionally, we propose directions for future research derived from the conceptual model.
- Methodological advancements in the context of technology integration are addressed.

Acknowledgments

The research reported in this article was supported by the Federal Ministry of Education and Research in Germany (BMBF) under contract number 01JA2009.

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