Pre-Service Teachers’ Mental Models of Digital Video Tools

Dissertation

der Mathematisch-Naturwissenschaftlichen Fakultät
der Eberhard Karls Universität Tübingen
zur Erlangung des Grades eines
Doktors der Naturwissenschaften
(Dr. rer. nat.)

vorgelegt von

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Tübingen

2012

Tag der mündlichen Qualifikation:	26.09.2012
Dekan:	Prof. Dr. Wolfgang Rosenstiel
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Figures

Tables

Introduction and Overview

Teaching is a complex and ill-defined task that requires teachers to be knowledgeable in several domains. First and foremost, teachers need to master the content of their subject areas. For example, a mathematics teacher must be able to prove that "0.9999..." equals "1" or a history teacher must know how, across historic periods and geographic regions, governments have tried to influence their populations. Second, teachers need to know about various learning activities, how to instruct and guide these activities, and which learning processes these activities support. In order to deliver appropriate guidance, this knowledge must include the basics of educational psychology, for example, in order to motivate a student who has just received a bad grade. Finally, today's teachers must be acquainted with a number of technologies that can effectively support learning in the different subjects. With this, the task of teaching has become even more complex due to the rapid development of emerging digital technologies that offer a wide range of possibilities for individual and collaborative learning. For example, computer-based simulations can foster conceptual learning in the natural sciences (Kulik, 2003), and the use of wikis (e.g., Moskaliuk, Kimmerle, & Cress, 2008) or web-based video tools (e.g., Zahn, Krauskopf, Hesse, & Pea, in press; Zahn, Pea, Hesse, & Rosen, 2010) can improve learning in collaborative settings. What makes these emerging technologies more challenging than established technologies, such as the blackboard, the overhead projector, or the VHS-player, is that most of them have neither been designed for educational purposes, nor has there been enough time for pervasive instructional patterns to evolve. Thus, with regard to emerging technologies, teachers are confronted with specific challenges. On the one hand, they have to face a continuously changing technological environment. This means, for teachers it cannot suffice to acquire knowledge about a core canon of relevant technologies, but instead they need to develop a flexible competence enabling them to adapt to these changes. On the other hand, the potential of many of the current technological inventions (wikis, video tools like YouTube, Facebook, etc.) is manifold with regard to learning; however, this potential is not spelled out by the software developers. This puts the teachers in charge of re-purposing these ubiquitous technological tools in order to turn them into learning tools. Therefore, teachers have to thoroughly understand the learning-relevant functions of these technologies and relate these functions to the other domains of their professional knowledge in order to leverage them for education. But, what does it mean for a teacher to understand the potential of a technology? And, how do prior professional knowledge and beliefs feed into this understanding? Following Heidt (1977), explaining a technology for educational purposes by describing its *structural* attributes, that is, which button to click, is only one aspect. The more important issue is to describe the corresponding cognitive and social processes, namely the *functional* attributes of the technology. Based on this, understanding technology in the case of teachers can be defined as recognizing the functions of digital technology as cognitive tools (Jonassen, 1995; Zahn, Pea, et al., 2010) and extrapolating how these might impact a user's learning. For example, the more important information for educational purposes regarding a feature for zooming in on a detail in a video software (structural attribute) would be its correspondence to cognitive processes of focusing the attention of oneself or an audience (functional attribute; cf. also Salomon, 1994). In conclusion, teachers do not simply need to know "where to click" to operate technological functions, but they need to grasp how these functions impact individual and collaborative learning.

A conceptual framework that tries to account for this perspective on technology and also considers the other mentioned domains of teachers' professional knowledge, namely, content and pedagogy is the Technological Pedagogical Content Knowledge (TPCK). This framework was first introduced by Mishra and Koehler (2006) and inspired by Shulman's (1986, 1987) work on Pedagogical Content Knowledge. With reference to Duncker (1947), Koehler and Mishra (2009) conceptualize this widening of the teacher's perspective on technology as rejecting the *functional fixedness* of technology. Not overcoming this fixedness, they argue, is an important reason why many office applications, such as Word, Excel, or PowerPoint are perceived as specific to the economic context, and the use of Blogs, Wikis, or YouTube as leisure time activity, respectively. Thus, the acquisition of (maybe) necessary but not sufficient operative technological skills is understood as merely a sub-goal. The actual goal for a teacher, in contrast, is acquiring knowledge of how to use technological functions to support (socio-) cognitive processes in the classroom. Mishra and Koehler (2006; 2008) acknowledge this basic assumption in their TPCK framework by adhering to a definition of teaching (with technology) as complex and ill-defined task. Based on this, they propose that the knowledge teachers require to solve this task needs to be complex and situated. Most important, the TPCK framework asserts that technological aspects of knowledge (TK) need to be considered as an integrated part of other relevant aspects of teacher knowledge, namely content knowledge (CK) and pedagogical knowledge (PK). All intersection constructs refer to specific aspects. Pedagogical Content Knowledge (PCK) refers to a teacher's knowledge about content-specific strategies for assessment and teaching as well as about students' prior knowledge and common misconceptions (cf. *Fachdidaktik* in the German tradition of teacher training), Technological Content Knowledge (TCK) indicates knowledge about how content and technology are interrelated, meaning that the content is transformed when presented with different technologies, and Technological Pedagogical Knowledge (TPK) refers to the knowledge about how a technological tool can change teaching and learning and at the same time how specific learning arrangements leverage different functionalities of a tool. Finally, the integration of all knowledge aspects, TPCK, is considered to encompass knowledge about how external representations and digital technologies can specifically support the conceptual understanding in a specific subject by combining it with certain tasks and adequate instructional guidance. For more detailed definitions see Table 1.1.

Addressing the needed competences of teachers who seek to integrate technology, the TPCK framework has fueled a movement toward a more complex view on teaching with technology as the ability to simultaneously address the connections and interactions between and among the elements of technology, pedagogy, and content situated in a particular context. As such, this perspective is the first to provide a more comprehensive framework for research and professional development to address the technology integration efforts of pre- and in-service teachers from the view of "what to do with [technology] instructionally" (Foulger, Krauskopf, & Williams, 2012; Harris, Mishra & Koehler, 2009, p. 402), rather than teaching technology skills in isolation. However, above and beyond characterizing the content of the proposed sub-domains, however, Mishra, Koehler, and authors in their tradition have neglected to provide a theoretical basis for more concrete and confutable assumptions. In accordance, related research has focused on either assessing the rather fuzzy knowledge domains proposed in the framework with self-report measures (e.g., Archambault & Barnett, 2010; Lee & Tsai, 2010; Schmidt et al., 2009) or supporting teachers to develop the also fuzzily defined Technological Pedagogical Content Knowledge (e.g., Angeli & Valanides, 2005; Koehler, Mishra, & Yahya, 2007; Niess, 2005). As a result, two broader issues remain unattended. First, in line with the lack of clear definitions (Cox, 2008; Cox & Graham, 2009; Graham, 2011), it remains an open issue how knowledge in the proclaimed sub-domains presumably interrelates. Is knowledge in some sub-domains a pre-supposition for more complex knowledge or are the sub-domains independent? Furthermore, how is this knowledge represented if it enables teachers to teach while effectively utilizing technology (cf. Shulman's discussion of teacher knowledge representations, 1986)? Second, it also remains an open issue whether TPCK as a construct defines a unique knowledge representation or a combination automatically arising from knowledge in the sub-domains (cf. *transformative* versus *integrative* view of TPCK, Angeli & Valanides, 2009). This issue is both due to a lack of empirical research as well as a lack of theoretically founded hypotheses about the learning processes leading to the construction of this knowledge. In conclusion, it is imperative to clarify TPCK as a framework and as a construct in order to provide more concrete assumptions about how teachers construct their understanding of emerging technologies.

In the present dissertation, I propose the following considerations to tackle the issue of clarifying the TPCK framework and construct. In line with Koehler and Mishra (2008), in the present dissertation, teaching supported by technology is defined as a complex, ill-defined (cognitive) task, which requires complex professional knowledge to be solved. Based on this definition, it is claimed that it is not sufficient for a teacher to simply remember the technological functions of certain software or examples of how other teachers have used technology in their instruction. Instead, teachers have to mentally represent how the technological affordances and how they interact with pedagogy and content. Hence, it is important to develop a more process-oriented conceptualization of the TPCK framework.

The notion of affordances has been raised as a possible perspective on understanding teachers' knowledge for teaching with technology (Angeli & Valanides, 2009). Moreover, it has been made clear that what is important are the teachers' *perceptions* of these affordances (cf. Suthers, 2006) when it comes to defining the potential of a learning environment (cf. the notion of teacher conceptions in Gerjets & Hesse, 2004). In order to specify this notion of perceived affordances, I define affordances in this context as the impact of *technological functions* on relevant dimensions of teaching and learning, namely, their functions in supporting cognitive, socio-cognitive, meta-cognitive and motivational learning goals. More important, with regard to the cognitive representation of these *learning-relevant functions*, it is proposed that in the case of teachers, understanding these functions means constructing mental models of these functions in relation to their impact on learners' access to the subject matter. Adhering to the concept of mental models seems an adequate way to conceptualize the representation of knowledge that is necessary for solving the complex task of teaching. In sum, I propose to elaborate the TPCK framework based on the notion of mental models as analogue knowledge representations (Brewer, 1987; Johnson-Laird, 1980, 1983). More concretely, it is claimed that in order to pedagogically leverage the potential of emerging technology, at a first level of cognitive integration teachers need to construct mental models that represent the technology's functions in the light of the complexity of the task of teaching and the teacher's prior professional knowledge.

Subsequently, this leads to the assumption that, on a second level of cognitive integration, TPCK as a construct needs to be considered as meta-knowledge to successfully coordinate all relevant aspects of task of lesson planning with emerging technology, the teacher's own knowledge, and the context. Another aspect resulting from the present approach to elaborating the TPCK framework is the importance of teachers' beliefs in addition to their professional knowledge (cf. Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2012). It is assumed that the construction of mental models is constrained by overarching framework theories (cf. Vosniadou, 1994). These framework theories, in turn, are composed of prior knowledge and beliefs. Thus, the approach presented here adopts the perspective that beliefs, in addition to knowledge, are an important factor to be considered when investigating the TPCK framework. Moreover, assessing teachers' prior knowledge, beliefs and their mental models of technology functions provides a basis to empirically investigate the open question described above: Does the knowledge of how to effectively integrate technology into their teaching arise automatically in teachers from their prior knowledge in the sub-domains of technology, pedagogy, and content? Based on these considerations, two broader research questions are addressed in the chapters of this dissertation:

1. *How can the TPCK framework be elaborated to focus on the underlying cognitive processes by employing the concept of mental models in order to derive assumptions about the proposed knowledge representations of the sub-domains and their interrelations?*

This first research question will be tackled in Chapters 1 and 2 of the present dissertation. *Chapter 1* will provide a general introduction into approaches to the technology-related competence of teachers and elaborate on teacher knowledge and teacher beliefs as two relevant aspects. Subsequently, a more specific introduction into the TPCK framework as the most prominent approach teacher knowledge will be provided and central findings from empirical research investigating the TPCK constructs will be summarized. This summary is complemented by a short overview over empirical research investigating teachers' beliefs. The considerations of this chapter are concluded by specifying the theoretical lack of clarity of the TPCK framework and shortcomings of the related empirical research. Before this background, the issue of theoretical clarity is addressed in *Chapter 2*. First, the concept of mental models is introduced and mapped onto the current TPCK framework trying to clarify what "knowledge" means in this approach. Based on this, mental models of teachers' understanding of the (socio-) cognitive functions of technologies are defined exemplarily as a more concrete understanding of the sub-domain of Technological Pedagogical Knowledge (TPK). Second, it is discussed how introducing the notion of mental models influences the overall conceptualization of the TPCK framework, and elaborate on it as a coherent theory, the TPCK construct, and the notion of expertise in TPCK.

Empirically, the challenge to construct appropriate mental models of the learning-relevant functions of a technology becomes particularly evident for more traditional technologies, such as film and video. On the one hand, these are "revolutionized" by the new technological developments. The World Wide Web has made video ubiquitous and easily accessible, and has altered its potential with a varying range of technological functions, such as annotating, selecting, or easy creation (Snelson & Perkins, 2009). On the other hand, the everyday use of video in the classroom does not offer pedagogies that make the integration of this potential easily possible. As Hobbs (2006) could show teachers display a limited use of the educational potential of video and mostly combine video with classroom activities not related to learning. On a more abstract level this means that teachers adhere to a perceived functional fixedness. That this fixedness is, however, not inherent to the audio-visual media itself could be shown in empirical research (Caspi, Gorsky, & Privman, 2005; Merkt, Weigand, Heier, & Schwan, 2011; Zahn, Barquero, & Schwan, 2004; Zahn, Krauskopf, Hesse, & Pea, 2010; Zahn et al., in press; Zahn, Pea, et al., 2010). Thus, video technology provides an interesting example for the issue of how important it is for teachers to understand the potential of a technology for learning and, in turn, to provide adequate learning arrangements to leverage the potential of this technology for learning. Therefore, digital video technology was chosen as an exemplar for emerging technologies in the empirical research tackling the second broader question.

2. *Can empirical studies provide initial evidence for the assumption that mental models of learning-relevant technology functions impact (pre-service) teachers' lesson planning for emerging technology, in this case web-based digital video tools? What is the role of prior pedagogical knowledge (PK) in this?*

To address this question, empirical findings of three studies will be presented to provide first evidence for the theoretical assumptions explained in Chapter 2. Using digital video tools as an example, the studies focus on how pre-service teachers mentally represent the learning-relevant functions of digital video tools and how this, in turn, affects their performance in lesson planning tasks. In these studies, lesson planning, especially the selection and design of tasks and learning activities is considered the most appropriate dependent variable for assessing the effects of teachers' knowledge and the subsequent pedagogical reasoning (cf. Bromme, 1992; Webb & Cox, 2004).

In all studies, pre-service teachers' prior pedagogical knowledge (PK) and technological knowledge (TK), as well as their pedagogical beliefs are assessed as potential presuppositions for these participants' understanding of digital video technologies as potential tools for learning. Understanding is operationalized as mental models of learning-relevant functions and coded from open answers following a methodological approach from cognitive psychology (e.g., Azevedo & Cromley, 2004) and in the third study additionally by a concept mapping task (cf. Kagan, 1991). Mapped onto the sub-domains of the TPCK framework these mental models are considered an indicator for the participants' Technological Pedagogical Knowledge (TPK), that is, the content-general potential of the respective technology. Accordingly, the lesson plans as dependent variables are considered indicators for the participants' performance in tasks requiring Technological Pedagogical Content Knowledge (TPCK), that is, indicators for their ability to further orchestrate their professional knowledge to include content-specific aspects. Mediation and moderation analytic techniques are used to scrutinize the relationships between the different sub-domains and teachers' beliefs, mainly investigating whether TK, PK, and TPK are predictors for pre-service teachers' performance in TPCK lesson planning tasks, and how they interrelate. With regard to the sample technology applied, Study 1 (*Chapter 3*) aimed at the mental models pre-service teachers construct when confronted with the task of re-purposing a known video technology (*YouTube*) for a broad range of subjects. Study 2 and 3 (*Chapters 4 and 5*) complemented this with focusing on the mental models constructed when introducing a new video tool (WebDIVER) of which only technological functions are introduced. In addition, Study 2 introduced a higher level of control by presenting all participants with the same knowledge about the video technology, restraining the content area to the subjects of history and language arts, and finally by including a sample lesson plan as an additional, more constrained dependent measure. Moreover, Study 3 introduced an experimental paradigm for contrasting the *integrative* and *transformative view* on TPCK, more detailed lesson planning tasks, and a transfer task, in order to investigate how more complex mental models and lesson plans can be supported.

In *Chapter 6*, finally, I provide a general discussion of the theoretical assumptions in relation to the presented empirical findings. Issues of generalizability, as well as implications for future research and practical application will further be considered.

To summarize, the main purpose of this dissertation is to provide a more specific conceptualization of the TPCK framework and the proposed constructs in order to improve upon it as a foundation for empirical research and as a basis for teacher training. The main goal on the theoretical level is to propose a more specific understanding of the knowledge representations proposed by the TPCK framework and to suggest more concrete conceptualizations of the assumed cognitive processes underlying the TPCK framework. In doing so, the present dissertation answers to the critical voices that have recently emerged in the related research literature (Angeli & Valanides, 2009; Cox & Graham, 2009; Graham, 2011). That is, by investigating prior TK, PK, and TPK as precursors for pre-service teachers' TPCK lesson planning it becomes possible to add empirical evidence to clarifying the boundaries between the proposed TPCK constructs. Additionally, the proposed empirical approach aims at widening the scope of methods reported in the literature on TPCK so far. First, besides introducing a possibility to assess (pre-service) teachers' mental models, the studies presented in this dissertation are the first ones trying to actually measure prior (pedagogical) knowledge instead of relying on teachers' self-reported confidence in their knowledge. Second, these studies are also the first in the area of TPCK research to simultaneously consider teachers' knowledge and beliefs trying to differentiate their effect on lesson planning for technology use.

The following chapter will provide an overview over the technology-related competence of teachers and will more specifically introduce the TPCK framework and the related empirical research.

1. Technology-Related Competence of Teachers and the Technological Pedagogical Content Knowledge Framework (TPCK)[1]

1.1 Technology-related Competence of Teachers

When looking at how technology-related competences of teachers are discussed in the research literature, three broader aspects can be extracted:

(1) Technology-related competences for utilizing *digital technology for conveying subject-specific content in pedagogical settings* (cf. mediendidaktische Kompetenz [didactic media competence], Blömeke, 2000; or Technological Pedagogical Content Knowledge, TPCK, Mishra & Koehler, 2006)

(2) Technological competences for the *personal use of digital technology* (cf. eigene Medienkompetenz [personal media competence]", Blömeke, 2000; or Technological Knowledge, TK, Mishra & Koehler, 2006)

(3) Competences to teach *about digital technology* as a content-area (cf. medienerzieherische Kompetenzen [media educational competence], Blömeke, 2000; cf. content knowledge, CK, Mishra & Koehler, 2006) including relaying ethical values and norms for handling digital technology.

Out of these three the first one was in the focus of the present dissertation. In this context, personal technological competences play a role to the extent to which schools fail to provide technical support (Law & Chow, 2008). Of course, it needs to be acknowledged that the personal technological competences of teachers might co-determine the barrier for a teacher to use technology at all. Therefore, the skills of a teacher to trouble shoot technological problems remains a factor for technology use in the classroom. Also, technology as lesson content is an important aspect of education, especially with regard to the ethical implications of its use. However, within the context of formal education the main task of the teacher is to provide and orchestrate learning

[1] This chapter is partly based on: Krauskopf, K., & Zahn, C. (2009). Medienkompetenz bedeutet nicht, zu wissen wo man klickt. Mentale Modelle (sozio-) kognitiver Funktionen digitaler Medien als Ansatzpunkt fächerübergreifender Medienbildung in der Lehramtsausbildung [Media-related competence is not about knowing where to click. Mental models of (socio-) cognitive functions of digital technology as an approach to technology instruction in teacher training]. *Ludwigsburger Beiträge zur Medienpädagogik, 12*, and: Scheiter, K., Krauskopf, K., Stalbovs, K., & Hesse, F. W. (2010). *Computerunterstützte Förderung der Kompetenzentwicklung – Lesen, Mathematik, Naturwissenschaften* [Computer-supported competence development – reading, mathematics, and the natural sciences]. Unpublished expert report for the Federal Ministry of Education and Research (BMBF).

arrangements (Helmke, 2009; Oser & Baeriswyl, 2001; for a focus on technology see Hudson, 2008; Salomon, 1992). In order to fulfill this specific role, the teacher needs to leverage the potential of emerging technologies for teaching. For this, pure technology accessibility, so called *first-level barriers*, have proven to be less relevant than *second-level barriers* (Cuban, Kirkpatrick, & Peck, 2001; Ertmer, 1999, 2005; Macaruso & Hook, 2007). These encompass mainly, aside from factors on the levels of school and society, a lack of a simultaneous development of teachers' pedagogical knowledge together with their technological knowledge that hinders the effective integration of emerging technologies (Cuban et al., 2001; Law & Chow, 2008; for video see, Hobbs, 2006; McNeil & Nelson, 1991). In sum, for accomplishing the tasks of effectively using technology for teaching, teachers need to know how to *evaluate* and *design* learning arrangements with regard to their potential to support the attainment of specific educational objectives (Schmotz, 2009; Tulodziecki, 1997). One aspect of this knowledge is the understanding of the affordances and constraints of a technology for learning, in order to utilize them as cognitive tools in the classroom (Angeli & Valanides, 2009; Webb & Cox, 2004). Based on this the pedagogical framing can be created appropriately. It can furthermore be assumed that the less pre-structured a technology is for educational use, the more it becomes the teachers' task to re-purpose it (e.g., Koehler et al., 2011). For the example of emerging video technologies, Zahn and colleagues could provide examples for leveraging the potential of this technology for learning by adequately selecting technology and providing specific instructions for student design tasks (Zahn et al., in press; Zahn, Pea, et al., 2010).

Considering generic models of teacher competence and teacher cognition in general (Baumert & Kunter, 2006; Bromme, 1992; Calderhead, 1996; Shulman, 1986, 1987), as well as literature overviews focusing on the use of technology for teaching (Mumtaz, 2000; Webb, 2011; Webb & Cox, 2004) teachers' *knowledge* and *beliefs* can be extracted a two main aspects. Motivational factors, such as teachers' self-efficacy or enthusiasm, are also mentioned as further aspects. However, because the focus of this dissertation is on *how* teacher are planning to use technology in their teaching, these motivational factors that focus on *whether or not* teachers will use technology will not further be investigated in the present dissertation.

In this literature strand, teaching – with and without utilizing technology – is considered an ill-defined domain (Berliner, 1992; Koehler & Mishra, 2008; Leinhardt &

Greeno, 1991) where a teacher's cognition comes into play in three different phases (Calderhead, 1996): *preactive* (planning and preparing for teaching), *interactive* (implementing and adjusting the planned activity to children and context), and *postactive* teaching (reflection of classroom events). While the interactive and postactive phases are considered to be largely concerned with the interaction between teacher and student (Webb, 2011) and students' actions and cognitions (cf. the *cognitive mediation model* of classroom processes, Calderhead, 1996; or the influence of students' conceptions in the case of educational technology, Gerjets & Hesse, 2004) it is the phase of lesson planning that is indicative of a teacher's ability to cognitively integrate their professional knowledge and beliefs (Baumert & Kunter, 2006; Blömeke, Müller, & Eichler, 2005; Blömeke, Rise, Müller, Eichler, & Schulz, 2006; Bromme, 1992). Especially task evaluation and task design are considered important parts of lesson planning and have proven relevant distinction in empirical studies (cf. also Kramarski & Michalsky, 2010; McElvany et al., 2009). Therefore, in the present dissertation aspects of lesson plans are applied as dependent variables and the focus will be on task evaluation and task design.

1.1.1 Professional knowledge and technology integration - the TPCK framework

With regard to teacher knowledge as a factor for technology integration in the classroom, more recently, the Technological Pedagogical Content Knowledge (TPCK or TPACK) Framework has been most prominently introduced by Mishra and Koehler (Koehler & Mishra, 2008, 2009; Mishra & Koehler, 2006) (see also, Doering, Veletsianos, Scharber, & Miller, 2009; Niess, 2005). This framework has inspired a body of empirical research (for a first overview see Abbitt, 2011) and has found its way as specification of teacher knowledge into broader frameworks of pedagogy with technology (Webb, 2011). The concept of Technological Pedagogical Content Knowledge has been developed based on prior theoretical work by Shulman (1986, 1987) and offers a heuristic to identify relevant aspects of the professional knowledge of teachers in relation to the instructional use of technology.

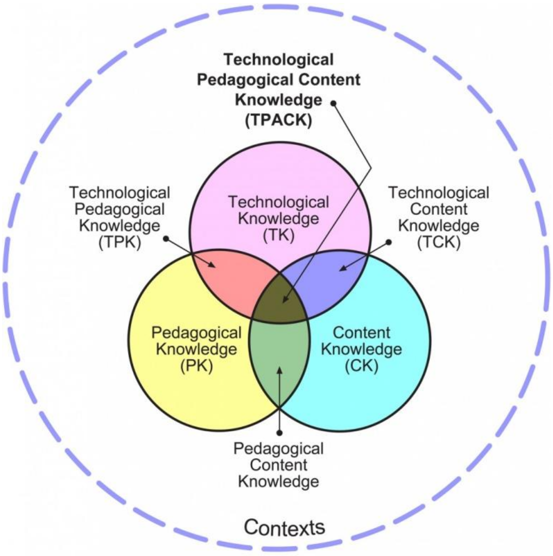

Figure 1.1. Graphic representation of the Technological Pedagogical Content Knowledge (TPCK) framework [sic!], http://TPACK.org/.

The TPCK framework asserts that a teacher's *Technological Knowledge* (TK), in order to become relevant for teaching, needs to be considered as an integrated part of other relevant aspects of teacher knowledge, namely, *Pedagogical Knowledge* (PK) and *Content Knowledge* (CK). Mishra and Koehler propose a depiction of the framework as a Venn-diagram (see Figure 1.1) based on these three sub-domains (TK, PK, and CK) that I will refer to as *basic sub-domains* here (for a detailed description of the proposed knowledge sub-domains based on Cox and Graham, 2009, see Table 1.1).

On a first level of integration three *intersecting sub-domains* refer to specific constructs of their own value. *Pedagogical Content Knowledge* (PCK) has first been introduced by Shulman (1986) and refers to a teachers knowledge about content-specific strategies for assessment and teaching as well as about students' prior knowledge and common misconceptions (this is related to the notion of subject specific didactics, *Fachdidaktik*, in the German tradition of teacher training). *Technological Content Knowledge* (TCK) indicates knowledge about how content and technology are interrelated, meaning that the same content is transformed when presented with different technologies (e.g., for video see Koehler, Yadav, & Phillips, 2005). For example an historical film screened on a projector versus presented with video software that enables the user to isolate film details and rearrange them provides a different access to this information source. Similarly, an EEG graph provides different information on the same brain activity than an fMRI image does. *Technological Pedagogical Knowledge* (TPK) refers to the knowledge about how a technological tool can change teaching and learning and at the same time how specific learning arrangements leverage different functionalities of a tool. For example, having individual students edit a video to summarize its main points supports different learning activities than using the same tool in a collaborative setting to support the students' discussions (cf. Harris, Mishra, & Koehler, 2009). On a second level, the integration of all knowledge aspects, TPCK, then encompasses knowledge about how external representations and digital technologies can specifically support the conceptual understanding in a specific subject by combining it with certain tasks and adequate instructional guidance. Parallel to Shulman's (1986) conceptualization of Pedagogical Content Knowledge, TPCK is defined as a knowledge base specific to teachers. The idea of two levels of cognitive integration in this way is a theoretical proposition of the present dissertation and will be explained in Chapter 2 in more detail.

Table 1.1

The constructs proposed by the TPCK framework. Definitions adapted from Cox and Graham (2009) and hierarchical structure as proposed in Chapter 2.

Hierarchical structure proposed in the present dissertation (see Chapter 2)	**TPCK constructs**	**Definition** (adapted from Cox & Graham, 2009)
Basic sub-domains	Technological Knowledge (TK)	Knowledge of (emerging) technologies that have not become transparent in the field of teaching yet (in contrast to books).
	Pedagogical Knowledge (PK)	Knowledge of the general pedagogical activities that might be utilized and pedagogical-psychological foundations. General activities are independent of a specific content or topic and include strategies for motivating students, communication, and classroom management.
	Content Knowledge (CK)	Knowledge of a subject area including the topic-specific representations, which is independent of pedagogical activities or using representations for teaching.
Intersecting sub-domains ***First level of integration***	Technological Pedagogical Knowledge (TPK)	Knowledge of how to combine emerging technologies with general pedagogical activities to follow general pedagogical purposes, such as students' motivation and learning.
	Pedagogical Content Knowledge (PCK)	Combined knowledge of activities or strategies and knowledge of content representations in order to facilitate student learning. Knowledge of content-specific pedagogical activities, their conceptual power and corresponding misconceptions of students.
	Technological Content Knowledge (TCK)	Knowledge of the bidirectional relation of content and (emerging) technology; knowledge of topic-specific representations in a given content domain that afforded by emerging technologies independent of their use in pedagogical settings.
Meta-conceptual awareness ***Second level of integration***	Technological Pedagogical Content Knowledge (TPCK or TPACK)	Knowledge of how to coordinate the use of subject- / topic-specific activities with topic specific representations both afforded by emerging technologies to support student learning.

Although this framework has provided a common ground for discussing what teachers need to know in order to leverage the potential of emerging technologies the TPCK construct, the sub-constructs and the boundaries between them remain fuzzy (Cox & Graham, 2009; Graham, 2011). So far the relationship between teachers' knowledge in the proposed sub-domains has not been specified. It remains, thus, unclear whether knowledge in the basic domains is a prerequisite for constructing knowledge on the first or second level of integration. As a result, the interplay between the different knowledge domains and how they are represented remains an unresolved theoretical and empirical issue. With regard to this question, Angeli and Valanides (2009) have contrasted a *transformative* view on TPCK as a unique body of knowledge that also requires specific instruction with an *integrative* view that assumes spontaneous construction of TPCK when knowledge in the sub-domains exists. The latter suggests that it is sufficient to train the separate sub-domains and assume TPCK development to follow. The authors argue that spontaneous construction of TPCK when sub-domain knowledge is given is unlikely and propagate the *transformative* view. According to Graham (2011) this is in line with how Mishra and Koehler have intended to conceptualize TPCK. However, the operationalization in Mishra and Koehler's empirical research does not adhere to this assumption (Koehler & Mishra, 2005; Koehler et al., 2007) and also studies by Angeli and Valanides (2005, 2009) do not systematically compare the two assumptions. To summarize, although the question of what TPCK is and how it is developed is discussed in the literature, theoretical specifications have not exceeded unspecific plausible assumptions (Koehler, Mishra, Kereluik, Shin, & Graham, in press) nor has empirical research specifically addressed these, yet. Therefore, the present dissertation will try to provide a new approach to address these issues from a different perspective.

1.1.1.1 Prior empirical research based on the TPCK framework

So far, empirical research referring to the TPCK framework has mainly focused on two broader aspects. First, a number of studies are concerned with fostering Technological Pedagogical Content Knowledge as a whole mostly operationalized as gaining a more complex understanding of the interconnections between technology, pedagogy and content. Second, a range of studies aims at developing self-report measures to assess TPCK and its sub-domains. Some of these then scrutinize the distinctiveness of the sub-facets in factor analytic designs.

Research on pre-service teacher training and professional development.

A strong focus of research based on the TPCK framework is concerned with evaluating and improving teacher training programs preparing pre-service to utilize technology in their future classroom. In line with this focus Abbitt (2011) has provided a first review of several methods that aim at assessing TPCK and its development. He comes to the conclusion that the existing measures – self-report measures tapping perceived knowledge, discourse analysis procedures, and rubrics for lesson plan evaluation – provide a initial basis for gaining insight into how teacher preparation programs impact future teachers "knowledge and cognitive processes" (Abbitt, 2011, p. 295), as well as outcomes relating to effective instructional use of emerging technologies. However he also acknowledges that further effort is still needed to clarify the relation of (perceived) knowledge measures and quality of lesson planning. For example, the lesson plan evaluation rubric proposed by Harris, Grandgenett, and Hofer (2010) has not yet been applied in any studies. Furthermore, he emphasizes that the context of teacher education varies greatly and will continue to propose challenges to this line of research. However, what he does not discuss, although it seems a central issue, is that it remains uninvestigated what the developed self-report measures assess. So far there have been no studies providing convergent and discriminant validity by relating these measures to actual knowledge tests or belief and attitude scales. In line with this the author does not discuss, why the constructs proposed by the TPCK framework are seemingly treated as equivalent, while only the TPCK construct is proposed to be the critical one. In conclusion, following Abbitt's (2011) appraisal, the current state of TPCK research provide a valid starting point for evaluating teacher training, however, from a theoretical more basic research perspective the conceptualization of TPCK and empirical research on its cognitive development remain unsatisfactory. Some of the studies reviewed by Abbitt (2011) will be presented in more detail to provide a more concrete picture of the empirical research as background for the theoretical considerations in Chapter 2 and the empirical studies presented in Chapters 3 and 4.

Since the earliest studies investigating pre-service teachers in teacher training programs Koehler, Mishra and colleagues make use of the approach of learning technology by design to support the development of TPCK. In a study with 4 faculty members and 13 students collaborating on designing online courses for the following academic year, Koehler and Mishra (2005)found that designing technological artifacts increased the participants' reflection on the specifics of technology based education and increased their awareness for the interrelations between technology, pedagogy, and content over a period of 9 weeks. Koehler, Mishra, and Yhaya (2007) report similar findings from a study with two of six groups of collaborating faculty members and students. They coded discourse episodes during 3 weeks for each group sampled from the first, second and third chunk of a semester. The analyses revealed that over the course participants discussed about technology, pedagogy and content in more integrated way, however, there were preeminent differences between the groups indicating that the development of TPCK is not a simple linear process and highly dependent on individuals prior knowledge and interpretation of their role as advocates for the different aspects of TPCK, namely a content, technology, or pedagogical focus.

Angeli and Valanides used lesson design tasks not as a means for developing TPCK but rather assessing the TPCK skills as outcome of teacher preparation (Angeli & Valanides, 2005, the concept of TPCK is here referred to as ICT-related PCK) In a design-based experiment (with reference to Design-Based Research Collective, 2003) they developed an instructional systems design model over three iterations and evaluated it with three subsequent classes of pre-service elementary teachers. Starting with an instruction based on presenting and discussing cases of teachers who had integrated ICT into their teaching in the first phase, the authors turned to modeling the use of specific technologies along with theoretical input on pedagogical and content issues. In the third phase, participants did not work with multimedia authoring tools but with software that was used to create and explore computer models of scientific phenomena. The pre-service teachers' TPCK (ICT-related PCK) competency was assessed by coding ICT-enhanced lessons participants had been asked to develop on four dimensions: *Indentifying topics to be taught with ICT*, *identifying representations to transform the content*, *identifying teaching strategies*, *infusing ICT activities in classroom instruction*. A fifth dimension *selecting ICT tools to afford content transformations and support teaching strategies*, which was theoretically proposed, was not included in the analysis. In general, the results showed that participants of the first phase displayed the lowest and participants of the third phase the highest scores on all dimensions (ICT-related PCK). In detail, participants in phase two performed better than phase one participants and equal to those of phase three with regard to identifying topics to be taught with ICT and identifying representations to transform the content. Considering the TPCK model of Mishra and Koehler (2006), these aspects can be interpreted in the sense of TCK, the intersection of technological and content knowledge. Participants in phase three, additionally, outperformed all others with regard to identifying teaching strategies and infusing ICT activities in classroom instruction. With regard to the TPCK model, these two aspects relate to the intersection of technological and pedagogical knowledge, TPK. The authors conclude that case-based learning does not suffice for pre-service teachers to generalize from the encountered technologies to others with regard to their instructional use. The authors further suggest, that the aspect of integrating ICT use with appropriate pedagogy is the most difficult to develop and that specific tools might afford this integration compared to others that make it easier to continue teaching in the established routines. Their data indeed suggest that it seems best to model the pedagogical use of a specific software with specific affordances. However, the study design urges care concerning this interpretation, because in the third phase content (modeling in science) and technology (modeling software) were most constrained and, thus, most difficult to compare with the other phases and to generalize on ICT in general. Finally, the question remains open, why the integration of ICT into pedagogy should be more difficult to accomplish than identifying and selecting representations that transform content.

In another study, Angeli and Valanides (2009) investigated how technology *mapping* influenced the growth of TPCK with a focus on using information and communication technology (ICT). Initially, the authors found in a survey with 45 dyads of technology experienced pre-service that the *conceptions about the affordances* of a specific software differed between participants with regard to the perceived affordances as well as their perceived connections to content representations and pedagogy, although they were all evaluating the same software. Then, during the course of three subsequent semesters a total of 215 pre-service elementary teachers, the instructor explained and modeled an instructional design approach that showed how to map the pedagogical affordances of specific ICT tools on specific content in order to create powerful learning that leveraged the potential of the technology and transformed the content. In a repeated measures within-subjects design students were asked to design ICT-enhanced learning activities for a topic of their choice in the beginning (week 5) and in the end (week 10) of the course. The design products were assessed by self-, peer-, and expert-ratings on different dimensions aggregated into a TPCK competency score. The results showed a significant increase in all TPCK performance criteria from the first to the second task. The authors concluded from these and qualitative results that complex skills like TPCK can be developed over the course of a semester and that design tasks proved to be a well fit assessment tool.

Similarly, Graham and colleagues (Graham, Borup, & Smith, in press) conducted a study looking into the gradual change over a semester in the pedagogical reasoning for using technology in a sample of 133 pre-service elementary teachers. First, participants were presented with randomly selected educational objectives in language arts, math, science, and social studies (based on Utah core curriculum standards). Then, participants were prompted to (1) describe a possible instructional scenario utilizing technology to support students in attaining this objective, and (2) to provide a rationale for choosing the respective technology. They analyzed approximately 25% of the answers provided at the beginning (pre-assessment) and the end (post-assessment) of a semester. Overall, the authors focused on TK, TPK, and TPCK and develop elaborate coding schemes to code the participants' rationales for choosing technology in their proposed instructional scenarios, and results show an increase in content-specific (TPCK) and content-general (TPK) pedagogical argumentation over time. The amount of rationales referring to general technological knowledge did, however, not change over time. This indicates that participants' content-specific use of technology was still less developed. From this the authors conclude for teacher education, namely, to plan well when in the course of training technology should be taught and by whom. With regard to future research, they suggest to investigate how teachers decide on the (technological) representations they will select or use. Overall, the authors seem to imply a developmental model assuming that more complex reasoning for utilizing technology is based on pedagogical and content knowledge (acquired in content and methods courses). These are plausible interpretations, yet, not directly supported by the data. Especially, whether

So far, only on experimental study has been conducted by Kramarski and Michalsky (2010) study with 95 pre-service teachers in a professional training program over 14 weeks working with a hypermedia environment. The authors compared two experimental groups, one with explicit encouragement of meta-cognitive discussion (IMPROVE self-questioning strategy, Mevarech & Kramarski, 1997)and one without. They assessed the participants' TPCK as one of the dependent variable. With regard to the operationalization they differentiated the assessment into TPCK *comprehension skills* and TPCK *design skills* (for a similar differentiation in assessing teachers' skill in teaching with multimedia see McElvany et al., 2009). To assess TPCK comprehension skills participants were presented a study unit based on TPCK and other theoretical approaches once in the pre-test and once in the post-test. The unit referred to a different topic in the post- and the pre-test. Participants were then asked to complete a questionnaire of ten open questions tapping five subscales of TPCK comprehension skills: understanding, application, analysis, synthesis, and evaluation. The answers were coded by expert raters. To assess the TPCK design skills, participants were asked design a two-lesson study unit including the use of technology by following four categories: indentifying learning objectives, selecting content, planning didactic material, and designing the learning environment. The topic of the lesson to be designed was preset by the researchers. With regard to both TPCK measures, the results showed a significant increase between pre- and post-test as well as a significant interaction indicating that the explicit instruction for meta-cognitive reflection lead to a higher increase in TPCK skills. In addition, TPCK measures in both conditions were significantly correlated with aptitude measures of self-regulated learning. These correlations were higher for the design skills. The authors conclude that in line with the findings of Angeli and Valanides (2005, 2009) the findings of this study suggests that indeed pre-service teachers need to be taught explicitly about the interactions of technology, pedagogy, and content. The positive effect of self-regulatory support on the increase in TPCK skills indicates that planning (designing) lessons that leverage the affordances of a technology is indeed a challenging cognitive task that demands from teachers to develop a deep understanding of a technology's functions and probe their relations to the respective content and pedagogy.

To summarize, the studies described thus far validate the plausibility of the TPCK framework and provide tentative support that technological knowledge of (pre-service) teachers needs to be integrated into more complex pedagogical reasoning to provide possibly effective learning environments. However, none of them investigates predictors for the observed changes in participants' lesson design or reasoning, and only one study includes a systematic variation of external factors. This study, investigated a specific factor, self-regulatory support, as a support for pre-service teachers mastering technology use for teaching. Thus, also this study does not provide any evidence on whether and how instructing (pre-service) teachers based on the TPCK framework adds distinctly to pre-service teachers' learning, compared to mere technology focused instruction or other common (university of professional development) course concepts as control groups.

Neither have prior knowledge or beliefs been investigated with regard to possible moderating.

Research applying self-report measures.

Another group of studies aims at the development of self-report measures to assess the proposed TPCK constructs trying to empirically discriminate between them. Schmidt et al. (2009) developed a self-report measure with scales tapping all the components of the TPCK framework, containing 75 items in total with three to eight items per scale. With regard to content knowledge they covered four different areas (mathematics, social studies, science, and literacy) with an individual scale each. They performed exploratory factor analysis (principal component analysis) within each scale using as sample of 124 mostly female (93.5%) pre-service elementary school teachers. The scales proved to be sufficiently reliable, Cronbach's alphas $\geq$ .75, and intercorrelations varied between $r(124) = .07$ and .71. The highest correlation of the TPCK scale were found with the TPK, $r(124) = .71$, the TCK, $r(124) = .49$, and PCK, $r(124) = .49$, scales. These results show, that some of the sub-domains of TPCK are more distinguishable in the perception of pre-service elementary teachers than others. A closer look at the item wording identifies the instrument as a self-efficacy measure. Furthermore, it becomes clear that some items, such as "I know how to assess student performance in a classroom" in the TPK scale, additionally tap general pedagogical beliefs and orientations: Knowing how to assess students is related to how a teacher believes students should be assessed. In the study no additional measures were included to investigate external validity. Thus, empirically, it remains an open question, whether the self-reported efficacy with regard to the different components of TPCK tapped by this instrument is related to teacher experience, testable knowledge, or classroom behavior. Because, due to the small sample, the authors did not perform a principal component analysis over the whole instrument there is additional empirical data about the distinctness of the different TPCK sub-domains.

In contrast, Archambault & Barnett, 2010 developed a self-report measure and performed an exploratory factor analysis over their whole instrument, which consisted of 24 items, with three to four items per scale. The factor analysis revealed three factors, *pedagogical content knowledge*, *technological-curricular content knowledge,* and *technological knowledge*. The authors suggest that, based on the data, the TPCK framework might not be valid with regard to the different proposed components existing in practice. The authors do not discuss, however, the alternative explanation, that the prevalent suboptimal use of digital media in classroom instruction might be due to the fact that teachers lack TPCK and, thus, rate items similar in a self-report measure. This means that, because they are not able to differentiate between the different components in their self-report of the role of technology in teaching, they are less able to carefully consider the influence each component has on teaching and learning and that specific combinations of these can afford certain added value. The authors also conclude that the TPCK models shows weaknesses in precision about the different components and its heuristic value for predicting outcomes and mark that future research should address the lack of assumptions with regard to the causative interaction and direction between the components. Of course, the correlative data derived from the applied self-efficacy measure in this study alone do not suffice to uphold such a strong claim; however, the criticism that a scientific model should lead to more concrete hypothesis and predictions is valid.

Complementary to these studies from the US, studies from Taiwan (Lee & Tsai, 2010) and Singapore (Chai, Koh, & Tsai, 2010; Koh, Chai, & Tsai, 2010) are starting to additional empirical evidence for scrutinizing the TPCK framework. Koh, Chai, and Tsai (2010) applied a slightly adapted version of the survey constructed by Schmidt et al. (2009) in a study with 1185 pre-service teachers. Similar to Archambault and Barnett (2010) the authors were not able to reproduce the factor structure proposed by the TPCK framework: Items supposed to tap PCK loaded on the same factor as did all general PK items and almost all TPK, TCK, and TPCK lumped together on one factor called "Knowledge of Teaching with Technology" by the authors. They do not report correlations between the factors. Overall, the authors conclude that, although there might be culture-specific elements to the participants' answers that their results should encourage further research to validate the TPCK framework and to improve measurement of the proposed constructs.

Another study that was not able to reproduce the proposed factor structure was conducted by Lee and Tsai (2010) with 558 pre-service teachers. The survey applies was changed more substantially from the one developed by Schmidt et al. (2009) in order to specifically address web-based technology. They replaced the items assessing Technological Knowledge (TK) with a sub-scale for participants' perceived knowledge about the use of the web in general, and about the use of the web for communicative purposes. Their findings from exploratory and confirmatory factor analyses showed that participants differentiated between these two web-specific scales as well as content-specific aspects of the web (≈TCK), however, items supposed to assess participants' knowledge about general pedagogical aspects of the web (≈TPK) fell on the same factor as the items for Web Pedagogical Knowledge (≈TPCK). Lee and Tsai also do not report correlations among the TPCK sub-scales, instead they additionally investigate correlations between these scales and participants attitudes towards web-based instruction. They report positive correlations between all sub-scales, ranging from, $r(558) = .26$, $p < .001$, for knowledge about the web as communicative tool (=TK) to, $r(558) = .61$, $p < .001$, for Web Pedagogical Content Knowledge.

Another study by Chai, Koh, and Tsai (2010) followed a slightly different approach. These authors used only the subscales assessing the basic domains (TK, PK, CK) and TPCK, and had 365 pre-service teachers complete these measures prior to and after a technology integration course (12 two hour sessions). The survey was also slightly adapted from the survey of Schmidt and colleagues (2009) and in this study the authors could reproduce the proposed factor structure for the applied sub-scales in an exploratory factor analysis. More importantly, the authors present the results of regression investigating the TK, PK, and CK sub-scales as predictors for participants TPCK self-reports. Unfortunately, the authors not apply a cross-legged design trying to predict post-course outcomes, controlling for pre-course measure, however they do report, that when controlling for content and technological knowledge, pedagogical knowledge proves as the strongest predictor in the pre, $\beta = .55$, $p < .01$, and the post-measurement, $\beta = 59$, $p < .01$, respectively. This is, to my knowledge the only study (except the studies presented in chapters 3 and 4 of the present dissertation) investigating knowledge in these basic domains as possible pre-requisites of the more complex understanding of technology in teaching signified by TPCK. Citing prior research, Chai et al. (2010) conclude from their results that content, and more importantly, pedagogical knowledge seem to be the foundations for starting to link technology to pedagogy and content as a basis for developing TPCK.

To summarize, the presented studies all applying self-report measures assessing the participants' confidence, or perceived efficacy, in their knowledge of the TPCK sub-domains showed repeatedly problems to replicate the factor structure proposed by the TPCK framework. Furthermore, due to the lack of reporting the interrelations between subscales the evidence for evaluating construct validity, as measured by self-report, is scarce. Only one study investigated this, and results suggest differences in the predictive value of the sub-domains. Overall, there are not studies trying to provide evidence for differentiating the self-report scales from actual knowledge measures or teacher beliefs about pedagogy and technology. What furthermore needs to be kept in mind is that underlying these studies are different interpretations of the sub-scales, which becomes apparent in the item formulation. This exemplifies the criticism of Cox (2008) who found a large number of different definitions in a body of TPCK based research. For example in the presented studies, especially operationalization of the TCK sub-domain differs greatly. Whereas, Schmidt et al. (2009) focus on knowing about technology that influences one's possibilities to understand certain content, Archambault and Barnett (2010) include aspects of delivering instruction, which actually is an overlap with pedagogical skills. As a result, results from all survey studies cannot easily be integrated given these differences.

1.1.1.2 Summary and open issues of TPCK research

Overall, the studies presented in the last two sections provide a first insight into the methodological approaches currently applied to operationalize TPCK. Across different approaches (design-based experiments, discourse analysis, and pre- post designs applying coding procedures and self-report surveys) there is tentative evidence that (pre-service) teachers' lesson planning for technology integration can be improved, or a more complex thinking about technology, respectively, can be fostered by teacher training programs. Additionally, the support of self-regulatory processes was shown to be a beneficial factor in supporting the development of these skills. However, there remain several open issues to be addressed. *First,* except for one study (Chai et al., 2010), there is no empirical evidence providing insights as to what pre-requisites for developing TPCK might be or how the proposes sub-domains are interrelated. In contrast to the assertion that understanding technology in relation to pedagogy and content constitutes a unique body of knowledge (TPCK), there are no studies that have disentangled how the proposed sub-domains (TK, PK, CK, TPK, TCK PCK) supposedly contribute to its development, or, vice versa, have provided evidence that they do not. *Second,* there is no research providing evidence based on a between-subjects control group design. Thus, for example, in the design-based experiment of Angeli and Valanides (2005), were the first phase is treated as a baseline, it is not possible to explain why some participants performed better than others. There are also not studies that try to explain such differences by introducing moderating variables, such as prior knowledge in the single sub-domains. *Third*, there is no study that has tried to apply knowledge tests measuring declarative aspects of a teacher's knowledge, as they have been developed for example by the Educational Testing Service (*Praxis Series*, ETS, 2006). This is in contrast to a line of research investigating pedagogical content knowledge in German and international samples of mathematics in- and pre-service teachers. For example, studies conducted within the COACTIV[2] and COACTIV-R project (Baumert et al., 2010; Krauss et al., 2008; Kunter et al., 2007; Voss, Kunter, & Baumert, 2011), as well as the TEDS-M [3] project (Blömeke, Kaiser, & Lehmann, 2008, 2010; Tatto et al., 2008) have applied elaborate tests to measure content, pedagogical, and pedagogical content knowledge. These studies were on the one hand able to show that these sub-domains can be separated from each other and prove to be valid predictors for measures of instructional quality, above and beyond measures of teachers' domain-specific beliefs. In conclusion, this evidence suggest, that it seems a valid approach to try to assess aspects of the TPCK framework with more rigid measures and integrate findings with those of other research on teacher knowledge. *Finally*, as was briefly mentioned, teachers beliefs are an important construct in the research on teacher cognition and competence in general (Baumert & Kunter, 2006; Calderhead, 1996; Dubberke, Kunter, McElvany, Brunner, & Baumert, 2008; Pajares, 1992; Staub & Stern, 2002), but also in the area of technology integration. The next section will provide short overview over research on teacher beliefs as predictors for the technology integration into their teaching as a relevant body of literature adjacent to TPCK-focused research.

1.1.2 Teacher beliefs and technology integration

Beliefs about teaching and learning and the general effectiveness of technology for teaching held by teachers are considered part of what Ertmer (1999, 2005) called second-level barriers to technology integration in the classroom. These considerations where formulated first in reaction to rising technology access in schools while its use remained low (Conlon & Simpson, 2003; Cuban et al., 2001). Moreover, with regard to

[2] COACTIV = Professional Competence of Teachers, Cognitively Activating Instruction, and the Development of Students' Mathematical Literacy. The extension R stands for *Referendare*, which refers to beginning teachers in an internship phase after university training specific to German teacher training programs.
[3] TEDS-M = Teacher Education and Development Study in Mathematics.

the rising attention to teacher knowledge Law (2008) has argued that teachers' beliefs have to be considered alongside knowledge and technological skills to more fully understand teachers' decision making and behavior regarding technology. This argument had, furthermore, also been by Webb and Cox (2004) and Mumtaz (2000) in their overview articles. Considering the complex and heterogeneous discussion around the significance of teachers' various beliefs for lesson design and teaching, however, shows that this construct needs to be approached carefully. For example, it has been argued that more concrete beliefs about pedagogy and teaching practices seem more relevant than rather abstract epistemological beliefs about the nature of knowledge and learning in general (Hofer & Pintrich, 1997; Schmotz, 2009; Tondeur, Hermans, van Braak & Valcke, 2008).

This is in line with empirical research showing that more concrete pedagogical beliefs prove to be a relevant factor influencing instructional quality (Dubberke, Kunter, McElvany, Brunner, & Baumert, 2008; Staub & Stern, 2002). Like Souvignier und Mokhlesgerami (2005) could show for the implementation of a literacy training program, it is mostly constructivist (compared to transmissive) orientations that benefit the appropriation of pedagogy and teaching strategies. Even though empirical research is still scarce (Ertmer, 2005), first results confirm this notion also in the area of technology integration into teaching. The cross-national study SITE 2006 (without the participation of Germany, International Association for the Evaluation of Educational Achievement, 2005), Law und Chow (2008) find negative correlations between teachers' traditionally transmissive pedagogical orientations and their use of Information and Communication Technology (ICT). A similar connection was also found in other studies (e.g., Conlon & Simpson, 2003; Sang, Valcke, Braak, & Tondeur, 2010).

Moreover, there is evidence that pedagogical beliefs of teachers do not only predict the magnitude of (the intention for) technology use in the classroom, but also *how* teachers intend to use technology in their teaching. Tondeur et al. (Tondeur, Hermans, van Braak, & Valcke, 2008) were able to show in a sample of 574 Belgian teachers that those with more constructivist pedagogical beliefs, compared to those with more traditional beliefs, tend to use digital technology more specifically as an information tool, i.e. for selectively obtaining and presenting information. In line with this, Schmotz (2009) identified in her study consisting of interviews and videotaped lessons of 22 German teachers, three patterns of instructional technology use (*student-centered*, *differentiated*, *teacher-centered*) that were related to specific beliefs about the potential of technology for educational purposes (*changing instructional culture*, *part of society's reality*, *auxiliary means*). She also concludes that constructivist instructional strategies applying complex tasks tend to leverage the potential of technology for educational objectives better. Finally, Becker (2000) in a large survey study with over 4000 US teachers, also finds that the small group of teachers who transform education with technology are characterized by a constructivist teaching philosophy. In line with Schmotz's (2009) student-centered pattern, the instruction of these teachers focuses on supporting the autonomy of students and collaborative settings.

Beyond this, one qualitative study comparing two cases by Chen, Looi und Chen (2009) investigated the interplay between teachers knowledge of technology affordances, their pedagogical beliefs, and their educational objectives (intrinsic of extrinsic). They argue that these have to be coordinated and for effective lesson planning map onto the affordances of a given technology.

1.2 Conclusion

Taken together, the notions of Technological Pedagogical Content Knowledge and teacher beliefs as well as the related research provide a basis to consider the teachers' technology related competence as an important factor contributing to the effective use of technology in the classroom. The two major aspects considered here were the teachers' knowledge in the sub-domains of technology, pedagogy, and content and their integration for pedagogical decision making as claimed by the TPCK framework (Koehler & Mishra, 2008; Mishra & Koehler, 2006) and the pedagogical beliefs, about more constructivist or more traditional transmissive teaching approaches.

However, the theoretical foundations of the TPCK framework lack a clearer definition of which knowledge representations it refers to. This is mirrored in the empirical research based on it. First, except for one study there is no empirical evidence as to how the proposes sub-domains are interrelated or whether they function as pre-requisites for TPCK, respectively. Second, no research has been conducted that applies knowledge tests measuring declarative aspects of teacher knowledge complementary to or instead of TPCK self-report scales. Third, no study has contrasted the TPCK constructs with teachers' pedagogical beliefs, although, based on the research literature, this seems highly relevant. Finally, there is no research applying between-subjects control group designs to identify specific effects of interventions on and pre-requisites of TPCK.

In the present dissertation some of these issues are tackled. The first goal is to improve the theoretical foundations of the TPCK framework by identifying relevant knowledge representations as mental models and discussing the coherence of the TPCK framework. In the course of this it will also be argued for conceptualizing TPCK as a meta-cognitive construct. This will be done the following chapter. Following an interlude introducing web-based video technology as exemplary emerging technology, results from three studies addressing some of the empirical shortcomings of the present TPCK research will be presented. First, both studies will apply a declarative knowledge test to assess the sub-domain of pedagogical knowledge (PK) that has proven to be relevant in prior research (Chai et al., 2010). Second, the Technological Pedagogical Knowledge (TPK) sub-domain is concretely defined as participants understanding of the affordances, i.e. the functions' impact on cognitive, socio-cognitive, meta-cognitive, and motivational learning goals, of a known (YouTube in Study 1) or a newly introduced (WebDIVER in Study 2) video technology, respectively. Third, both will be investigated in relation to each other and separated from teachers' pedagogical beliefs with regard to their interactions and predictive validity for pre-service teachers' lesson planning for the respective video technology. Finally, an experimental paradigm will be introduced trying to manipulate the construction of mental models of (socio-) cognitive tool functions and to empirically scrutinize the assumed processes underlying the TPCK framework. These studies and their results will furthermore lay a foundation for hypotheses to be tested in future experimental research.

2. Mental Representations and Cognitive Processes Underlying TPCK – Mental Models, Coherence, and Adaptive Expertise.[4]

Emerging technologies (Graham, 2011) can be utilized as cognitive tools for learning (Koehler et al., 2011; Putnam & Borko, 1997; Zahn, Pea, et al., 2010). For example, they can enable learners to access information in constructive ways, such as creating web content by writing Wikipedia articles or annotating YouTube videos. However, possible educational uses for emerging technologies are manifold and not predetermined in advance. This reinforces the demand on the teacher to repurpose (Koehler et al., 2011) these technologies for classroom instruction. In order to be able to do this, teachers first have to understand the different affordances and constraints of emerging digital technologies (Angeli & Valanides, 2009; Gamage, Tretiakov, & Crump, 2011; Koehler & Mishra, 2008; Suthers, 2006) for teaching and learning. Because different visible structures, such as desk arrangements, collaborative settings, or tasks are orchestrated by the teacher to support specific learning goals, the teacher needs to be conscious of what the underlying learning processes are that she is aiming at (cf. Oser & Baeriswyl, 2001). This is even truer when utilizing emerging technologies. To sum up, teachers have to understand how a technology impacts the students' individual (cognitive) and collaborative (socio-cognitive) learning processes, the students' self-regulation (meta-cognition), and their motivation. Teachers have then to respond to this knowledge by selecting and creating appropriate learning activities (Harris et al., 2009). Thus, in order to adequately use technology in their teaching, teachers need to plan this use carefully (Bromme, 1992; Webb, 2011; Webb & Cox, 2004). In other words, the challenge for the individual teacher to leverage the potential of a technology (for example of digital video tools as in the empirical studies presented in Chapters 3 and 4) begins with understanding and adequately representing technology's (socio-) cognitive functions in the light of their prior professional knowledge.

The Technological Pedagogical Content Knowledge (TPCK) framework has provided a common ground for discussing these issues, based on its central claim that

[4] This chapter is partly based on, Krauskopf, K., Zahn, C., & Hesse, F. W. (accepted for publication). Mental Representations and Cognitive Processes Underlying TPCK – Mental Models, Coherence, and Adaptive Expertise. In Charoula Angeli & Nicos Valanides (Eds.). *Technological Pedagogical Content Knowledge*. New York: Springer.

technology can only add value to learning environments when considered *simultaneously* with pedagogy and the subject matter (Angeli & Valanides, 2009; Harris et al., 2009; Mishra & Koehler, 2006; Niess, 2005). However, TPCK research has largely focused on the practice of teacher training and professional development, as well as measures to evaluate respective training programs (for an overview see Section 1.1.1.1). Hence, less effort has been put into developing TPCK as a theory (cf. Graham, 2011) and specifying the assumed cognitive processes underlying the development of TPCK.

As a result, the conceptualizations of the sub-domains proposed by the framework, Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), and Technological Content Knowledge (TCK), and finally Technological Pedagogical Content Knowledge (TPCK) are perceived as incoherent and the boundaries between the individual constructs as fuzzy (Cox & Graham, 2009; Graham, 2011). Additionally, the pervasive representation of the framework in a Venn diagram (see Figures 1.1 and 2.1), does not add to the clarification of these issues. In the research literature, this is discussed as the competing *integrative*[5] view of TPCK as automatically emerging knowledge when the teacher possess knowledge in the sub-domains TK, PK, and CK versus the *transformative* view, defining TPCK as a unique body of knowledge that is qualitatively different from all other proposed sub-domains (Angeli & Valanides, 2009; Graham, 2011). Yet, what characterizes this transformation and how the changes of knowledge representation occurring during this transformation are conceptualized has not been specified.

The main focus of this chapter is to elaborate on the theoretical assumptions of the TPCK framework proposing more concrete conceptualizations to help clarify these issues. Overall, two levels of cognitive integration characterizing the development of TPCK are proposed (cf. Table 1.1). On the first level, the transformation of knowledge of the basic sub-domains (TK, PK, CK) into knowledge of the integrated sub-domains (PCK, TPK, TCK) is defined as the construction of mental models (Brewer, 1987; Johnson-Laird, 1980, 1983). For the second level of integration, referring to the

[5] Overall, the following theoretical considerations and the results of the studies presented in Chapter 3 and 4 strengthen the support for the *transformative* view proposed by Angeli and Valanides (2009). However, in order to define the cognitive processes, I propose to elaborate the TPCK framework. I will use the term integration to describe processes of any mental combination in general. When referring to the meaning of *integrative* proposed by Angeli and Valanides, it will be *italicized*.

construction of TPCK, considerations from the conceptual change literature are followed (Clark, D’Angelo, & Schleigh, 2011; diSessa, Gillespie, & Esterly, 2004; Ioannides & Vosniadou, 2002; Vosniadou, 1994) and TPCK is conceptualized as meta-conceptual awareness of the demands of the teaching task, the teachers own knowledge in the integrated sub-domains, and the context. More concretely, these propositions will be presented in the next four sections as follows:

1. How should the knowledge representations of the proposed basic (TK, PK, CK) and integrated sub-domains (TPK, PCK, TCK) be conceptualized in order to provide an effective basis for lesson planning and classroom implementation of emerging technologies? Overall, I assume that the construction of mental models is a necessary first level of integration and this will elaborated using the example of Technological Pedagogical Knowledge (TPK).This sub-domain is defined as the mental models that teacher construct of the (socio-) cognitive functions of a technology. These should co-determine how teachers leverage the specific potential of the respective technology in the classroom. Overall, complex and adequate mental models of technology functions should lead to more flexible planning for technology integration (Harris et al., 2009) and to scrutinizing the specific added-value (Angeli & Valanides, 2009) of the respective technology.

2. Which functional relations can be assumed between the knowledge sub-domains? In the current research, there have been different conceptualizations explicit (*transformative* versus *integrative* view, Angeli & Valanides, 2009) or implicit in the operationalizations of research designs. Whether knowledge in the basic or integrated sub-domains is a necessary prerequisite for TPCK, or a stepping stone, or something unrelated has not been elaborated. Based on the approach presented here to consider the notion of mental models for elaborating the TPCK framework, I suggest mental models as mediator and knowledge in the basic sub-domains as moderators in the relationships between the proposed sub-domains and lesson planning for teaching with technology (TPCK tasks).

3. Considering the knowledge representations in the basic and integrated sub-domains along with assumptions about their interrelations, the question is how to conceptualize TPCK as a construct. If developing TPCK is supposed to enable teachers to react flexibly to the emergence of new technologies that offer different transformations of content (Angeli & Valanides, 2009) for teaching and learning,

TPCK cannot sufficiently be conceptualized as a fixed body of knowledge. Instead, it needs to be defined as knowledge about the demands of the teacher's task, the professional knowledge at his or her disposal, and the context. This issue will be discussed in the light of coherent versus fragmented conceptual understanding based on the conceptual change literature and suggest that on a second level of integration, TPCK needs to be constructed as meta-conceptual awareness.

4. Finally, based on a conceptualization of the TPCK framework as a coherent theory and the assumption that developing TPCK as meta-conceptual awareness, expertise in TPCK is defined as adaptive, namely, mastering the ability to adjust to changing contextual constraints (in contrast to routine expertise, cf. Forssell, 2012; Hatano & Inagaki, 1986). It will be discussed how the professional learning processes for teachers in this domain could be described and how learning (processes of cognitive integration) might be different for each the inexperienced and experienced.

In conclusion implications for research, teacher training, and professional development will be described.

2.1 Teacher Knowledge as Mental Model Representations

In line with Koehler and Mishra (2008), in the present dissertation, teaching supported by technology effectively is defined as a complex, ill-defined (cognitive) task. This leads me to claim that it is thus not sufficient for a teacher to simply remember the technological functions of the software or examples of how other teachers have used technology in their instruction. Instead, teachers need to construct a mental model of the functions of the respective technology in relation to their impact on learners' access to the subject matter. First mental models will be defined more concretely, then it will be elaborated what this means conceptually when mapped on the TPCK framework, and finally as an example, a tentative model for the generic content dimensions of the integrative sub-domain, Technological Pedagogical Knowledge (TPK), will be laid out.

Mental models are representations of elements in situations and their interrelations that people construct based on their prior knowledge and beliefs. With regard to *how* they are represented, cognitive psychology assumes that they are analogue and continuous representations of elements and their interrelations that can be directly manipulated. They are more situated and specific than general beliefs or declarative knowledge (Brewer, 1987; Johnson-Laird, 1980, 1983; Westbrook, 2006). Also, mental models exceed what is explicitly asserted in given premises, and are therefore effortful to construct. As a result, mental models signify a deeper understanding (Azevedo & Cromley, 2004; Chi, 2000) – compared to list-like propositional representations. Constructing a mental model of the task and the constraints for solving it is necessary for accomplishing complex tasks that require drawing inferences and making predictions based on innately incomplete information, like classroom situations. Brewer (1987) distinguishes mental models from schemas in a way that further clarifies the notion of mental models considered here. The author defines *schemas* as precompiled *generic knowledge structures* consisting of old generic information that can be instantiated in a situation. In contrast, the author defines *mental models* as *specific knowledge structures* constructed at the time of input of new information and being constrained by specific generic knowledge. Input of new information includes questions stating a particular problem or task. Taking Study 2 presented in this dissertation as an example, this could be a question like "How would you implement this new video technology in teaching a specific historical topic?"

Mental models following Johnson-Laird (1980) or Brewer (1987) are considered cognitive structures that are constructed in the situation when – in the present case – teachers are confronted with tasks such as lesson planning. Hence, mental models are not considered long-term memory structures (cf. the notion of mental models as rather long-term memory structures, Gentner & Stevens, 1983). However, a feedback process is assumed when over time the production of different solutions will enable the teacher to characterize the commonalities of a set of solutions (Johnson-Laird, 1983) and abstract across the concrete task contexts better and also improve in the construction of mental model representation. Thus, task solutions such as lesson plans or experiences with implementation in class are likely to be "stored" in propositional representations, that is, abstract and list-like. Nevertheless, such a propositional representation of combined knowledge of the sub-domains for a specific lesson does not suffice to accomplish the next task ahead. An example for a propositional representation could be to present cases of teachers' implementing a certain digital technology, which alone, as seen in the study by Angeli and Valanides (2005), was not sufficient to develop pre-service teachers' identification, selection, or infusion of ICT for teaching purposes themselves.

2.2 First Level of Integration – Mental Models Mapped on the TPCK Framework

The Venn-diagram shown in Figure 2.1 depicts the most common representation of the TPCK framework. As Graham (2011) puts it, this visualization adds to the theoretical fuzziness and also suggests an *integrative view*. This means that growth in either of the basic sub-domains (Graham, 2011, speaks of core categories) would automatically result in growth of all the sub-domains depicted as overlaps of the basic sub-domains. Such an assumption does not adequately represent the current empirical results (e.g., Angeli & Valanides, 2005, 2009) and is a contradiction to the initial reasons to introduce the TPCK framework as well. Concretely, this is the claim that purely technological knowledge does not lead educators to use technology to transform their teaching of a specific content (Mishra & Koehler, 2006; cf. also,) (Cuban et al., 2001; Ertmer, 1999). Even though also Koehler and Mishra have described TPCK in a *transformative* way from the start (cf. Graham, 2011), that is, conceptualizing TPCK as a distinct body of knowledge not arising automatically from its adjacent sub-domains, the literature has not directly addressed the assumed relations among the seven proposed constructs. To what extent does the TPCK framework assume knowledge in the basic sub-domains, depicted more peripherally in Figure 2.1, for example in technology and pedagogy, as a prerequisite to constructing knowledge in an integrated sub-domain, such as TPK? And, following from this, how do all these intermediate constructs ultimately feed into the development of TPCK?

The precising definitions of the TPCK constructs introduced by Cox and Graham (2009) provide a clearer understanding of each sub-domain and their unique features (see Table 1.1); however, it remains an open theoretical question as to how the knowledge in different sub-domains is cognitively represented and how they relate to each other. In sum, TPCK has only been formulated as a structural model, and the formulation of a process model, such as the more generic one by Baumert & Kunter (2011) has been neglected.

This is furthermore an open empirical question. Studies applying TPCK surveys and quantitative analytic methods (Archambault & Barnett, 2010; Chai et al., 2010; Koh et al., 2010; Lee & Tsai, 2010; Schmidt et al., 2009) have focused on factor analyses and examining the intercorrelations of the subscales investigating the questions of whether pre-service teachers could differentiate between the proposed constructs in self-reported confidence in their respective sub-domain knowledge. Most of these studies did not have any prior assumptions about which constructs should show stronger or weaker relations. Only one study (Chai et al., 2010) used regression analytic techniques to test TK, PK, and CK self-efficacy ratings as predictors for TPCK, thus assuming that the basic sub-domains are prerequisites for TPCK. Qualitative studies (Graham et al., in press; Koehler & Mishra, 2005; Koehler et al., 2007) similarly coded the occurrence of discourse that was attributable to each of the sub-domains, but did not elaborate on the relations between them, even when looking at TPCK development over time (Koehler et al., 2007). Similarly, studies using other methodologies, such as design based research (Angeli & Valanides, 2005, 2009) or experimental designs (Kramarski & Michalsky, 2010) focused on participants in tasks designed to assess their overall TPCK without looking into which constructs – from within the TPCK framework or additional variables such as beliefs and attitudes – might act as prerequisites for performance in TPCK tasks.

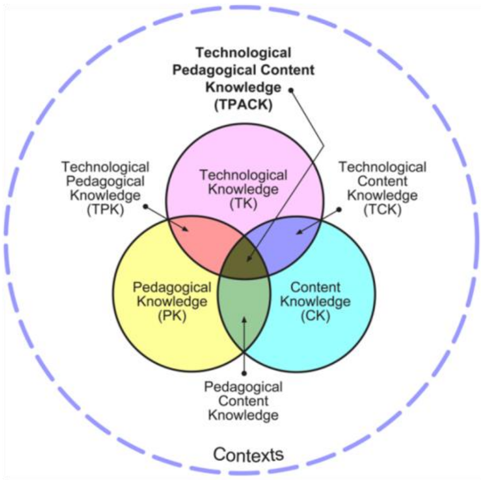

Figure 2.1. Graphic representation of the TPCK framework [sic!], http://TPACK.org/.

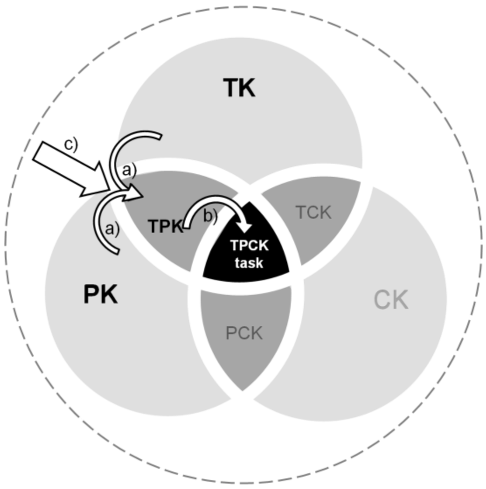

Figure 2.2. The notions of independent knowledge domains (light grey), mental models (dark grey) and lesson plans (black) mapped onto the TPCK framework. Curved arrows indicate the cognitive transformative process for integrating pedagogical and technological knowledge aspects into mental models (a) here of TPK as an example and subsequently into lesson plans for concrete content and technology (b), considering that these processes might need external support (c).

2.2.1 Interrelations of the TPCK sub-domains

When mapping the described notion of mental models onto the TPCK framework, how should we assume that the seven sub-domains relate to each other? Following Brewer (1987), generic knowledge provides a frame of reference that constrains the construction of mental models. Thus, when getting to know a new technology or planning a lesson to apply technology, prior knowledge should influence this process (which should also apply to lesson planning in general). However, as a first step, how does the prior knowledge in the basic sub-domains contribute to the construction of knowledge in higher-level sub-domains? I propose that integrating knowledge in the sub-domains needs to happen in a specific way in order to solve the complex task of teaching content (cf. Calderhead, 1996; Leinhardt & Greeno, 1991) utilizing emerging technologies (see Figure 2.2): Teachers need not only to combine rather independent basic knowledge domains into more interrelated aspects in order to solve the overall lesson planning and implementation task. But, with regard to the representational format, teachers also have to transform their combined knowledge into a mental model representation of elements and interrelations that can be manipulated and from which inferences can be made.

Because the issues regarding the fuzzy boundaries between the TPCK constructs are also prevalent in the most frequent visualization of the TPCK framework as a Venn-diagram shown in Figure 2.1 (Cox & Graham, 2009; Graham, 2011), it seems appropriate to also alter this visualization. As a first step, the sub-domains should be clearly separated and the different levels of integration could be further visualized by the intensity of the shading. By doing so, it becomes apparent that crossing the depicted boarders is related to cognitively effortful processes and that also the complexity of the knowledge representation increases from the periphery to the center. With regard to TPCK as a construct, this has broader implications, which will be discussed in Section 2.3.2. Keeping the constructs of PCK, TPK, and TCK suggests that these are actually helpful for describing the complexity of what teachers need to understand when teaching with technology. This also allows for making more precise assumptions about the cognitive processes involved. Figure 2.2 depicts these changes to the framework as an attempt to illustrate the relations between the content of the sub-domains, representational form of knowledge and knowledge building processes the following can be considered relevant in teaching with digital media: For a teacher to get from the outer areas (light grey) to the inner areas (grey and black), it is not only a matter of integrating different content areas, but rather a matter of transforming the knowledge (see arrow a in Figure 2.2) representation by constructing a mental model of elements within this domain and the interrelations between them. The subsequent steps should then be in part concerned with combining mental models based on prior knowledge into possible solutions for planning a lesson (for the example of TPK, see curved arrow b in Figure 2.2). However, it is also of importance to consider whether the construction of mental models that cognitively integrate pedagogical and technological knowledge happens spontaneously or, if not, how this process needs to be supported (see arrow c in Figure 2.2).

Following Figure 2.2 as a tentative visualization, my description of the TPCK framework elaborated by the notion of mental models is as follows: The light grey shapes in the periphery refer to knowledge in the three basic domains, technology, pedagogy, and content, which are independent from each other and also not innately related to the task of teaching a specific content with the support emerging technology. Regarding its representational format, this knowledge can be represented *propositionally* as a linear string of symbols in an abstract mental language as well as in analogue *mental models* that contain elements and their interrelations (cf. Johnson-Laird, 1980). In this respect, a propositional representation signifies a more superficial understanding and a mental model a deeper understanding. It is an open question whether new information is always translated into propositional representations and whether mental models are based on them; however, to solve complex tasks that require drawing inferences, mental models need to be constructed (Johnson-Laird, 1980, 1983). This is because propositional representations only include given information but do not integrate prior knowledge or further constraints (cf. also Shulman, 1986).

For example, considering content knowledge separately, a physicist's knowledge of electronic circuits can be propositionally represented so that she can name important elements and a set of rules related to the building of electronic circuits. When being confronted with the task of evaluating the functionality of an existing circuit or planning for building a new one, however, following Johnson-Laird (1980, 1983), a propositional representation is not sufficient to accomplish these tasks. The physicist needs to construct a mental model of the relevant elements and interrelations of electric circuits integrating the new information that was presented in the task problem. This analogue representation can then be manipulated mentally and different versions can be simulated. This allows the physicist to predict which modifications to a circuit should still be acceptable to create a functioning exemplar.

Likewise, with reference to Study 2 presented in Chapter 4, an historian's knowledge of post-war Berlin can be propositionally represented so that he can name the facts and figures relevant to the topic and reproduce a set of rules extracting such information from historical sources. When confronted with the task of evaluating a new source, however, a propositional representation is not sufficient to accomplish this task. The historian needs to construct a mental model of the elements and their interrelations in the historic situation in the light of the task at hand, such as persons and events, how they relate to each other and also, which sources provide concordant or conflicting information. This model can be manipulated and different relations between a new source and the existing elements and interrelations represented in the model can be scrutinized. This would allow the historian to make inferences about the historical narrative and how it might change by introducing a new source.

Both examples illustrate that, taking the general definitions of mental models into account, a superficial propositional representation might be necessary but not sufficient to accomplish a domain-specific task that requires drawing inferences. Instead, the accomplishment of such a task requires the construction of a mental model. Similar cases could be made for the technological knowledge of a software developer or the pedagogical knowledge of a social worker.

As argued above, this should also hold true for the task of (planning for) teaching a specific content while utilizing emerging technologies. The specific aspect here is that the deep understanding (mental model) of a teacher in one of the TPCK sub-domains should be sufficient to perform well in a respective sub-domain-specific task, such as editing a video with a specific software (TK), instructing a collaborative learning task (PK), or interpreting an historical source (CK); however, it should not be sufficient to perform the overall TPCK task of teaching supported by emerging technologies. To accomplish this task the different components need to be combined. Based on the considerations above, I propose that this combination must happen in a specific way: Teachers need to construct mental models (form of representation) when they combine knowledge of the independent basic sub-domains (content of representation), meaning that a transformative (process) needs to take place.

2.2.1.1 Integrating teacher knowledge - transforming the representational form

With regard to the representational form, integrating knowledge in the basic sub-domains leads to a mental model of the respective sub-domain on the first level of integration. This means a transformation that adds theoretical and practical value to these constructs in form of analogue cognitive representations of relevant elements and their interrelations because such a representation can be manipulated to draw inferences and predict outcomes. Even though constructing such mental models is considered more effortful, the respective knowledge is subsequently more economically accessible (Johnson-Laird, 1980, 1983). If knowledge in the higher level sub-domain is represented in this form, teachers can utilize it to "compute" solutions to the task at hand (see arrow (b) in Figure 2.2). First and foremost, the value of this conceptualization emerges for solving the complex tasks of teaching that necessitate teachers to infer concrete hypotheses about the classroom situation and student learning. This assumption is also evident in the operationalizations of teachers' knowledge in the overlapping sub-domains on the second level, as well as in more general approaches to teachers' reasoning and planning for technology integration (Webb, 2011).

The assumption that teachers' knowledge needs to be represented in mental models to solve their professional tasks is also implicit in the operationalization of *Pedagogical Content Knowledge* (PCK) tests in the work of Baumert and colleagues in the COACTIV project with a representative sample of German mathematics teachers (Krauss et al., 2008; Kunter et al., 2007; Voss et al., 2011) as well as in the international TEDS-M project of the IEA (for the German sample, see Blömeke et al., 2008; for the overall framework see Tatto et al., 2008). Participants in these studies were asked to generate multiple solutions for solving the given tasks of answering a student's "why" question, predicting students' errors in given scenarios, or asking them to come up with various explanations for mathematical solutions. All these tasks require teachers to go beyond what they know and to construct a mental model to produce task solutions.

Similarly for *Technological Pedagogical Knowledge* (TPK), this assumption can also be found in operationalizations as teachers' decision making and providing rationales for lesson plan decisions (e.g., Graham et al., in press). In a similar fashion, in the studies presented in Chapters 3 and 4, the operationalization followed a procedure applied in cognitive psychological research (e.g. Azevedo & Cromley, 2004). Participants were prompted to describe the three most *relevant* functions of YouTube (Study 1), or select the most *relevant* functions of a newly encountered video tool (WebDIVER) from all the functions that they had recalled. Because mental models are considered more elaborate representations exceeding mere facts, participants were asked here to prioritize functions of respective tools and additionally justify their decision (Study 2 and Study 3).

For *Technological Content Knowledge* (TCK) this should be assumed as well, considering the specific task here to use technology in a way to represent content to single out specific features or concepts; however, as mentioned above there is a lack of research on this construct and therefore no operationalizations to review here. It has been stated that in the area of teaching, no meaningful TCK can exist; however, no one would argue that there is no meaningful CK for teachers to master. Therefore, this issue can be considered important for research to identify who the experts on the mutual relation between content (representation) and technology are and to investigate the link to the teaching profession. Thus far, the discussion of TCK has pointed out that it might be subsumed under PCK or CK in the teachers' own perceptions (Hofer & Harris, 2012), however theoretically, this construct needs to be considered more thoroughly first before dismissing it.

Overall, for none of the integrated sub-domains has there been any research done that has defined the representational form of teachers' knowledge or has tried to tap the represented elements and their functional relations more directly with instruments such as concept mapping techniques (Kagan, 1990).

2.2.1.2 Integrating teacher knowledge - transforming the content

With regard to the content of mental models, a transformation should lead to knowledge with theoretical and practical value emerging from the combination of two of the basic sub-domains at a time that is specific to this combination: For example, how a collaborative learning setting influences the interpretation of an historical source (PCK).

Pedagogical Content Knowledge (PCK) in itself is a concept with a longer tradition going back to Shulman (1986, 1987). It includes knowledge on how best to represent and formulate the subject to make it comprehensible to others, as well as knowledge on students' subject-specific conceptions and misconceptions. In mathematics work has been done to lay out the sub-domains of pedagogical content knowledge. For the COACTIV project, Krauss and colleagues (Krauss et al., 2008) came up with three sub-facets of PCK in mathematics: (1) knowledge about the potential of mathematical tasks, (2) knowledge of students' typical misconceptions and comprehension difficulties in mathematics, (3) knowledge of specific instructional methods for mathematics. Another suggestion for sub-facets of mathematical PCK is provided by the international comparative study of primary and secondary mathematics teachers, TEDS-M (Blömeke et al., 2008, 2010; Tatto et al., 2008) They provided a model with two overarching facets, (1) curricular and planning-related knowledge and (2) interaction-related knowledge, with each specified for the four mathematical areas of (a) number, (b) algebra, (c) geometry, and (d) data. Taken together, all these authors point out that PCK has distinct characteristics that are not innate to purely pedagogical or content knowledge and can even empirically distinguish PCK from CK (Krauss et al., 2008) and PK (Voss et al., 2011). My assumptions are in line with Kunter and colleagues (Kunter et al., 2007) who formulated a model in which teachers' content knowledge (mathematics) is conceptualized as a prerequisite for the respective pedagogical content knowledge, showing this in a study with a representative sample of mathematics teachers.

Technological Content Knowledge (TCK) addresses knowledge of how to represent content with emerging technology without considering a pedagogical context (Cox & Graham, 2009). Following the example of the present dissertation, video software that enables the user to isolate and rearrange details in an historical film document provides a different access to this information source than a common video player. Similarly, an EEG graph provides different information on the same brain activity than an fMRI image does. However, no taxonomies of either representations or specific content areas have been developed so far that could describe the transformation of certain content by emerging technologies more systematically. This is mirrored in the empirical research on TPCK related to TCK, as Hofer and Harris (2012) conclude in their review. Besides the general relative negligence of this construct in the literature, the authors furthermore report that in most (10 out of 12) reviewed studies, TCK also shows the lowest occurrence in the data. Even though this negligence might be plausible for a domain that is not inherently pedagogical (PK is by definition not involved), still knowing about the different potential of content-specific representations and applications is relevant to teachers. Thus, it remains an open issue to apply more effort in defining a more graspable framework for the content of this sub-domain.

Technological Pedagogical Knowledge (TPK), in contrast, is reported to be more often in the focus of research and more often to be found in qualitative data (Hofer & Harris, 2012). Cox and Graham's (2009) define it clearly as knowledge of general pedagogical activities utilizing emergent technologies, for example, for motivation or organizing collaborative learning, independent of a specific content. For example, video software guides the interaction of students in a collaborative setting by allowing them to zoom in on details within the video, no matter what it is about. Whereas qualitative studies are able to distinguish TPK from content specific constructs – mainly TPCK (Graham et al., in press) empirical studies using teachers' self-reported confidence measures cannot show this differentiation in factor analytic designs (Archambault & Barnett, 2010; Koh et al., 2010; Lee & Tsai, 2010). However, in accordance with the theoretical and empirical work of Graham and colleagues (Cox & Graham, 2009; Graham, 2011; Graham et al., in press), it can be assumed that the boundaries between general (TPK) and content-specific (TPCK) understanding of emerging technologies for teaching can be defined and that elaborating on this distinction is relevant with regard to developing a theoretical model of how teachers learn about the transformative use of technology. This is especially relevant for emerging technologies that are not common in everyday instruction and, therefore, lack established patterns of instructional use, which could provide an orientation of teachers. Such established patterns of instructional use that are pervasive throughout the teaching community would reduce the need for the individual teacher to construct knowledge of specific affordances. In this case, Graham and colleagues argue TPK would merge into either general PK (Cox & Graham, 2009), or PCK (Graham, 2011). However, the technological development is vast and it seems impossible to define a canon of technologies for which can be taught a number of instructional patterns. Therefore, in the next section, a generic framework will be proposed for the dimensions that should be considered for determining the added value of emerging technologies with regard to teaching and learning goals in general (TPK).

2.2.1.3 An example: TPK as mental models of (socio-) cognitive technology functions

As mentioned above emerging technologies specifically afford and constrain how a user or a group of users deals with the presented content. Therefore, how teachers repurpose the respective technology for educational settings is based on how they represent the impact these affordances on student learning. As a result, affordances are defined as the impact of technological functions on relevant dimensions of teaching and learning, namely, their functions in supporting *cognitive*, *socio-cognitive*, *meta-cognitive* and *motivational* learning goals. By reviewing the literature on these four dimensions of learning, these dimensions of teachers' mental models of technology functions can be described more concretely.

Cognitive functions refer to a student's individual learning and how he or she deals with the information presented in learning material and tasks. These goals are related to the cognitive processes involved. They were extensively described by Bloom's taxonomy of educational objectives (1956) and more recently in a revised version by Andersen and Krathwohl (2001). They comprise a range of processes from remembering to creating that are translated by the teacher into learning goals by specifying which of the respective processes are tackled by the material and task at hand. In the case of computer supported learning, the teacher needs to ask herself how the available functions of a technology can specifically support some of these goals, such as how a zooming feature can support the detailed processing of visual information in a digital video (Salomon, 1972).

Socio-cognitive functions refer to collaborative learning settings in which knowledge and activities are distributed over several learners. Thus, in addition to the described individual cognitive processes, the sharing, processing, and integrating of the distributed knowledge are specifically relevant (Salomon, 1993). Therefore, in the context of computer-supported, collaborative learning settings, a prominent issue is how the specific affordances of a technology can be used to support knowledge exchange, negotiation of meaning, and building of new knowledge (Scardamalia & Bereiter, 2006; Zahn, Pea, et al., 2010). In this context, Suthers (2006; Suthers & Hundhausen, 2003) describes three central functions of how such learning processes in groups can be supported by digital technology: *initiating exchange*, *facilitating deixis*, and *establishing group memory*. Initiating exchange refers to the function of a technology to support learners in explicating and discussing their understanding of a certain matter before they make a contribution to a shared digital artifact. Because they need to clearly state their understanding, learners are more inclined to want to give a reason. Facilitating deixis refers to the function of a technology to support knowledge exchange between learners because it can provide visible referential 'anchors' that can be referred to in subsequent negotiations. The group memory describes the function of a technology that can preserve prior ideas of the group in external representations that are thus less likely to be ignored or forgotten in the ongoing discussion. For the case of advanced video tools, Zahn, Pea, Hesse, and Rosen (2010) could show that specific socio-cognitive functions of these tools can support these socio-cognitive learning processes.

Meta-cognitive functions are widely discussed, especially when learners need to self-regulate in the context of authentic tasks and inquiry-based learning (Azevedo, 2009). Accordingly, in the literature on computer supported (individual and collaborative) learning, meta-cognitive aspects are being widely studied. With regard to the technology, there are different approaches to use the technology to support the development of meta-cognitive skills (e.g. prompting, Bannert, 2006; or scripting, Kollar, Fischer, & Hesse, 2006). I refer here to a more general notion of meta-cognition, also derived from Anderson and Krathwohl’s version of Bloom’s taxonomy because in the present dissertation specific approaches are not in the focus, but rather whether teachers are attributing general meta-cognitive potential to a technology. In their definition, Anderson and Krathwohl (2001) include knowledge about learning strategies and the actual regulation of one’s own learning process.

Motivational functions are, next to achievement, an important goal in formal education. Broadly, motivation in educational psychology is concerned with extrinsic and intrinsic motivation and domain-related interest (Deci & Ryan, 2002; Krapp, 2002). With regard to the use of technology, discussion in the literature is about whether technology is just an incentive to catch learners’ interest that fades quickly or whether technology can be used to established longer lasting motivation in students to solve certain tasks or elaborate on certain content (Raby & Meunier, 2011).

In conclusion, with regard to TPK, I propose that understanding the affordances of a technology in relation to their impact on teaching and learning is a necessary precondition for creating content-specific learning scenarios leveraging the specific potential of this technology. Understanding is defined as a teacher’s constructing a mental model of the functions that a technology has or does not have, respectively in relation to *cognitive*, *socio-cognitive*, *meta-cognitive,* and *motivational* goals. Furthermore, a more complex mental model that contains more of these aspects should enable teachers to create better solutions to the complex task of teaching with technology.

To sum up, it can be assumed that cognitively integrating knowledge of the basic sub-domains should create a specific theoretical and practical value as a knowledge representation as proposed by the TPCK framework. Given this assumption, it follows that integrating all sub-domains on a second level into TPCK as a construct needs further to lead to a specific quality beyond the integrated sub-domains of PCK, TPK, and TCK. Otherwise, the construct would not add much to the understanding of teachers' reasoning for utilizing technology. In the next section, it will therefore be discussed how to conceptualize TPCK as a *framework* and as a *construct* with regard to its representational form and its content in ways to add to its theoretical power.

2.3. Second Level of Integration – TPCK as Framework and as Construct

So far a first level of cognitive integration of teachers' knowledge for teaching with technology has been described, leading from rather separate basic sub-domains of Technological, Pedagogical, and Content Knowledge to integrated mental models in the overlapping sub-domains of Technological Pedagogical Knowledge, Pedagogical Content Knowledge, and Technological Content Knowledge. Based on this, however, the issue remains how to conceptualize the construct supposedly integrating all these aspects, namely Technological Pedagogical Content Knowledge. There are two possible ways to understand this second level of integration.

One possibility is to assume that knowledge represented in the mental models of the integrated sub-domains is further integrated into one mental model under given contextual constraints. Such a mental model would represent very specific and circumscribed content: A model of how one technology combined with one specific instructional approach to represent one specific content topic would impact student learning under given contextual constraints. Although such a mental model fits the notion of specificity of mental models constructed in the light of a specific (teaching) task (see Section 2.1), it does not meet the most central claims of TPCK. First, that of Technological Pedagogical Content Knowledge going *beyond* knowledge of concrete content, pedagogy, and technology (Koehler et al., 2011), and, second, that of signifying a more comprehensive understanding of teaching with technology (Koehler & Mishra, 2008).

Therefore, it is necessary to consider a second conceptualization of TPCK, which is in line with this claim. Cox and Graham (2009, p. 64), for example, define TPCK as knowledge of how to "coordinate the use of subject-specific activities[...] or topic-specific activities [...] with topic-specific representations using emerging technologies", when understanding emerging technologies as "not yet [...] a transparent, ubiquitous part of the teaching profession's repertoire of tools". The definition of TPCK as knowledge of "how to coordinate" different knowledge domains clearly alludes to the notion of a meta-conceptual construct. In line with this, this notion is repeated throughout the TPCK literature. Harris et al. (2009, p. 401) define TPCK as concerned with the "multiple interactions" of the sub-domains, Koehler, Mishra, Kereluik, Shin, and Graham (in press) as the knowledge to orchestrate and coordinate the different sub-domains and Abbitt (2011, p. 283) as the knowledge "of the complex interaction among the principle knowledge domains". In conclusion, all these definitions and descriptions allude to the specific theoretical and practical value of the TPCK construct itself as knowledge *about* the knowledge being at the teacher's disposal in relation to the context and the instructional task. This understanding on the meta-level enables teachers to engage in the iterative process of creating solutions for the complex and ill-defined task of teaching with technology (cf. Koehler & Mishra, 2008). From this it can be concluded that a mere integration of prior integrated knowledge does not sufficiently describe the cognitive processes of constructing TPCK, but instead it is necessary to assume another knowledge transformation, implying a second level of integration. This second level is characterized by meta-knowledge of what – according to the TPCK approach – is necessary for mastering the domain of teaching with emerging technology. Vosniadou and others (diSessa et al., 2004; Ioannides & Vosniadou, 2002) specify that such an elaborate, scientific understanding is characterized by a meta-conceptual awareness of what a theory is about and what it is for. Therefore, I will hence refer to the knowledge representation of TPCK as a construct as *meta-conceptual awareness*. The use of this term is furthermore in line with Shulman's work, who defined a teacher's knowledge about his or her knowledge and the capability of explaining their decisions, as being a central point for defining themselves as professionals (he uses the term meta-cognitive awareness, Shulman, 1986, p. 13)

But, how do novices in the domain of teaching with emerging technology develop this notion of TPCK? In the remainder of this section, first an argument will be provided for why the conceptual change literature can be a valuable source for trying to answer this question and conclude with a more elaborate suggestion of how to define Technological Pedagogical Content Knowledge as meta-conceptual awareness.

2.3.1 Conceptualizing TPCK as a framework

A novice's understanding of a new concept compared to that of an expert is considered to exhibit a relation analogous to that of children to that of adults (cf. Hatano & Inagaki, 1986). Discussions with regard to children's naïve conceptual understanding of new (complex) phenomena and the development of more scientific understanding of important theoretical ideas and empirical research can be found in the literature dealing with conceptual change (Clark et al., 2011; diSessa et al., 2004; Ioannides & Vosniadou, 2002; Mason, 2001; Vosniadou, 1994; Vosniadou & Brewer, 1992, 1994). If we follow this analogy and assume that inexperienced teachers – or in the present case inexperienced with utilizing technology – can be considered novices (Berliner, 1992, 2001; Leinhardt & Greeno, 1991), it is possible to apply findings and theoretical considerations of the conceptual change literature to teachers' developing a conceptual understanding of TPCK.

Considering the conceptual change literature based on this, it becomes apparent that there are two theoretical perspectives on how naïve conceptual understanding is cognitively represented: The first view of conceptual understanding assumes novices to construct a fragmented system of "Knowledge in Pieces", that is, a rather large number of fragmented and not systematically integrated explanatory primitives that are activated in specific contexts (Clark et al., 2011; diSessa et al., 2004). The other view assumes novices to construct a "Theory Theory", that is, a rather coherent and compactly characterizable framework theory by which any specific explanation is constrained (Ioannides & Vosniadou, 2002; Vosniadou & Brewer, 1992).

Mapping both these perspectives on the question of how to conceptualize developing TPCK will, on the one hand, provide two distinct assumptions about how this knowledge might be represented in a novice's mind. And, on the other hand, the conceptualization of TPCK as a coherent framework will further prove to be in line with the notion of TPCK as a meta-conceptual construct and will provide a basis to elaborate TPCK as a scientific theory.

2.3.1.1 The TPCK Framework as incoherent Knowledge in Pieces

In the Knowledge in Pieces approach (Clark et al., 2011; diSessa et al., 2004), conceptual understanding is considered to be made up of a large number of "intuitive elements", whereas some of these elements might have a wider scope (covering more than one context) and others a narrower scope (covering only one context). Elements here are defined as *phenomenological primitives* that are always activated as a whole and describe “what happens naturally in the world” and thus can be characterized as sub-conceptual entities (diSessa et al., 2004, p. 857). Each element is specified by itself and therefore a compact specification of an overall concept is hardly possible. Boundaries are expected to be unprincipled and instable and elements are expected to overlap between contexts (diSessa et al., 2004). Although following independent developmental trajectories, sub-groups of elements can be cued in the same situation and therefore show *local* coherence; that is, the Knowledge in Pieces perspective does not assume purely random interactions between elements. Inconsistencies in phenomena, however, can only be explained at the vague level of resolution that *something influencing the phenomenon in question must act somehow differently* (diSessa et al., 2004, p. 857). Learning following this approach then is defined as a process of reorganizing elements and their interrelations that *may* result in an overarching understanding (Clark et al., 2011). So reorganizing these elements (phenomenological primitives) will result in some connections between contexts and prioritizing elements by importance. Yet, even if there are elements with common attributes their great number and independent developmental paths constitute an “intrinsic difficulty of developing an integrated view[...]” (diSessa et al., 2004, p. 857). As a consequence of this, no *meta-conceptual awareness* of one’s own theories can be attained.

For TPCK, as mentioned above, the task to be mastered is the transformational use of technology in teaching. Conceptualizing TPCK as incoherent or locally coherent, respectively, leads to the assumption that teachers abstract “‘self-explanatory’ schemata” (diSessa et al., 2004, p. 857) from everyday situations of the teaching profession. This then results in a large number of context specific elements (phenomenological primes) such as: “In this class, using teamwork in the computer lab leads to chaos”. There may be common attributes of several elements that would lead to locally coherent explanations for related contexts, such as “In the afternoon, when students are tired, teamwork in the computer lab leads to chaos”, or differentiation between or within domains. Using the example of digital video technology applied in the empirical studies of this dissertation, this could be “Using digital video technologies as a supplement is helpful for discussing expository texts, but not for literary texts”. Accordingly, there would be loosely connected abstractions for the basic sub-domains, technology, pedagogy, or content, as well as those on the second level: content specific teaching strategies (PCK), the impact of different technologies on learning (TPK), and content-specific technological representations (TCK). Finally, TPCK would be assumed to also consist of a sub-sample of these elements each applying to specific contexts, topics, technologies, or teaching strategies. These can be locally coherent, such as: “Using graphing calculators in project teamwork is beneficial for *a number of* mathematical topics.” Overall, however, this conceptualization is similar a number of example lesson plans that do not go beyond the given facts of the examples (like propositional representations defined in Section 2.1). Thus, TPCK as a framework conceptualized in this manner is less helpful for reasoning about changing constraints such as new classes or emerging hard- and software. Finally, it is unlikely that an overall understanding on the meta-conceptual level develops systematically, that is, what a teacher understands about the factors involved in teaching with technology and how they interact.

An example inspired by the material used in the empirical study presented in Chapter 4, could be as follows: A teacher might know certain video software from editing private videos. When she is preparing a lesson on propaganda films she remembers the software and uses it to create a selection of example sequences to illustrate her introductory classroom presentation for students to get an overview over a period in history (TPCK Element 1). A colleague tells her about an emerging video technology that allows users to cut out sequences, re-order them, add subscript comments, and includes a sharing function for online collaboration. She adopts this technology for teaching about propaganda in films for a different class. She asks students to create new messages from the provided historic video material to support their critical reflection of mass media messages (TPCK Element 2). Over some time she comes up with different topics that she uses this emerging video technology with (TPCK Elements 3, 4, 5). She also creates different tasks for the students to work on with this technology (TPCK Elements 6, 7, 8). From all these experiences she abstracts understanding in the form of individual TPCK elements. Following this approach, developing TPCK would then mean assembling a wider collection of explanatory elements for how to use video technology in teaching that might be connected by common attributes such as similar content or learning goals. More concretely, this teacher will develop a greater collection of lesson plan examples that can be individually refined over time; however, she will not be able to define a coherent framework underlying her teaching with technology or her respective decision making.

2.3.1.2 The TPCK framework as coherent Theory Theory

Conceptual understanding as a Theory Theory by Vosniadou and colleagues in the context of learning physics (e.g., Vosniadou & Brewer, 1992) assumes that learners initial ontological and epistemological presuppositions are organized into general framework theories. The framework theories are causal, explanatory frameworks organizing physical phenomena (Clark et al., 2011). Constrained by these framework theories, specific theories (e.g. mental models) and beliefs are constructed based on everyday observations and culturally transmitted information (beliefs) to explain, interpret, or predict specific phenomena (Vosniadou, 1994). Constraining framework theories are such that only a few specific theories are extrapolated and they are considered rather stable and hard to change. Learning following this conceptualization is thought of as a developmental progression from mental model to mental model via the integration of new information and forming of interim models (Clark et al., 2011) by processes of *enrichment* or *revision* (Vosniadou, 1994). Whereas revision varies between weak restructuring, referring to increasing differentiation and hierarchical integration of existing structures, and radical restructuring, referring to the emergence of new theoretical structures out of several pre-existing ones (Vosniadou & Brewer, 1992), this kind of change is considered difficult to achieve. One reason is that changes in the ontological and epistemological presuppositions are bound to have serious implications on all the knowledge structures based on them (Vosniadou, 1994). To further develop such naïve theories into a scientific understanding, a person would need to acquire meta-conceptual awareness of her framework theory, which insinuates a different cognitive representational form (Ioannides & Vosniadou, 2002).

The notion of mental models in this approach is congruent with the one described above (Brewer, 1987; Clark et al., 2011; Vosniadou & Brewer, 1992, 1994). They are conceived of as analogue representations of "the state of affairs" that have a dynamic structure and are created on the spot for the purpose of solving problems. The creation of mental models is thought to be based on and constrained by underlying conceptual structures (framework theories, above) that act as presuppositions that are often based on everyday experiences. Thus, initial mental models are formed based on such a set of presuppositions. New information is assimilated into synthetic models while trying to keep as many of their presuppositions intact. Learning in the sense of conceptual change would ultimately mean a reinterpretation of the underlying presuppositions. In conclusion, this debate about knowledge structure coherence of the naïve understanding of scientific concepts adds valuable theoretical perspectives to consider with regard to how different conceptualizations of TPCK can inform the research on its development.

For TPCK, the task to be mastered is the transformational use of technology in teaching. In this way, basic framework theories could hold ontological and epistemological presuppositions such as “There is educational software and there is software for private use” (ontological), “The use of emerging technologies is not different from using any kind of teaching material” (ontological), “That some technologies are not made for learning does not need to be explained” (epistemological), or “Why students learn better with certain representations needs to be explained” (epistemological, cf. Figure 1 and 2 of Ioannides & Vosniadou, 2002). The cultural context of the teacher, where information for constructing specific theories with regard to technology use is received, is constituted by the epistemologies of the subject domains (Buehl, Alexander, & Murphy, 2002; Hofer, 2006b) and the teaching profession itself. It can be assumed that pre-service teachers in general and experienced teachers with a low rate of technology integration, while not being able to provide pedagogical reasons for this low rate, have naïve conceptions of what is circumscribed by TPCK. In line with this, they would lack meta-conceptual awareness of which knowledge of the sub-domains discussed earlier they need to orchestrate in order to provide added-value for learning scenarios with emerging technologies. Following the perspective of a coherent theory, developing TPCK means that by constructing initial mental models based on framework presuppositions and then continuously integrating new information into interim models, over time the framework pre-suppositions would change. Even more important, teachers would develop meta-knowledge on what pre-suppositions their local theories (e.g. lesson plans and classroom decisions) are based and how they construct these. This perspective also suggests that “teaching” teachers about innovatively utilizing emerging technologies should be difficult because teacher educators will have to try to alter basic presuppositions. Changing these will not only be effortful, but most likely connected to unpleasant emotions, because it deconstructs trusted ways of understanding the teaching environment.

An example parallel to the one in Section 2.3.1.1 could be as follows: A teacher acting based on the presupposition "There is educational software and there is software for private use", has learned in university methods courses that videos for teaching history are used for illustrating concepts familiar to students, for example a documentary providing students with an overview over a certain period in history. Then he learns about an emerging video technology that allows users to cut out sequences, re-order these, add subscript comments, and includes a sharing function for online collaboration. In a professional development course, he creates a lesson plan for this tool for a specific use of video in history, such as propaganda purposes. The task for the students is to create new messages from a provided historic video material to support their critical reflection of mass media messages. After making several such experiences, developing TPCK should take place in the form of changing his prior presupposition accordingly. Instead of strictly separating technology for educational and private use, he now might assume: "Based on what a technology can do for the student, the teacher can repurpose a lot of different technologies for education".

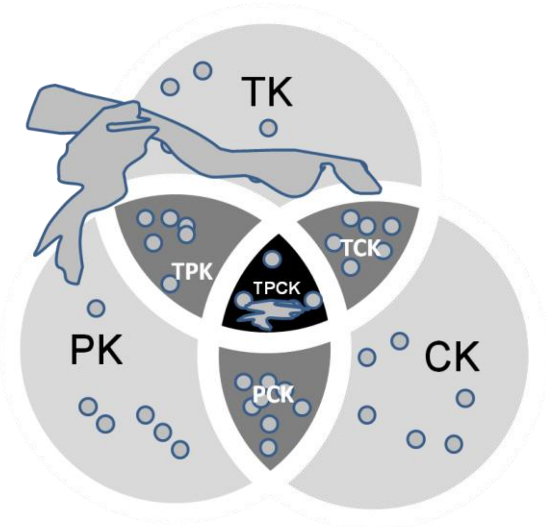

Figure 2.3. TPCK as incoherent system of local explanatory elements (Knowledge in Pieces). The scientific framework theory of TPCK is "covered" by many independent elements. The boundaries of the single elements may be fuzzy, overlapping, and differ in width of scope.

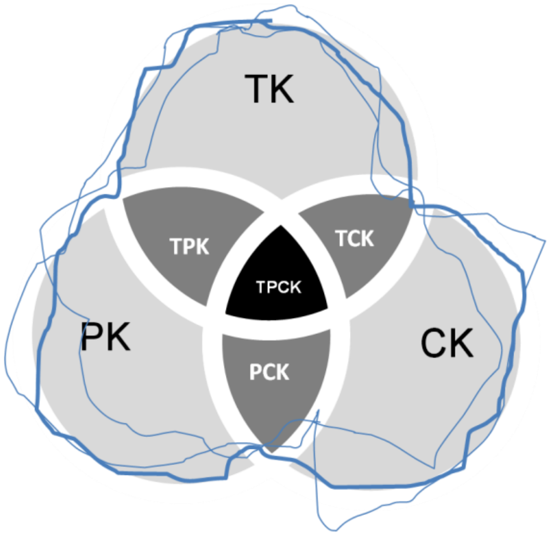

Figure 2.4. TPCK as a coherent intuitive theory (Theory Theory). The conceptual boundaries roughly match those of the scientific framework theory of TPCK, while the boundaries are fuzzy and subject to change.

To sum up, two figures from diSessa et al. (2004, fig. 1 and 2) were adapted trying to illustrate the difference between the Knowledge in Pieces and the Theory Theory perspectives as they are mapped on the TPCK framework (see Figures 2.3 and 2.4). Figure 2.3 depicts TPCK defined as a mostly incoherent system of single explanatory elements that are abstracted from everyday (teaching) experiences. This depicts how a novice teacher who has not yet developed TPCK might represent his or her own understanding of professional knowledge about the domain of teaching with technology. Some of these cover broader contexts and go beyond the sub-domain boundaries, for example into private domains or those of other professions. TPCK itself in this illustration would be a sub-sample of these elements where aspects of all sub-domains are considered. This would not grant TPCK as a construct additional value with regard to its representational form. The context is included in the single events that the elements are based on and in the local coherence for contexts with similar attributes. Figure 2.4 depicts TPCK defined as a coherent intuitive theory by a teacher. This depicts how a teacher who has developed TPCK would need to represent her or his own understanding of professional knowledge about the domain of teaching with technology. Following this perspective, having TPCK means developing a conceptualization that roughly covers the same sub-domains, their interrelations, and the role of context as it is proposed by the TPCK framework. The relevance of the context is here implicit in the extent to which the presuppositions of the framework theories define context as a relevant factor.

2.3.1.3 Conclusion TPCK as framework

Now, after describing these two different possible perspectives, how should TPCK be conceptualized as a scientific theoretical framework to describe teachers' competence in using technology and the underlying cognitive processes? TPCK needs to be conceptualized as a coherent theory in order to establish a normative understanding of how knowledge in the domain of teaching with technology needs to be defined by researchers and expert teachers. A more detailed description of this conceptualization becomes possible applying the three foci for the accountability for details in conceptual understanding proposed by DiSessa et al. (2004): *contextuality*, *specification*, and *relational structure*. As a result, TPCK as a coherent scientific framework theory is (1) a unitary shape with a clear application context (teaching with technology), (2) the assumption of a limited number of pre-suppositions about technology, pedagogy, and content (ontological and epistemological) that constrain the construction of more specific theories (mental models) derived from them. Finally, (3) the framework proposes a meta-conceptual frame for the systematic relations of these presuppositions and the teacher's knowledge of the sub-domains.

I suggest this normative conceptualization while being aware that novices might be more likely to represent their understanding as Knowledge in Pieces. Thus, it is important to be aware that, depending on the form of the initial naïve concepts, the processes of changing these naïve concepts (conceptual change) are assumed to differ. The most relevant transformation seems to be the transition from a fragmented to coherent understanding of teaching utilizing technology.

2.3.2 Conceptualizing TPCK as a construct – meta-conceptual awareness of knowledge of task, knowledge domains and context

Following the conceptualization of the TPCK framework as a coherent theory, the TPCK construct should be defined as meta-knowledge. By this it becomes possible to circumvent the issues involving the fuzzy boundaries between constructs on the same cognitive level, and broad definitions of technological knowledge (TK) that cover aspects defined as TPCK. This might not be essential for established technologies. But for repurposing emerging technologies, a more fine grained understanding of technology for teaching is relevant (Graham, 2011). Leaving the definition of the TPCK construct unclear and open to be subsumed under other sub-domains bears the risk of developing a very individual understanding of TPCK for teachers coming from different backgrounds. For example, a skilled pedagogue using digital technology might then just expand the boundaries of his PK concept. Or for a technology expert entering the teacher profession, teaching could fall within the boundaries of a wide TK concept. However, if TPCK is also to serve as a normative standard of how emerging technologies have to be understood in teaching, both of these examples are at conflict with the proposed conception of TPCK.

On the other hand, if TPCK is defined as meta-conceptual awareness, there is no need to define boundaries or specify an array of sub-facets, as it has been done for the other sub-domains, for example, PK (Tatto et al., 2008; Voss et al., 2011), PCK (Baumert, Kunter, Blum, Brunner, Voss, Jordan, et al., 2010; Blömeke et al., 2008; Kunter et al., 2007), TPK (see Section 2.2.1.3 and Graham et al., in press). By meta-conceptual, I refer to what a teacher knows about her or his own knowledge in the TPCK sub-domains and their strategies to intertwine these for planning and implementing lessons that add value by technology or by consciously refraining from using technology, respectively. Furthermore, to successfully master an ill-structured and complex domain such as teaching with emerging technologies, the current task at hand has to be understood as another source of varying constraints (Koehler & Mishra, 2008), an aspect that Berliner (1992) has described as the sensitivity to the demands of the teaching task and the situation. This is necessary for the teacher to determine the available (cognitive) resources and strategies for reaching the desired goal state of creating solutions for the task of teaching, namely, concrete learning opportunities. Overall, TPCK is then to be understood at the level of meta-conceptual awareness that provides a high level of organization to an expert's knowledge (Koehler & Mishra, 2008; Leinhardt & Greeno, 1991), but not as a body of knowledge that is circumscribable and fixed.

In sum, Technological Pedagogical Content Knowledge is defined as a construct comprising *teachers' meta-conceptual awareness of the demands of the teaching task at hand, the teacher's knowledge in the sub-domains, and the contextual constraints.* Figure 2.5 depicts this notion of TPCK by also determining these three elements as coherent concepts. The central area of the diagram, formerly pointing to TPCK as a construct, is here replaced by the teaching task at hand. This is because following the visual logic the most central area is the most specific one, which complies more with the idea of a concrete lesson (plan) than with a general competence (cf. the introduction of Section 2.3).

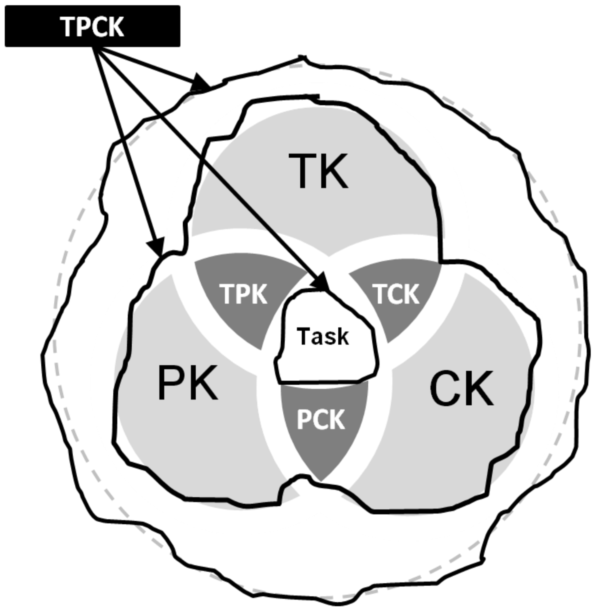

Figure 2.5. Content of TPCK as a construct: Meta-conceptual awareness of the demands of the respective teaching *task*, the teacher's own *knowledge in the sub-domains*, and the *contextual* constraints. The conceptual boundaries of these elements roughly match those of the scientific framework theory

Defining TPCK as meta-conceptual awareness is, furthermore, in line with operationalizations of developing TPCK in qualitative studies as the increase in the complexity of participants' explicit argumentations for using technology in the ways they did or planned to do (Graham et al., in press; Koehler et al., 2007). Furthermore, Kramarski and Michalsky (2010) found direct empirical support of a positive influence of self-regulatory support on pre-service teachers' performance in TPCK tasks (comprehension and design of study units intertwining specific technology, pedagogy, and content).

2.4. Expertise in TPCK

In Section 2.3, it was argued that developing TPCK for a teacher could either be thought of (1) as developing as a coherent conceptualization by sequentially constructing and re-constructing mental models that are constrained by pre-suppositions of the TPCK framework theory, which in turn reshapes these pre-suppositions. Or developing TPCK could be thought of (2) accumulating instantial elements, that is, experiences in the wider domain of using technology in teaching and then reorganizing these elements so that they might result in a more coherent understanding of the overall domain over time, which is, however, intrinsically unlikely. In line with this, expertise in TPCK can be described in two different ways, either as *adaptive expertise* or as *routine expertise* (Forssell, 2012; Hatano & Inagaki, 1986)[6].

According to Hatano and Inagaki's (1986) approach, *adaptive experts* can, on the one hand, efficiently perform procedural skills in the area of expertise, for example, a teacher efficiently grading a number of mutually similar tests, but on the other hand, also understanding the meaning of this skill. For example, a teacher is not only able to conduct certain learning activities, but can explain why they are having certain impact on student learning. Just as much, adaptive experts can judge the appropriateness of variations of conventional procedures and - most important for the argument being made here - can modify the skill in response to changes in constraints (a self-regulatory process!). In contrast, *routine experts* are only able to perform skills efficiently and fail when confronted with different constraints, that is, new problems (e.g. different goals of assessment, emerging technologies). They rely on culturally transmitted skills (routines) and repeated application of these procedures only in similar situations without variation. Therefore, it can be assumed that routine experts also do not know which information they need to gather in a new context to return to their level of expert performance.

Adaptive expertise is assumed to develop by accumulating experience during problem solving in a specific domain while utilizing relevant prior knowledge in this domain, especially when trying to solve more complex problems (within this domain). Berliner (2001) refers to adaptive expertise as their ability to draw on case knowledge and Hatano and Inagaki describe this process as resulting in conceptual knowledge. Taken together, this results in the notion of conceptual knowledge as the construction of mental models as simulations that allow studying teachers to come up with explanations for unknown situations or make predictions about them. Overall this maps on the coherent understanding based on framework theories (prior knowledge) described above (cf. Vosniadou, 1994). In contrast, a routine expert when confronted with a new task (within the domain!) or variation in contextual constraints has to fall back to a trial and error strategy. As a result, routine expertise would result in high performance in tasks without changing contexts or constraints, rather than high performance under varying

[6] Although Hatano and Inagaki (1986) refer to Gentner's definition of mental models, which considers them to be more like schemas in the sense of Brewer (1987); they also adhere to the function of mental models for extrapolating solutions for new problems for varying contexts, which is in line with the argumentation here.

circumstances as would adaptive expertise. What is left open is to what extent these different experts try to stabilize their environment in order to minimize or maximize, respectively, the likelihood of contextual constraints to vary.

2.4.1 TPCK expertise as adaptive

For the domain of TPCK, namely, leveraging the potential of technology for the teaching of specific content, I have argued to conceptualize the TPCK framework as a coherent concept. Furthermore, I have already mentioned that the way in TPCK has been proposed the literature formulates the goal of adaptive expertise. First, because of its reference to the constraint of continuously emerging technology (Graham, 2011; Koehler et al., 2011; Koehler & Mishra, 2008), and second, because of its reference to the ill-defined and ever-changing nature of teaching as domain in general, requiring the creation of many "solutions" in form of planning lessons, assignments, and assessments (Koehler & Mishra, 2008; Oser & Baeriswyl, 2001). Concretely, teachers with adaptive expertise should be able to apply their knowledge to understand what needs to be changed in a given lesson plan or included in a future one to reach the teaching and learning goals at hand. Furthermore, they need meta-conceptual awareness of what they already know and what they still require to accomplish the appropriate actions. This would include reflecting the beliefs transmitted by culture, that is, of the teaching profession (Baumert & Kunter, 2006; Maggioni & Parkinson, 2008), the domains (Hofer, 2006a; Muis, Bendixen, & Haerle, 2006; Trautwein & Lüdtke, 2007), or the individual school (Teo, 2009a; Windschitl & Sahl, 2002).

In conclusion, it can be assumed that expertise in TPCK should be understood as adaptive expertise and that the necessary processes to gain this expertise are to a large extent self-regulatory in nature. In addition to the empirical evidence that pre-service teachers' performance profits in general from self-regulatory support (Kramarski & Michalsky, 2009), there is initial evidence specifically for increased performance in TPCK evaluation and design tasks (Kramarski & Michalsky, 2010). Kramarski and Michalsky (2010) prompted participants with comprehension, connection, strategic, and reflection questions to support their meta-cognition during both learning from a study unit adhering to TPCK principles (these principles were based on Angeli & Valanides, 2005) from the perspective as students as well as creating such an unit from their perspective as (future) teachers. Results showed that supporting participants' meta-cognitive activities improved their evaluation and design of TPCK study units compared to a control group.

Beyond that, however, even though there have been suggestions about which developmental or training paths actually lead to TPCK (Koehler et al., 2011, in press), there is only little empirical evidence. There are two main points that can be inferred from these considerations. First, because cognitive processes among the described knowledge structures are considered to occur iteratively during the instructional planning (TPCK tasks), I do not propose that there is an *ideal* starting point for successfully integrating the knowledge into the different sub-domains and different framework theories, respectively, in order to develop TPCK expertise. Instead, it should be assumed that the starting point will depend on the individual's prior knowledge in technology, pedagogy, or content, respectively, and the given context. However, these differences in prior knowledge in the respective sub-domains should influence the developmental or learning pathway.

Second, existing expertise should be expected to act as a *moderating* variable for these developmental or learning pathways. Defining expertise in TPCK as adaptive expertise helps us to better understand the notion of "routines" that have been described for expert teachers (Berliner, 1992; Leinhardt & Greeno, 1991). Research has shown that expert teachers follow routines but are able to explain and appropriate teaching activities to contextual variation, which novices could not. Thus, even though expertise in teaching seems connected to developing automaticity and routine procedures, expert teachers are aware that their performance is context dependent and aware of which information they need to gather about a new context in order to perform well. In this sense, effective routines of experts are actually considered to be built on the basis of an adaptive expertise because they are balanced with what can also be considered a meta-conceptual awareness. This, in turn, leads to the assumption that experienced in-service teachers with established (effective) routines start at a different point when developing TPCK expertise compared pre-service teachers and beginners without (practically proven) routines in place. These routines, in contrast to the notion of routine described by Hatano and Inagaki (1986), should also be adaptive towards emerging technologies allowing establishing technology to become part of new routines. This also builds on Cox' (2008) and Graham's (2011) description of how when emerging technologies become transparent, the differentiation of TPCK becomes less imperative and respective knowledge merges into their general pedagogical or pedagogical content knowledge. However, it has to be kept in mind that the notion of adaptive expertise, too, can only develop within the parameters for teachers' expertise described by Berliner (1992), that is bound to the field of their experiences: their actual classroom and their domains.

2.5. Discussion

Affordances and constraints of emerging technologies (Angeli & Valanides, 2009; Koehler & Mishra, 2008) are a relevant factor for teaching and learning because they impact both the visible structures of the classroom activities as well as the students' learning processes. Thus, teachers need to plan carefully in order to leverage the potential of such technology in their teaching (Webb, 2011; Webb & Cox, 2004). The TPCK framework has provided a common ground for discussing these issues (Angeli & Valanides, 2009; Harris et al., 2009; Mishra & Koehler, 2006; Niess, 2005). However, there is still need for developing TPCK as a framework and construct (cf. Graham, 2011) to promote the development of TPCK toward a more comprehensive model of teachers' competence. In this chapter, theoretical assumptions of the TPCK framework were elaborated by integrating the concept of mental models (Brewer, 1987; Johnson-Laird, 1980, 1983), perspectives from the adjacent conceptual change literature (Clark et al., 2011; diSessa et al., 2004; Ioannides & Vosniadou, 2002; Vosniadou, 1994; Vosniadou & Brewer, 1992, 1994), and developmental notions of expertise (Hatano & Inagaki, 1986).

This chapter focused on the following four issues. First, mental models that teachers construct of the (socio-) cognitive functions of a technology were proposed to play a significant role in determining how teachers leverage their specific potential in the classroom. Second, the issue whether knowledge in the sub-domains is a necessary prerequisite for TPCK was discussed. Based on an approach introducing the notion of mental models, mediating or moderating relationships between the proposed sub-domains of the TPCK framework and a teacher's ultimate performance in teaching tasks were suggested. Third, as a consequence of the mental model approach, the question was addressed how to conceptualize TPCK as a framework and as a construct. This was discussed this issue in the light of coherent versus fragmented theories based on the conceptual change literature and suggest an understanding of the TPCK framework as coherent and the TPCK construct as a teacher's meta-conceptual awareness of the teaching task, the available knowledge in the TPCK sub-domains, and the context.

Finally, based on a conceptualization of TPCK as a coherent theory, expertise in TPCK was defined as adaptive expertise (Forssell, 2012; Hatano & Inagaki, 1986).

2.5.1 Mental models

Elaborating on content as well as on the representational form of the knowledge sub-domains of teacher knowledge proposed by the current TPCK framework, it was possible to lay ground for deducing hypotheses about their interrelations. Research in teacher competence focusing on technology integration (Teo, 2009a, 2009b; Teo, Chai, Hung, & Lee, 2008) or not (Baumert & Kunter, 2006; Dubberke et al., 2008; Klusman, Kunter, Trautwein, Lüdtke, & Baumert, 2008; Krauss et al., 2008; Kunter et al., 2007; Staub & Stern, 2002; Voss et al., 2011) claims that teachers' prior knowledge and specific beliefs to be important pre-requisites for teachers' actions and classroom quality. The approach presented in the present dissertation is based on the idea that framework theories constrain the construction of mental models when understanding the affordances of emerging technology. Framework theories, in turn, are composed of prior knowledge and beliefs. Thus, the approach presented here adopts the perspective that beliefs are an important factor and integrates it explicitly into the TPCK framework. As an answer to the situation that to date there is almost no research looking into the predictive value of prior knowledge in the sub-domains for teachers' self-reported TPCK or lesson planning (except Chai et al., 2010 and the studies presented in Chapters 3 and 4), a foundation is provided for more specific assumptions with respect to how differences in prior knowledge in the respective sub-domains should influence the learning path of teachers. With regard to its impact on the creation of solutions to TPCK performance tasks (e.g., Angeli & Valanides, 2009; Kramarski & Michalsky, 2010), mediation and moderation effects are assumed. Future research, including qualitative studies as well as experimental and longitudinal studies can investigate these effects.

2.5.2 TPCK as framework and construct

I propose that, as a scientific framework, TPCK needs to be defined coherently and to include assumptions about the proposed knowledge representations of the proposed sub-domains as well as about their interrelations. Based on this, I propose that in order to conceptualize the TPCK construct as a teacher's meta-conceptual awareness of the demands of the teaching task, the available knowledge in the TPCK sub-domains, and the context has implications for further theoretical development and empirical research.

As a next step, further theoretical effort should be put into explicating the underlying presuppositions, in order to make it possible to delineate concrete interventions and hypotheses about the outcome of teachers' reasoning and activities. This effort was started by defining the representational format of teachers' knowledge as mental models in general and specifying TPK as understanding the relevance of cognitive, socio-cognitive, meta-cognitive, and motivational functions of technology. In empirical research these concrete descriptions can be used in both quantitative (experimental) as well as qualitative in-depth research. Additionally, mapping theoretical and empirical framework theories can serve as a heuristic analytic framework for the analysis of ethnographic and interview data. The conceptualization of TPCK construct as meta-conceptual awareness can extend initial research looking into SRL and TPCK and can act as guiding principle for intervention studies on how to support TPCK development.

In spite of all the potential benefits described here, it is necessary to keep in mind that coherent Theory Theories bear the risk of overestimating coherence and simplicity (diSessa et al., 2004) and that with regard to instruction, they produce heuristics rather than detailed strategies to resolve specific individual conceptual difficulties. Such individual difficulties might even arise especially because a teacher has formed a fragmented understanding of the domain of teaching with technology and then develops explanations for different situations independently. Therefore, especially with regard to understanding the spontaneous reasoning and acting of (pre- and in-service) teachers in the classroom situation, it is important to understand that they might act upon naïve conceptions represented as incoherent Knowledge in Pieces (cf. Clark et al., 2011 for empirical findings on students' naive understanding of science). This can improve our communication with teachers and our understanding of their specific misconceptions during training and for designing effective training and professional development courses. As a result, it seems most valuable to further discuss and research TPCK and its development in teacher training and professional development in the tension *between* these two perspectives.

2.5.3 Developing TPCK expertise

Taken together, conceptualizing teachers' knowledge representation in the TPCK sub-domains as mental models, understanding the TPCK framework as coherent, and defining TPCK itself as a meta-cognitive construct, also provides a foundation for formulating more precise assumptions about expertise in TPCK. Expertise in TPCK needs to be understood as adaptive expertise to live up to the standards set by the framework initially, that is, the competence to professionally include continuously changing emerging technology. As a result, the necessary processes to gain this expertise should be greatly self-regulatory. This also means, however, that the professional development of teachers differs between life phases. Thus, in addition to prior experience with integrating technology or general expertise as important factors for TPCK development, it must be assumed that in different stages of the teacher's career (cf. Huberman, 1989), the likelihood of experimenting with new instructional practices will generally vary. Richter and colleagues (Richter, Kunter, Klusmann, Lüdtke, & Baumert, 2011), for example, found a curvilinear relation between the uptake of learning opportunities of teachers of mathematics and their age in a cross-sectional design with a peak at the midpoint of their career, around age 42. This trend was found for different topics of professional development, whereas older teachers relied more on professional literature and younger teachers more on teacher collaboration. Although this might be explained by a cohort effect, nonetheless, it is important to remember that teachers at different levels of their professional career will most likely need to be approached differently to support their TPCK development.

Another critical point is to remember that the focus of the present considerations is only on *cognitive* processes. Thus, the present considerations do not explicitly address social aspects of teachers' expertise (e.g., their personal relation to their students, Berliner, 1992) or emotional factors (e.g., Klusman et al., 2008). However, given this limitation, it was possible to distinctly complement the current understanding of TPCK. From a theoretical point of view, it can predict why existing expertise should act as a *moderating* variable for the developmental or learning pathways of teachers on different levels of experience. From a practical point of view, describing how teachers might cognitively integrate new information about technology in teaching (incoherent abstraction or enrichment and revision of coherent presuppositions and beliefs) can help to guide them to establish heuristics for obtaining adaptive TPCK expertise. As an example, educating teachers *about* the TPCK framework as a meta-cognitive guideline could provide a basic structure for teachers to scaffold the organization of their knowledge as one characteristic of expert knowledge.

2.6 Conclusion

Overall, it can be concluded that the considerations presented here provide a valuable addition to the theoretical framework of the TPCK approach. With regard to further theoretical issues, it seems important to specify the sets of pre-suppositions that should ideally underlie a teacher's reasoning for utilizing emerging technologies. With regard to research, these then would provide a basis for comparing teachers' pre-suppositions found in empirical data. More important, the considerations presented in this chapter need to be followed up by empirical research to determine the actual role of teachers' mental models for lesson planning and instruction. In Chapters 3 and 4 of the present dissertation, this will be addressed by investigating the impact of pre-service teachers' mental models of an already known and a newly encountered web-based video technology on their lesson planning. Along with this, the assumed predictive roles of prior knowledge (here Pedagogical Knowledge) and pedagogic beliefs are investigated.

Before presenting these studies, I will first provide in the following interlude a rationale for choosing web-based video technology as an exemplar for a family of emerging technologies that is relevant for classroom instruction.

Interlude – Digital Video Technology as Exemplary Emerging Technology

Recently, the role of video technology as a means in teacher education has been discussed with regard to supporting teachers' reflections on teaching practices (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Brophy, 2004). Respective research has shown that indeed (pre-service) teachers can profit from this use of video (Seidel, Stürmer, Blomberg, Kobarg, & Schwindt, 2011; Zottmann et al., 2011). Together with the potential for supporting reflection on teaching activities, new digital video technologies also harbor the potential to support individual and collaborative student learning in the classroom. This holds a new challenge for (pre-service) teachers, namely, stepping out of the role of the learner and putting on their professional glasses to consider the affordances of a technology in the light of their prior professional knowledge as well as teaching and learning goals. However, such use of video technologies with students in the classroom has not been a focus of research on teacher education in the past. Accordingly, it is a challenge for many teachers to use video in class effectively as was shown by Hobbs (2006). He found a majority of teachers uses video not related to learning. This situation is unlikely to resolve itself automatically as has been shown for technology use in general (Russell, Bebell, O'Dwyer, & O'Connor, 2003).

In contrast, in another area of research it has been shown that digital video technologies – often web-based - can be utilized as cognitive tools for learning. For example, advanced video tools can guide and support students' learning activities in the classroom when they access video sources in constructivist settings (Smith & Reiser, 2005; Zahn, Krauskopf, Hesse, & Pea, 2010; Zahn, Pea, Hesse, & Rosen, 2010) or in comparison to texts as instructional material (Koehler et al., 2005; Merkt et al., 2011). Yet, considering the findings of Hobbs (2006), without pedagogical integration, video technology may add very limited value to teaching and learning, like other new technologies (Conlon & Simpson, 2003; Cuban et al., 2001). In conclusion, this leads to the question, how teachers perceive these new technologies and what influences, how they would integrate them into their teaching.

The studies presented in Chapters 3 and 4 will provide first steps to answering this question. But first, a short overview will be presented over relevant findings with regard to investigating the relation between the affordances of video technologies and student learning outcomes.

Digital Video Technology as Tools for Learning

There are two main strands in research investigating digital video technology for learning: one focusing on individual learning processes and one focusing on collaborative learning processes. Research focusing on individual learning has investigated digital video mainly as an information vehicle for students' knowledge acquisition. The empirical studies have focused on aspects of technology design, such as complexity (e.g. Furnam, deSiena, Gunter, 2002) or multi-media effects (Meyer, 2001). Additionally, the level of interactivity has been investigated, such as, for example, hyper-videos suggesting non-linear paths through networked video-based information (Chambel, Zahn, & Finke, 2005) or presenting the learner with possibilities to regulate the flow of information by tables of content or indices (Merkt et al., 2011). Studies based on this approach found that differences in the use of these navigation functions impact individual learning; however, patterns of use that benefit learning do not occur spontaneously (Merkt et al., 2011; Zahn, 2003; Zahn et al., 2004). Taken together with findings that show a positive relationship between schooling and students' use of search strategies in texts (Kobasigawa, Lacasse, & MacDonald, 1988; Rouet & Coutelet, 2008), this suggests that students tend to misunderstand the functions of a tool when not guided by pedagogy (Merkt et al., 2011).

Research focusing on collaborative learning views digital video technologies in their function as mediating tools that influence the structure of activity in which learners use video collaboratively (Zahn, Pea, et al., 2010). Based on the idea of differential affordances of representational tools (cf. Suthers & Hundhausen, 2003) specific video tools are assumed to facilitate specific ways of how groups of students negotiate meaning and collaboratively construct knowledge from a video source. For example Zahn and colleagues (Zahn, Pea, et al., 2010) found in a lab setting that a video tool that was specifically designed for collaborative scenarios (WebDIVER), in comparison to a video player software, lead to a higher performance of participants in recognition and transfer tasks, and to different foci in the dyads' conversations. In exemplary cases the authors could show, how the different technological features supported the learners in establishing a common ground for discussing the video content. In another study Zahn and colleagues (Zahn, Krauskopf, et al., 2010) were further able to show that these differential effects on students' interactions in the actual classroom setting. Furthermore, they found that subtle differences in the instructional guidance were leveled out by the technologies' affordances. In a third study that simulated a classroom setting in the lab, Zahn, Krauskopf, Hesse, and Pea (in press) found that students performance while using different emerging video tools (Asterpix and WebDIVER) increased, when their collaborative use of these tools was specifically supported. From these findings the authors conclude that paying attention to the social problem space of collaborative learning settings is a factor for teachers to pay explicit attention to when using technology in these settings. Overall, it can be concluded that the potential of emerging digital video technologies can be leveraged, for example by complex, authentic student design tasks (cf. also Goldman, 2004). Nevertheless, as a prerequisite to creating added-value for student learning, the overall task design and the explicit instructional guidance need to be consciously modulated to create learning environments that leverage the specific potential of a technology. Against this background, it is important to remember that in the actual classroom both - task design and instructional guidance - are provided by the teacher.

In conclusion, both lines of research provide evidence that the affordances of new (video) technologies can provide potentials for learning in the classroom; however these potentials need to be leveraged by teachers creating a pedagogical setting and selecting content. In turn, to be able to do so, teachers will need specific knowledge that enables them to relate video tool affordances to learning goals and learning settings. These findings are in line with the theoretical assumptions of the TPCK framework discussed in Chapters 1 and 2. Against this background, three studies will be presented in the following that investigate selected issues of teachers' knowledge and their understanding of the affordances of video technology described in Chapter 2, and how these impact their lesson planning.

3. Study 1: Leveraging the Affordances of YouTube: The Role of Pedagogical Knowledge and Mental Models of Technology Functions for Lesson Planning with Technology[7]

The first goal of this first study was to provide initial evidence for answering the question of how prior pedagogical knowledge and pedagogical beliefs impact participants' mental models of the educationally relevant functions of a video technology that was privately known to them, YouTube. Second, it should initially be investigated how these mental models relate to prior knowledge and how they impact lesson planning. Ideas for ideal and intended lesson plans were used in this study as indicators for participants application of TPCK, this means in the sense of their ability to solve the task to design learning scenarios that leverage the potentials of an emerging technology. Therefore, a web-based video technology was utilized that is on the one hand well known, but, on the other hand continuously developing, for example features for annotations, creating hyperlinks or video editing, namely. YouTube.

How can teachers overcome the sub-optimal pedagogical practices for video usage and support *learning* instead? In Chapter 2 it was proposed that the mental models of video technology affordances that teachers construct or activate are an important factor in their cognition for planning the use of video in class. Lesson-planning plays an important role in integrating technology into a pedagogical situation (Webb & Cox, 2004) and is a complex cognitive task (cf. Calderhead, 1996; Leinhardt & Greeno, 1991). When tackling this task, teachers are confronted with many unknown variables and need to rely on their prior knowledge when inferring adequate structure and content for creating a learning environment. Therefore, it can be assumed that they need to represent the functions of a technology in the form of a mental model. Their mental model would have to contain the tool's functions relevant to learning and motivating to learn, namely the tool's potential consequences for individual, collaborative, and self-regulated learning. Firstly, in order to

[7] This chapter is based on: Krauskopf, K., Zahn, C., & Hesse, F. W. (2012). Leveraging the affordances of Youtube: The role of pedagogical knowledge and mental models of technology functions for lesson planning with technology. *Computers & Education*, *58*(4), 1194–1206. doi:10.1016/j.compedu.2011.12.010.

pedagogically integrate a technology, teachers need to understand these affordances of the specific technology for learning, rather than merely knowing how to operate it (cf. Heidt, 1977). Secondly, based on this knowledge they need to relate the affordances to their teaching goals during lesson planning. In other words, the challenge for the individual teacher in leveraging technology affordances of digital video technology in their classroom is to construct mental models which integrate the technology's learning-relevant functions with their pedagogical and subject matter knowledge (cf. the Technological Pedagogical Content Knowledge (TPCK or TPACK) framework, Angeli & Valanides, 2009; Harris, Mishra, & Koehler, 2009; Koehler & Mishra, 2009).

Mapping this notion of mental models on the TPCK framework leads to the proposition that integrating different professional knowledge aspects (T, C, P) needs to happen in a specific way in order to solve the complex task of teaching content (cf. Calderhead, 1996; Leinhardt & Greeno, 1991) with technology: Teachers need not only to combine from more independent knowledge domains (light grey) more interrelated aspects (darker grey), in order to solve for the overall task (black). Rather, with regard to the representational format, this combination needs also to be accompanied by a transformation into a mental model representation of elements and interrelations that can be manipulated and from which inferences can be made (for the path studied here, see curved arrows (a) in Figure 2.2). Then, the added value of specific combinations of Technology, Pedagogy, and Content are likely to be more accessible (Johnson-Laird) and can be utilized to construct task solutions. My assumption of such a transformation process is in line with the transformative view of Angeli and Valanides (2009) and elaborates on it from a cognitive perspective. The subsequent step is then to combine mental models based on other knowledge aspects into possible solutions for planning a lesson (for the path studied in here, see curved arrow (b) in Figure 2.2). Thus, it should not be assumed that TPCK is a fixed body of knowledge but rather a higher level mental model that helps teachers to integrate their prior knowledge, which arises from multiple interactions of the different aspects, as Harris et al. (2009) put it.

It can be assumed that mental models act as a mediating variable between a teacher's abstract knowledge and planning the integration of the respective tool into their teaching. Initial empirical support can be drawn from the finding that the importance of the perceived usefulness of a technology predicts teachers' intentions to use technology in their instruction (Teo, 2009b). Additionally, Luik (2011) found positive correlations between secondary teachers' effectiveness ratings of some educational software and students' respective learning outcomes. In conclusion, mental models of tool affordances are proposed to be an important step in teachers' cognition when planning to teach with technology.

3.1 Research questions of Study 1

Taken together, a teacher's mental model of the pedagogical affordances of a technology should contain its technological functions in relation to *cognitive, socio-cognitive*, *meta-cognitive* and *motivational* goals. Furthermore, a more complex mental model that contains more of these aspects should enable teachers to create better solutions to a TPCK task, namely the planning of a lesson that leverages the affordances of the technology.

The present study investigated this general assumption for the publicly known digital video technology YouTube. Participants' pedagogical knowledge was expected to predict their lesson planning, namely the intended and ideal use of YouTube with students in class. However, this relation not to be a direct one, but should be mediated by the complexity of their mental models of YouTube. It was also explored what pre-service teachers see as barriers that might prevent them from implementing their ideas for ideal instructional applications of YouTube and the role of participants' pedagogical beliefs.

The sample of this study (and the following) was recruited from the population of German pre-service teachers. This means that participants were still studying at university, with most of them having had a few months of practical experience in schools (Phase 1 of the German teacher education system; Phase 2 refers to the Referendariat, i.e. 1.5 years supervised teaching with ongoing obligatory seminars, and Phase 3 refers to professional development of contracted in-service teachers). Drawing on the considerations on teacher novices in Chapter 2, this means this study's participants are assumed not to have established routines for effective teaching nor have they established an evidence-based sensitivity to contextual constraints. Additionally, due to their younger age they can be assumed to have more private experiences with web-based technologies, such as YouTube. As a result this is a specifically interesting population: On the one hand, the participants of the present study belong to a population that is still in need of developing the different sub-domains of professional knowledge. On the other hand, privately, they are presumably more technologically proficient. Thus, it is of special interest to investigate, how they are able to integrate their private and their developing professional knowledge when asked to plan lessons utilizing technology they might only know for a private context.

3.2. Method

3.2.1 Sample

The study was administered online and participants were recruited via a German online forum for pre-service teachers (http://www.lehramtforum.de). This forum is set up for students of various subjects enrolled in university teacher training programs mainly in western Germany. It contains general and subject specific section, but section devoted to technology in education. 60 pre-service teacher users of this forum completed the questionnaire. All participants reported to be enrolled in university programs studying to become educators at the secondary level, and 83% had already completed internships as assistant teachers with an average length of M = 3.7 months, SD = 2.5. Concerning the participants' majors (multiple answers possible), the five areas participants named most frequently were science (36.7%), mathematics (36.7%), foreign languages (35.0%), German language arts (28.3%), and social science (26.7%). As compensation participants who completed all the measures took part in a lottery of ten 25€ Amazon vouchers and received general information on the study's results.

3.2.2 Procedure

Participants completed an online questionnaire, which consisted of three parts. Before working on the questionnaire participants gave their consent to anonymously use their data for scientific purposes. First, participants answered demographic questions (age, gender, high school grades) and specific details about their university training so far. Then, they responded to two scales measuring their general pedagogical beliefs and completed a test measuring aspects of their general pedagogical knowledge (for details see below). They were asked not to use any additional material (books, internet) to answer the questions and to try and work on the questions to the best of their knowledge. Finally, they were presented open questions concerning (a) their general perception of the functions of YouTube and (b) the potential for these functions to be used in their teaching. In one item they indicated whether they intended to use these functions in their teaching and to give a concrete example for an intended use if possible. In a second item they were asked about an ideal use of the functions of YouTube in teaching their subjects. In a third question they were asked to name barriers that would keep them from realizing this ideal. After completion they were asked to provide their e-mail addresses, which were stored in a separate data base, so they could be informed in case of winning an Amazon voucher and information on study results. Participants could also indicate whether they wanted to be informed about the possibility of participating in future studies.

3.2.3 Measures

3.2.3.1 Pedagogical knowledge.

A measure of 22 items inquiring into declarative aspects of participants' pedagogical knowledge (for items see Appendix Table A.2 and A.3) was constructed by combining items from two existing measures. One was a test created in line with the standards for pedagogical psychology in German teacher education (Schulte, Bögeholz, & Watermann, 2008). The other was comprised of sample items from the ETS Praxis Series™ (2009 teaching foundations multiple subjects and English, and Technology Education, available at http://www.ets.org/praxis). Even though the ETS Series is available on the internet, those items were considered appropriate for use with a German sample, especially because there is no equivalent of the ETS in Germany and pre-service teachers are not familiar with standardized tests during their training. Additionally, item-analyses showed that items based on the ETS instrument were on average more difficult to solve for the participants than items based on the measure by Schulte et al. (2008). Considering the heterogeneity of the aspects touched on by the items, the internal consistency was sufficient, Cronbach's $\alpha = .70$.

3.2.3.2 Mental models of YouTube Functions.

For the analysis of the three uses of YouTube participants had named, a procedure applied in cognitive psychological research (e.g. Azevedo & Cromley, 2004) was followed. In this approach, mental models of participants are extrapolated by coding and then quantified by counting relevant aspects mentioned in participants' open answers. This procedure aimed at tapping into more general descriptions of the functions participants related to YouTube, as well as to find out how their understanding of these functions related to teaching and learning goals (TPK). Therefore, two coding schemes were created.

The first coding scheme for *emerging categories* was created based on the answers provided by participants. The first author and a trained research assistant read all answers carefully and tagged them independently with relevant aspects. Subsequently, they compared their results, which showed that both had come up with seven major categories. Finally, they agreed upon category names and the definitive assignment of subcategories. The seven final categories were *Entertainment*, *Information Repository*, *Accessibility and Actuality*, *Information and Opinion Exchange*, *Productive Use of YouTube*, *Vividness of Content*, and *School Purpose* (for coding examples see Table 3.1). They were then used by two independent trained raters to code all open answers. The categories were not exclusive and one answer could receive more than one code. Rater-agreement was satisfactory in all categories with a median of Cohen's $\kappa = .75$, and ranging from .52 to 1.0. Differences in codes were resolved by discussion.

The second coding scheme was created to tap the *theoretically derived categories* (TPK) described above, based on the descriptions of the relevant aspects in the literature for *cognitive*, *socio-cognitive*, *meta-cognitive* and *motivational* learning goals. Again all answers were coded by two trained independent raters (see Table 3.2), categories were again not exclusive and one answer could receive more than one code. Rater-agreement was satisfactory in most categories with a median of Cohen's $\kappa = .82$, ranging from .60 to 1.0. Differences in codes were again resolved by discussion.

To qualitatively characterize the *content* of the mental models with regard to both coding procedures, the percentages for the occurrence of each category for both coding procedures were computed (see Figure 3.1 and Figure 3.2).

Based on the assumption that a more complex model would include more different learning goals the codes for cognitive, socio-cognitive, meta-cognitive and motivational learning goals were aggregated into an indicator to represent the *complexity* of the mental models. Codes were summed up for each reported way of use (1 to 3) and then averaged across them (for means and standard deviations see Table 3.3).

3.2.3.3 Lesson planning: Intended and Ideal use of YouTube with students.

Intended and ideal instructional uses proposed by participants were coded with regard to the different instructional aspects they contained. The coding scheme was based on emerging categories from participants' answers. The procedure for creating the categories was parallel to the one for coding general descriptions of YouTube functions and additionally considered the categories found there. Finally, a coding scheme consisting of twelve categories was created: *Vividness, Teacher presentation, Information Repository, Content elaboration, Foreign language learning, Students' media literacy,* *Students' productive use, Exchange, Accessibility, Lesson start, Entertainment, Motivation* (for coding examples see Appendix Table A.1). Rater-agreement was satisfactory for the emerging categories, median of Cohen's κ = .73, ranging from .57 to .92, as well as the theoretically derived categories, median of Cohen's κ = .75, ranging from .60 to 1.0. Differences in codes were again resolved by discussion. The answers to the question of what participants perceived as *barriers* to using YouTube in this ideal way were again categorized by two independent raters, with sufficient rater-agreement, median of Cohen's κ = .79, ranging from .65 to .90. Then, the percentages for the occurrence of each emerging category were computed (see Figure 3.3 and Figure 3.4).

Table 3.1
Coding scheme 1: Theoretically derived categories (see Section 3.2.3.2) for coding mental models of YouTube functions.

Category	Definition	Example answers (Item: *Please describe the three most important functions of YouTube*), keywords in **bold**
Cognitive functions	Individual learning processes: Remember, recognize, recall; Understand, interpret, exemplify, classify, summarize, infer, compare, explain; Apply, execute, implement; Analyze, differentiate, organize, attribute; Evaluate, check, critique; Create, generate, plan, produce.	"**Illustrating** phenomena" "**Explain** information about politics, culture, and other content via video" "**Watch** political addresses" "**Doing research** on persons"
Socio-cognitive functions	Collaborative learning processes: Initiating exchange, Facilitating deixis, Group memory	"**global communication**" "search engine **points to** similar results that could be also interesting" "**interlinking** similar videos" "**equality** in the sense of equal rights to **publish** own content"
Meta-cognitive functions	Knowledge about learning strategies, Regulation of one's own learning process	"**rehearse** music" "**freedom of choice**"
Motivational functions	Extrinsic and intrinsic motivation, Domain-related interest	"possibility to find **interesting** and **motivating** material to start a topic" "**fun while dealing with** everyday phenomena"

Based on the assumption that a better lesson plan for using YouTube would contain more different valid aspects, a score representing *lesson plan quality* was computed by counting the number of different codes for intended and ideal use of YouTube, respectively (for an overview of constructs and for means and standard deviations see Table 3.3). This measure was considered as an indicator for aspects of participants' application of TPCK.

3.2.3.4 Control Variables.

The control variables assessed were gender (0 = *male*, 1 = *female*), participants' experience with YouTube, and their general pedagogical beliefs. Participants' experience with YouTube was identified by two items, one asking participants how frequently they used YouTube (1 = *daily*, 4 = *less than once a week*) and the other asking them to rate their own experience with YouTube on a 5-point Likert scale (1 = *very low*, 5 = *very high*). The two items were substantially correlated, $r(60) = -.66$, $p < .001$, and therefore z-transformed and aggregated into one measure of participants' YouTube experience as an indicator of their technological knowledge (TK) with regard to YouTube.

Table 3.2

Coding scheme 2: Emerging categories for coding mental models of YouTube functions.

Category	Examples (keywords in bold)
Accessibility	"**access** digital versions of seminars"
	"**possibility to** watch videos about **current events**"
Entertainment	"to **entertain** and **amuse** people"
Exchange	"**exchange** on current global events and individual opinions about them"
	„individual videos can be **distributed** to everyone"
Information repository	"many different **contributions** are **available**"
	"**information research**"
Productive use	"**interlinking** similar videos"
	"**comments**"
School-related	"getting your hands on useful and entertaining material for **school**"
Vividness	"**Illustrating** phenomena"
	"Possibility to use **examples** for instruction"
	"**Explain** information about politics, culture, and other content **via video**"

General pedagogical beliefs were assessed, in order to be able to differentiate between the more global aspects and fundamental assumptions of pedagogical beliefs and pedagogical knowledge that has been validated in scientific discourse. To tap into this construct participants rated items from two subscales (*constructivist teaching*, 8 items, and *traditional teaching*, 9 items) of an established scale the Teacher Beliefs Survey (TBS, Woolley, Benjamin, & Williams Woolley, 2004) on a 6-point Likert scale (1 = *completely disagree*, 6 = *completely agree*). Both scales showed sufficient internal consistencies, Cronbach's $\alpha \geq .71$, and were uncorrelated, $r(60) = .20$, $p > .10$. In order to consider the relative preference participants held for either a constructivist or a traditional orientation, they were combined by subtracting their score on the traditionalist scale from their score on the constructivist scale. For the resulting difference score, positive values indicate a relatively more constructivist pedagogical belief and negative scores a relatively more traditionalist pedagogical belief.

Table 3.3
Zero-order correlations, means (M) and standard deviations (SD) for scales and coded open answers.

		2)	3	4)	5)	6)	7)	8)	9)	*M*	*SD*
1)	Gender	-.11	**.28***	.16	.16	-.06	.04	-.16	-.03		
2)	YouTube experience		.09	-.09	.23	-.21	-.16	-.09	-.02	2.98	0.47
3)	Practical experience			.16	**.29***	-.01	.18	.14	-.09	3.70	2.47
4)	Constructivist pedagogical beliefs				.16	.03	.16	.08	.06	0.81	0.87
5)	Pedagogical knowledge					**.29***	**.31***	**.30***	.16	11.97	3.84
6)	Complexity of mm of YouTube functions (tc)						**.33***	**.43****	.21	0.45	0.41
7)	Number of aspects, intended instructional use (ec)							**.43****	**.34****	1.32	1.94
8)	Number of aspects, ideal instructional use (ec)								**.54****	1.77	2.23
9)	Number of barriers to using YouTube (ec)									0.77	0.79

Note. mm = mental model, ec = emerging categories, tc = theoretically derived categories.
[a]in months [b]theoretical maximum = 22.
* $p < .05$, ** $p < .01$.

3.3 Results Study 1

3.3.1 Mental models of YouTube

The average length of answers in words for the general functions of YouTube participants described were, M = 3.5, SD = 3.0, M = 3.0, SD = 3.5, and M = 3.0, SD = 3.5, for the three functions, respectively.

Results for the coding of emerging categories (see Figure 3.1) show that the function named first referred most frequently to three categories: YouTube as a source of entertainment, as a repository for a wide range of information, and the accessibility YouTube provides for content that is recent or otherwise difficult to obtain (≥ 30%). The function named second mostly contained entertainment aspects as well (≥ 20%). However, with the other dominant aspects here being Information and Opinion Exchange and the possibility for Productively Using YouTube (e.g. uploading and commenting), the focus shifted towards the role of the user as a participant rather than a consumer. The function named third did not show any specific pattern and followed the overall frequency distribution over the categories. Overall, in spite of a strong focus on entertainment, participants also considered YouTube as an information source for keeping up-to-date with regard to various topics and, more importantly, they acknowledged its affordance to enable them to actively engage in content and social interactions. Participants rarely referred to school related uses explicitly.

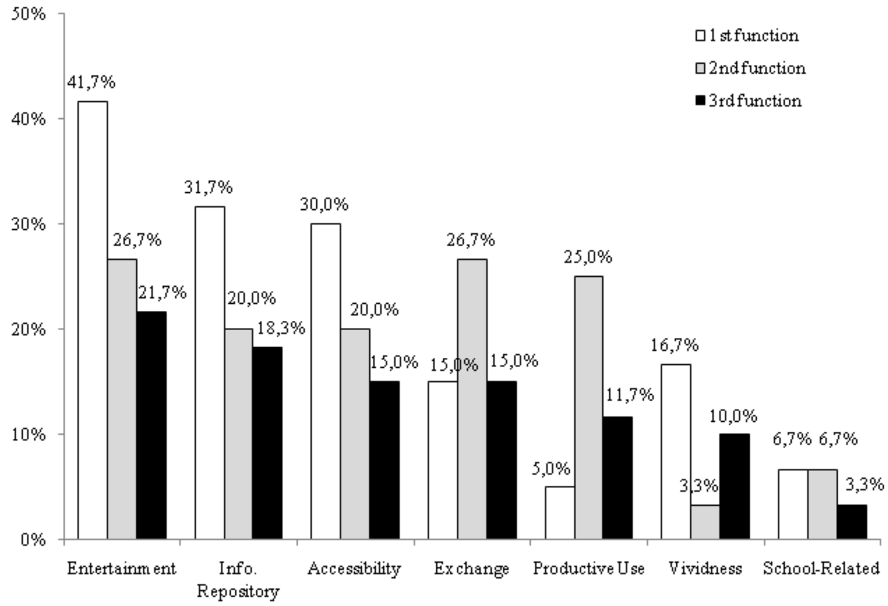

Figure 3.1. Frequencies for emerging categories of mental models of YouTube functions.

Results for the coding of theoretically derived categories show that the most frequently coded category for all three named functions were socio-cognitive ones (≥ 20%, see Figure 3.2). This mostly reflects the codes of Exchange and Productive Use from the emerging categories. There were, however, fewer answers referring to individual cognitive aspects (≤ 15%). Noticeably, motivational and meta-cognitive aspects were only rarely named.

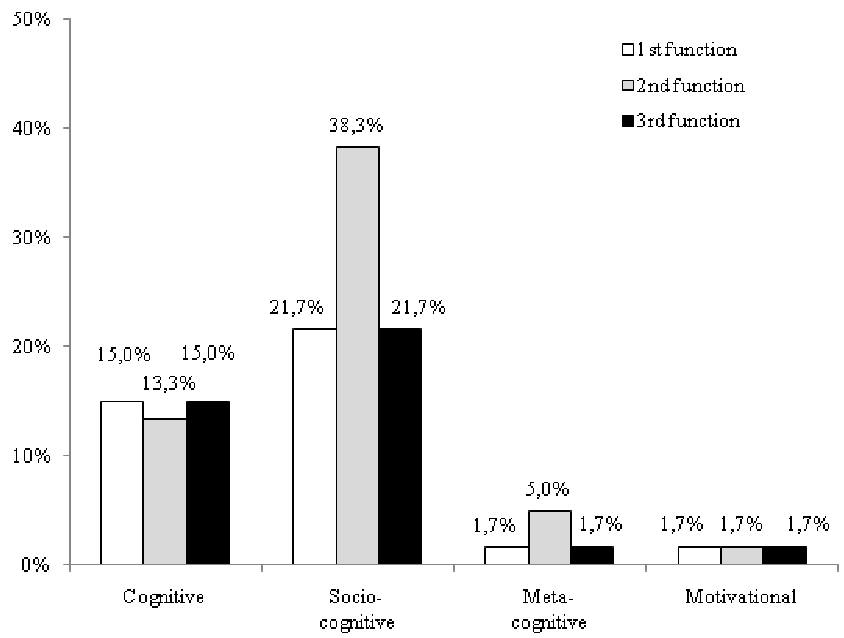

Figure 3.2. Frequencies for theoretically derived categories of mental models of YouTube functions.

3.3.2 Lesson planning for using YouTube (TPCK) – ideal and intended use

Average length of answer in words was, M = 9.5, SD = 13.5, for the intended instructional use and M = 8.0, SD = 10.0, for the proposed ideal instructional use of YouTube, respectively. Category frequencies for the participants' proposed instructional uses of YouTube are shown in Figure 3.3.

The four most frequently coded categories for both ideal and intended use of YouTube in class were Vividness, Teacher Presentation, Information Repository, and Content Elaboration. Overall, for ideal use these aspects were addressed more often and the prominence of these four categories relative to other aspects was more pronounced. Like in the general descriptions of YouTube Motivation plays a minor role. What seems important to notice is that the top four categories do not include Exchange and Productive Use (students). Taken together with Teacher Presentation, which was one of the most frequent categories, it can be seen that in the proposed uses of YouTube in the lesson context, the focus was on video material being presented, rather than being used by students. This is different from the participants' mental models of YouTube functions above (see Figure 3.1), where Exchange and Productive Use were named more often, especially where they were named second as an important function.

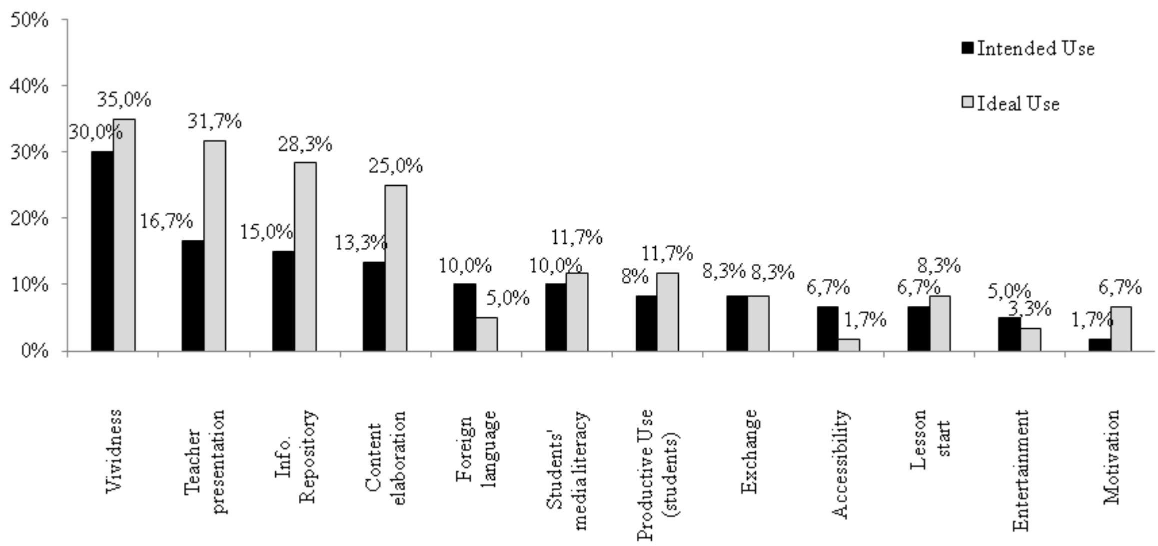

Figure 3.3. Frequencies for aspects in lesson plans, intended and ideal instructional use of YouTube.

3.3.3 Barriers to using YouTube in the "ideal" way

The average length of answer to the question about what participants perceived as barriers to implementation of their proposed ideal uses of YouTube was in words, $M = 8.0$, $SD = 9.0$. As the category frequencies show (see Figure 3.4), participants perceived the *Technological Equipment* (33.3%) of schools and classrooms as the main barrier to using YouTube. Other barriers were doubts about YouTube's *Reliability as a Source*, deficits in the *Usability of YouTube*, contradictions to their *Own Pedagogical Orientation*, *Classroom Management* Issues, lack of support from the *School System*, and *Legal Issues* concerning the further use of YouTube material. All these were, however, named considerably less (≤ 12%). Furthermore, the data show roughly two groups of barriers. One group is more related to issues on side of the technology (*Technological*

Equipment, *Reliability as Source*, *Usability of YouTube*), the other more to the human factor (*Own Pedagogical Orientation*, *Classroom Management*, *School System*, *Legal Issues*).

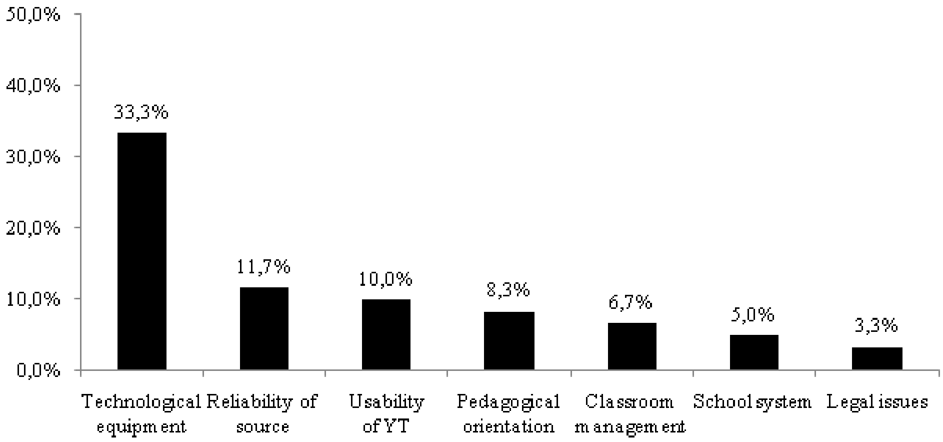

Figure 3.4. Frequencies for barriers to using YouTube in the suggested ideal way.

3.3.4 Mental models as mediators of pedagogical knowledge

For quantitative analyses the aggregated codes were used as indicators for the mental models' complexity and lesson plan quality as described in Sections 3.2.3.2 and 3.2.3.3 to satisfy the assumption of interval level data. All conditions for multiple linear regression (Cohen, Cohen, West, & Aiken, 2003, pp. 117) were satisfied. In a first step to quantitative analysis, zero-order correlations were computed among control variables, pedagogical knowledge, the complexity of participants' mental models of YouTube, the number of aspects in the proposed intended and ideal instructional use of YouTube, and the number of barriers hindering the instructional use of YouTube (see Table 3.3, also for means and standard deviations). The level of significance for all analyses was set to $\alpha = .05$.

Overall, the correlations showed the predicted pattern: Pedagogical knowledge was positively correlated with the complexity of participants' mental models of YouTube affordances (both coding procedures). Pedagogical knowledge was also correlated with the number of different aspects in participants' descriptions of intended and ideal use for teaching. The complexity of the mental models was also positively correlated with the number of different aspects in both intended and ideal use of YouTube with students.

Whereas the two constructs were only moderately related, $r(60) = .43$, $p < .001$, it was indicated that indeed different aspects of lesson planning ideas were tapped. The number of barriers participants perceived in how to use YouTube ideally was positively correlated with the number of aspects mentioned in the proposed intended and ideal use. This indicated that participants whose proposed use of YouTube encompassed more different aspects also reported more potential barriers. Overall, correlations were of small to medium size.

First, to test whether pedagogical knowledge predicted intended and ideal instructional use of YouTube, multiple hierarchical regressions were run with the aggregated codes for the intended and ideal use, respectively, as dependent variables. In the first step, the control variables (gender and YouTube experience) were entered; in the second step, the scores for pedagogical knowledge and constructivist pedagogical beliefs, and in the third step, the interaction term of pedagogical knowledge and constructivist pedagogical beliefs. For both, intended and instructional use, pedagogical knowledge emerged as the only significant predictor, $\beta = .36$, $t(59) = 2.74$, $p = .01$ and $\beta = .38$, $t(59) = 2.96$, $p = .01$, respectively. Then, to test whether the complexity of participants' mental models of YouTube explained this effect, additionally mediation analyses were performed. The procedure proposed by Preacher and Hayes (2008) was followed for estimating and comparing indirect effects of a mediator. This procedure It estimates an unstandardized coefficient (*b*) for the indirect effect and tests its significance with a bootstrapping technique by estimating standard errors and confidence intervals. Analyses revealed that the mental models completely mediated the effect of pedagogical knowledge on the ideal use of YouTube participants described, indirect effect: $b = .08$, SE = .03, CI $\alpha = .05$ [.03; .16], and revealed a marginally significant indirect effect for their intended use: $b = .04$, SE = .03, CI $\alpha = .10$ [.002; .10]. All mediation analyses were controlled for participants' technological knowledge (prior experience with YouTube), which revealed a significant negative effect on the mental model measure, $\beta = -.29$, $t(59) = -2.42$, $p = .02$. This indicated that, when controlled for the influence of pedagogical knowledge, more experience with YouTube was associated with less complexity of the mental models of YouTube functions. Controlling the analysis additionally for the number of barriers participants had named did not notably change the results for ideal use. However, the indirect effect for intended use was rendered non-significant, $p > .10$. Overall, the amount of variance in lesson plan quality explained by these indirect effects was relatively small. As shown in Figure 3.5, for the ideal planned use entering participants' mental models of

YouTube as a mediator reduced the variance explained directly by pedagogical knowledge from 11% to a non significant 3 %. For the intended use this variance was only reduced from 19% to a still significant 11% of variance directly explained by pedagogical knowledge.

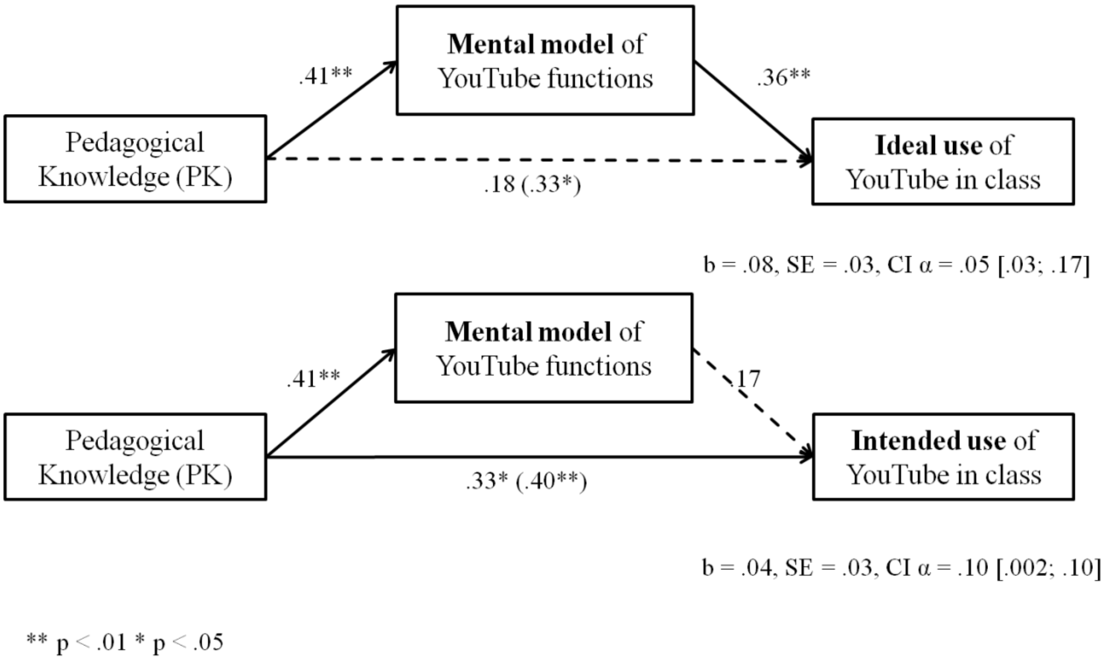

Figure 3.5. Results of the mediation analysis.

3.4 Discussion Study 1

The aim of this study was to investigate whether in a sample of pre-service teachers' pedagogical knowledge can predict the complexity of their mental models of YouTube functions (affordances), and whether that complexity in turn predicted two aspects of planning the use of YouTube with students in class: The intended use and an ideal use. It was also explored what participants expected to be the barriers that might prevent them from implementing their ideas for ideal instructional applications of YouTube. The results were in line with my expectations: There was a mediation effect of mental models for ideal instructional applications and a marginal indirect effect for the intended use. Overall, the statistical effects were of moderate to small size. In their lesson plan ideas for instructional use of YouTube, participating pre-service teachers focused on YouTube as an audio-visual medium, and as a searchable database with additional Web 2.0 features.

3.4.1 Mental models of YouTube functions and planning their use in class

How the participating pre-service teachers describe the functions of YouTube (Table 3.2 and Figure 3.1) indicates that, on the one hand, YouTube is understood as a Web 2.0 tool, which is easily accessible, up to date, and open for active participation (categories: *Information Repository, Accessibility, Exchange*). On the other hand, it is also characterized in ways that are also applicable to film and video in general: entertaining with audio-visual content that is presented vividly (categories: *Entertainment*, *Vividness*). The finding that the entertaining function of YouTube seems to be more prominent to participants than the vividness of the audio-visual material is in line with research on film and video in the educational context. Hobbs (2006) could show that video is often used by teachers in class as entertainment or as an incentive unrelated to learning. From the work of Salomon (1984) it is also known that students in turn connect the use of video with investing less mental effort in processing the content. Taken together with these findings, the present results could point out that the use of new developments in digital video technology in the classroom might be constrained by already established general patterns of using film and video in this context. This idea also relates to the aspects that participants mentioned in their intended and suggested ideal uses of YouTube in class. In their mental models of YouTube (Table 3.1 and Figure 3.2, for detailed discussion see Section 3.4.2) they did mention functions that are relevant for learning, and they clearly acknowledge the potential for collaborative learning (socio-cognitive learning goals, Figure 3.2). In contrast, the most pronounced aspect in the ideas for lesson planning is the vividness of YouTube content, and the dominant suggestion for applying YouTube in class is that of the teacher presenting a (short) clip (Teacher Presentation, Figure 3.3).

Although only lesson plan ideas were collected from the participants in this study, this focus on teacher presentation corresponds with classroom research and might indeed predict a similar focus in their future classrooms. Research based on videotaped lessons without a technology focus has shown that teachers follow a limited range of behavioral scripts in their classroom instruction (Kunter et al., 2006; Seidel, Schwindt, Rimmele, & Prenzel, 2009). Schmotz (2009) could further show that this is also the case for the use of information and communication technology. Based on classroom video data and interviews with 20 German high school teachers (grades 11-13), she found three scripts that teachers seem to adhere to when using technology in class: teacher-centered (n = 10), differentiated (student-centered, n = 6), and autonomous (student-centered and autonomy supportive, n = 4). Furthermore, these scripts correspond to teacher beliefs. These findings suggest that the data could be interpreted as follows: Even if (pre-service) teachers understand the different functions of the pervasive possibilities for productive and collaborative use of video on the internet, for example in YouTube, they will be confronted with shared mental models of how to use video in class. This factor might be another barrier preventing the co-evolution of appropriate pedagogical methods leveraging the tools specific affordances. If this is the case it could suggest that new developments in video technology are instead likely to be adapted to fit the established patterns. This is an assumption that future studies need to tackle.

In the present data, this possible barrier does not appear as part of the participating pre-service teachers' own reasoning about barriers to using YouTube in class. When asked what kept them from using YouTube in their own suggested ideal way, most of the participants' answers in this study referred to the technological equipment of their schools. As a result, the data show that instead of reflecting on their own knowledge, mental models or established patterns as relevant influences on their actions, they focus on external factors. As Ertmer (1999) put it, in their reasoning, the pre-service teachers in this study were describing more *first-order barriers* than *second-order barriers*. Interestingly, with regard to my focus on general pedagogical knowledge, participants never mentioned that they felt they were lacking specific knowledge.

3.4.2 Mental models and TPCK

In this study the integration of technological knowledge into teachers' professional knowledge was investigated. General pedagogical knowledge was chosen as the starting point and interpreting the integrated sub-domain Technological Pedagogical Knowledge (TPK, knowledge about how a technological tool can change teaching and learning and how specific learning arrangements can leverage the functionalities of a tool) based on the notion of mental models (Johnson-Laird, 1980, see also Section 2.1). It was assumed that TPK needs to be represented in the form of mental models of tool functions in relation to what these functions can mean for teaching and learning. Based on these assumptions four relevant dimensions of learning goals were suggested that need to be represented in these mental models, namely *cognitive*, *socio-cognitive*, *meta-cognitive*, and *motivational* learning goals. Coding the participants' answers showed that they do perceive the potential for supporting cognitive and also socio-cognitive learning goals. Meta-cognitive and motivational goals, however, were almost never mentioned. For meta-cognitive goals this is not surprising, because YouTube as such does not contain information about learning strategies or other meta-cognitive aspects. What can be considered a counter-intuitive finding is that the participants' mental models of YouTube did not contain motivational aspects, although research has shown that film and video are frequently used for motivating students as described above. However, looking at the present data, it seems that YouTube is represented as a tool for entertainment and taking a break from learning, but not for motivating students to learn.

The significant indirect effects of pedagogical knowledge show that this rather abstract knowledge could be one prerequisite for teaching with technology, but that it is not sufficient. These indirect effects explain a small, yet important part of the variance in participants' lesson plans. They suggest—in line with my assumptions—that having a more complex mental model of what the functions of YouTube can mean for learning is another important aspect that is associated with lesson plan ideas that are more differentiated. That the effects are stronger for the participants' proposed ideal use fits my methodological assumption that this measure is less confounded with personal and technological barriers and constraints imposed on them by the educational system and their colleagues. Thus, these results focus on the initial potential seen by the participants for leveraging the affordances of YouTube in class.

Due to the cross-sectional design the results show how the participating pre-service teachers' prior knowledge and their mental models of YouTube are related in their existing body of knowledge. However, the results do not differentiate between how the teachers' prior knowledge has influenced the process of constructing their mental models of YouTube over time and their mental models when they first encountered YouTube. It still needs to be tested whether this cognitive integration of technological knowledge into a teacher's prior knowledge takes place spontaneously when learning about a new technology, less associated than YouTube with commonly shared stereotypes. However, it was possible to show that the link is mainly indirect and thus that transformation of pedagogical and technological knowledge indeed seems to be important and further research in this direction is necessary.

In addition, the findings were not qualified by teachers' general pedagogical beliefs. Although research shows that teacher beliefs can be an important part of teacher cognition, it could be shown in this study that pedagogical knowledge has a distinct influence on the participants' planning for technology integration. This has not been done in this area of research so far. Additionally, the general pedagogical beliefs assessed in this study did not show any significant effects. This might be due to the fact that the relevant research has mostly shown effects for subject- or technology specific teacher beliefs (for an overview on technology beliefs see Anderson & Maninger, 2007; for mathematics, e.g. Staub & Stern, 2002).

3.4.3 Limitations

Besides the already mentioned points there are limitations of this study that need to be discussed. Although studies conducted online have been shown to be comparable in most ways to studies in the laboratory with regard to participant responses (e.g., Yetter & Capaccioli, 2010), the results have to be interpreted cautiously. A problem which can easily occur in research involving technology is the high probability of a selective sample where technophile participants are overrepresented. For this study, however, there were a number of participants who uttered concerns about using YouTube in their instruction. They also explicitly expressed their doubt about using YouTube in teaching at all. Thus, for this sample it can at least be shown that it was mixed and included participants who expressed a critical view of the instructional use of technology. However, due to an anonymous online sample it is important to be careful with generalizing the results of this study to the general population of (German) pre-service teachers. This is also, because this is not a random sample. First, members of a forum might belong to a specific group, for example they might be overly motivated in general, because in addition to the resources they are provided with by their universities they look for further information online. Second, with a group of non-respondents of unknown size there is no information available about which factors might have contributed to participants' decision to fill in the questionnaire.

With regard to the assessment of the mental models in the present study, a text-based assessment was used in this study and focused on the content of the mental models. Other possible tools to assess mental models are mind-mapping or graphic measures (e.g., Chi, 2000). These could reveal additional information about the interrelations among the elements represented in the mental models and provide spatial information, such as how YouTube functions are related to classroom arrangements.

Also, over the long term, content-related knowledge tests and actual classroom behavior of teachers should be included in studies. With regard to exploring TPCK as a dependent variable, a more detailed assessment of lesson plans could further our understanding of specific cognitive processes. And in addition to identifying teachers'

TPCK *design skills* (lesson planning) also *comprehension skills* should be assessed (Kramarski & Michalsky, 2010).

3.5 Conclusion Study 1

In conclusion, this study has several implications. On a theoretical level it is interesting and challenging to combine the results of this study with suggested contrasting views on the TPCK framework, namely the transformative and the integrative viewpoint (Angeli & Valanides, 2009). The different components of the TPCK concept should further be investigated in order to learn more about their interplay and the process of their cognitive integration. One step in this direction would be to map the notion of mental models addressed here onto the TPCK-framework. In Chapter 2 the construction of mental models was defined as the first level of cognitive integration based on the basic sub-domains of technology, pedagogy, and content of a (pre-service) teacher's prior knowledge. In this study, for example, participants' prior pedagogical knowledge (PK indicator) was assessed, then it was investigated how this was integrated with their mental models of the affordances of YouTube (TPK indicator), and how both of these were related to their planning of using YouTube in the classroom (TPCK indicator). In line with this, it will be important to conduct experimental research to investigate causal effects of the mental models addressed here (see Study 3 in Chapter 5). These studies will tackle the following issues: Which elements of information about a technology are relevant for the construction of beneficial mental models of this tool's affordances? How much does cognitive integration need to be built in by the teacher educator, for example by specifically situating technological affordances into a pedagogical context? Does pedagogical knowledge act as a guide in this? Implications for the practice of teacher education, however, have to be drawn rather carefully.

An important concern for teacher educators is their students' actual use of technology in their future teaching. So how does knowledge of ideal and intended use of technology assist teacher educators in planning their teacher training courses? This question can be related to two poles of a dimension of possible approaches towards technology in teacher education. One approach for teacher educators would be to first support teacher trainees in planning complex technology-supported learning scenarios. Here the focus would be on utilizing preferably all affordances of a technology by designing tasks and selecting content accordingly. Then, in a next step, the educator could support the trainees in implementing (maybe only parts of) these plans in the classroom. The complementary approach would be to encourage teacher trainees to consider the challenges of implementation right from the start. The results of this study are interpreted based on the former approach. In line with it, this can be considered as a starting point for further research to build on the pedagogical knowledge base of pre-service teachers' and to find out how to help them to make use of this knowledge for leveraging the affordances of a video tool in class. Better ideal plans for using a video tool should make it more likely that the added value of a technology becomes visible in a lesson. And if this added value does not become clear during planning, pre-service teachers should also be supported in generating pedagogically sound explanations for not using technology.

4. Study 2: Understanding Video Tools for Teaching: Mental Models of Technology Affordances as Inhibitors and Facilitators of Lesson Planning in History and Language Arts.

In the previous study it could be shown that prior pedagogical knowledge predicted the quality of ideal and intended lesson plans for utilizing YouTube across a number of different subject areas. Moreover, it could be shown, that the mental models participants constructed of the learning-relevant functions of YouTube partly mediated this relationship. Nevertheless, YouTube is widely known as an application used for users' self-expression and for unclear legal status of some of its content. This was also reflected in the answers of participants of the previous study. These are confounds for investigating the question of effectively utilizing video technology for teaching in class. Additionally, the design of Study 1 allowed for a large possible source of variance stemming from the many subject areas in participants' lesson plans. Implicitly, that means large variation with regard to participants' areas of content knowledge. Thus, the first goal of this study was to investigate, whether the findings of Study 1 could be replicated for a newly encountered video technology (WebDIVER) and when constraining the content area for lesson planning to history and language arts. The second goal was, to apply refined measures for lesson planning that assess evaluation and design aspects separately. Finally, more subject specific scales were used to tap into participants' pedagogical beliefs.

In this study, too, the focus was on pedagogical knowledge and the representation of Technological Pedagogical Knowledge (TPK, knowledge about how a technological tool can change teaching and learning and how specific learning arrangements can leverage the functionalities of a tool) in the form of mental models of tool functions. With regard to the content of these mental models, in contrast to Study 1, the present study focuses only on *cognitive* and *socio-cognitive* functions, because they are most relevant given the theoretical foundation of the sample video technology of WebDIVER (see Section 4.2.3, and Zahn, Pea, et al., 2010). Cognitive functions refer to a student's individual learning and how he or she deals with the information presented in learning material and tasks. They comprise a range of processes from remembering to creating that are translated by the teacher into learning goals by specifying which of the respective processes are tackled by the material and task at hand (Anderson & Krathwohl, 2001; Bloom, 1956). Socio-cognitive functions refer to collaborative learning settings in which knowledge and activities are distributed over several learners. Thus, in addition to the described individual cognitive processes, the sharing, processing, and integrating of the distributed knowledge are specifically relevant (Salomon, 1993).

4.1 Research Questions of Study 2

In the present study, the spontaneous understanding of pre-service teachers of the functions of an exemplary video technology was investigated (mental models of tool functions). It was furthermore examined how this understanding would influence their lesson planning for students. It was expected that the construction of mental models of tool functions would be an important aspect of a (pre-service) teachers' cognition that would influence planning to teach with this technology. Furthermore, it was expected that when a teacher's mental model contained specific functional aspects, this would influence teachers' performance differentially when planning a lesson that leverages the affordances of the technology (TPCK indicator). In addition, the question was asked what to expect with regard to how prior (pedagogical) knowledge is involved in this process. Do mental models and prior pedagogical show discriminant effects for lesson planning with a newly encountered technology? Can the mediating effect of mental models found in Study 1 be replicated under these conditions? In accordance with prior empirical research on the effects of technological affordances of digital video (Merkt et al., 2011; Zahn, Krauskopf, et al., 2010; Zahn, Pea, et al., 2010), the present study focused on the subjects history and language arts.

4.2. Method

4.2.1 Sample

The study was administered online and participants were recruited via postings in online forums and teacher candidate groups in StudiVZ (a German version of Facebook). The final sample consisted of N = 24 pre-service teachers (high school graduation grade, M = 2.2, 1 = *best*, 6 = *worst*, SD = 0.7, 17 female and 7 male). All were enrolled in university programs studying to become secondary educators (Gymnasium level) in the west and southwest of Germany. 79% had already completed internships as assistant teachers with an average length of M = 3.6 months, SD = 1.3. Concerning the participants’ majors, 16 were studying German language arts or history, five both, two English language arts or social science, and one participant did not answer this question. As compensation, participants who completed all measures took part in a lottery of three 50€ Amazon vouchers and received general information on the study’s results.

4.2.2 Procedure

Participants completed an online questionnaire which consisted of four parts. First, participants answered demographic questions (age, gender, high school grades) and about their university based teacher training. They also responded to two scales measuring their subject (history and language arts) specific pedagogical beliefs and completed a test measuring aspects of their general pedagogical knowledge (for details see below). Second, participants were shown a 10-minute video tutorial introducing the basic *technological* functions of the web-based digital video tool WebDIVER (see below for details). Third, after watching the tutorial, participants were asked to (a) recall the functions of WebDIVER, (b) to write down which were the most important functions and why they thought so. Then, they were (c) asked to sketch an idea for an ideal use of WebDIVER in teaching their subjects (history or language arts), and (d) to name barriers that would keep them from realizing this ideal. Finally, participants watched a video presenting sample content (a historic news reel from post-war Germany, 1948). Subsequently, they were (c) asked to design a lesson plan to include this video and WebDIVER in their future teaching and (d) to evaluate an example lesson plan of how WebDIVER could be combined with this sample video. This order was chosen so that participants would not be influenced in the design of their own lesson plan ideas by the provided task example. Results will, however, be presented vice versa following the increasing transfer effort from evaluation to design task.

After completing all measures, participants provided their e-mail addresses, which were stored in a separate data base for informing them in case of winning an Amazon voucher and distributing study results.

4.2.3 Measures and materials

The video tutorial covered the technological functions of the WebDIVER software and how to operate them. It was created with a screen-recording software (Camtasia 5®, TechSmith, 2007). References to any learning goals were not included. After a short overview of the basic functions and the layout of WebDiver`s graphical user interface, each of the functions was individually introduced and modeled in the screen video. These functions included: *Saving a private copy of a video, play and pause a video, cutting out still images or sequences* (= creating *DIVE panels*), *zooming in on details before cutting out, watching cut outs, annotating cut outs with titles or comments, commenting on other users' cut outs, duplicating cut outs, changing the order of cut outs via drag & drop, watching the flow of cut outs* (see Figure 4.1 for the graphical user interface). The average time participants spent watching the video was M = 14.2 minutes (SD = 6.8) and was not correlated with any of the other variables considered in the analyses, $p \geq .12$.

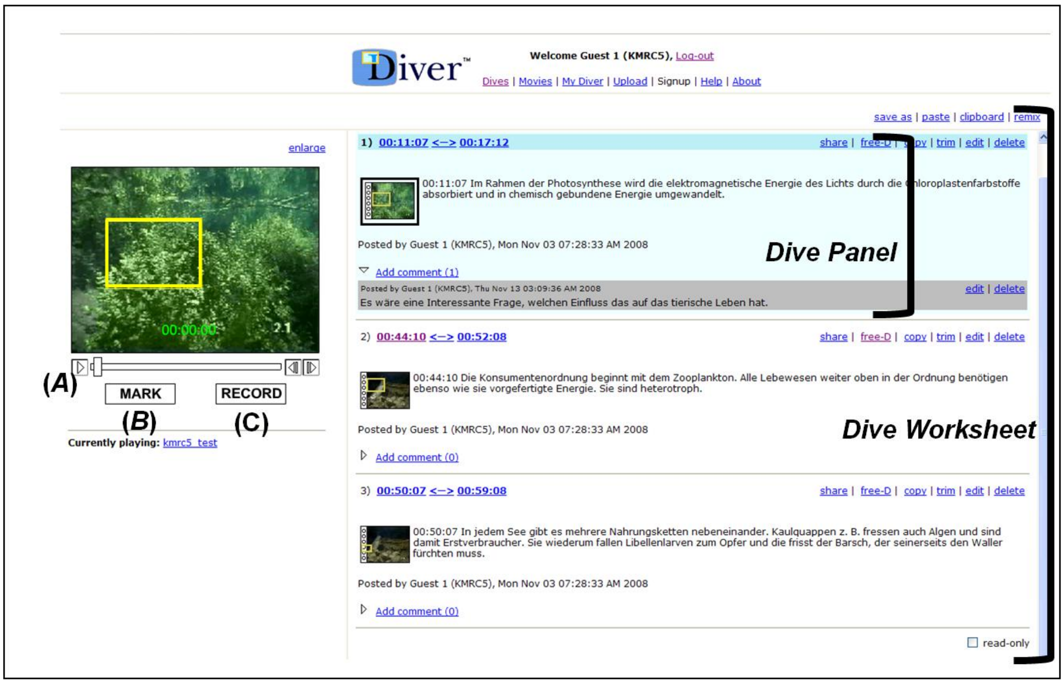

Figure 4.1. Screenshot of WebDIVER with the functions for video playback (A), selection of screenshots (B), and sequences (C) on the left side of the image, and the Dive Worksheet consisting of the already selected and annotated screenshots and sequences on the right side.

4.2.3.1 Pedagogical and technological knowledge

Because the study was conducted online, it was tried to keep the overall length to a minimum. Therefore, a 7-item short version of the measure used in Study 1 was used to assess declarative aspects of participants' general *pedagogical knowledge* (PK, see Appendix Table A.2 and A.3). After each item, participants rated their confidence in their answer on a 5-point Likert scale (1 = *very uncertain,* 5 = *very certain*). Answers to the PK items were weighted with the given confidence rating and integrated by computing a sum score. According to Cierniak and colleagues (cf., Cierniak, Scheiter, & Gerjets, 2009), this procedure has two advantages which are especially important when conducting studies online: First, the reliability of the measure is increased by circumventing the problem of a guessing probability. Second, answers that participants are more confident about are assumed to reflect more consolidated knowledge. Thus the consolidation aspect of participants' prior pedagogical knowledge is taken into account. Considering the shortness of the scale and heterogeneity of the aspects touched on by the items, the internal consistency of the measure was sufficient, Cronbach's $\alpha = .66$.

To assess participants *technological knowledge* (TK), in this case of WebDIVER, the number of correct features recalled after watching the video were counted, $M = 3.6$, $SD = 1.4$. Inter-rater reliability was high, Krippendorff's $\alpha = .97$. Additionally, participants' self-rated computer experience was assessed on a 6-point Likert scale (1 = *very low*, 6 = *very high*), $M = 3.6$, $SD = 1.4$. Computer experience was not correlated with any of the variables addressed in the analyses reported below, $p = \geq .11$.

4.2.3.2 Mental models of WebDIVER functions

To tap into participants' mental models of the learning-relevant functions of the video tool WebDIVER, that is, their technological pedagogical knowledge of the tool (TPK), the same procedure applied in Study 1 was followed (cf. Azevedo & Cromley, 2004). In this approach, mental models of participants are extrapolated by coding and then by counting relevant aspects mentioned in participants' open answers. Because mental models were defined as more elaborate representations exceeding mere facts (see Section 2.1), participants' answers were coded according to what the most important functions of WebDIVER were and why they thought so.

The coding scheme was created to cover the *theoretically derived categories* described above, based on the descriptions of the relevant aspects in the research literature, namely, *cognitive*, *socio-cognitive*, *meta-cognitive*, and *motivational* learning goals. All answers were coded by two trained independent raters. Categories were not exclusive and one answer could receive more than one code (see Table 4.1 for categories and examples). The codes meta-cognitive and motivational did not occur and these categories were therefore not considered in the further analyses. Rater-agreement was satisfactory, cognitive Krippendorff's α = .69, and socio-cognitive, α = .75. Differences in codes were resolved by discussion.

Table 4.1
Coding scheme for theoretically derived categories for coding mental models of WebDIVER functions.

Category	Definition	Example answers (Item: *Please explain what the most important functions of WebDIVER are.).* Keywords in **bold.**
Cognitive functions	Individual learning processes: Remember, recognize, recall; Understand, interpret, exemplify, classify, summarize, infer, compare, explain; Apply, execute, implement; Analyze, differentiate, organize, attribute; Evaluate, check, critique; Create, generate, plan, produce.	"This way I can **edit** a "ready-made film" **for my own** specific lessons to then **us it sensibly**" "You can **cut out relevant parts** of the film and students could **comment** on the sequences they watched **as homework**" "Simply by changing the sequence [of the screenshots and sequences] students will **take** a sort of **meta-perspective**. Besides that, by zooming you **can point out important details** in the film."
Socio-cognitive functions	Collaborative learning processes: Initiating exchange, Facilitating deixis, Group memory	"Other **users can access** the videos" "The **exchange** is important, for **noticing** mistakes you yourself overlooked" "**Integrating [it] into** your own material, like a **presentation**"
Meta-cognitive functions	Knowledge about learning strategies, Regulation of one's own learning process	*no examples*
Motivational functions	Extrinsic and intrinsic motivation, Domain-related interest	*no examples*

Based on the assumption that depending on which functions are represented in mental models they would differentially influence different indicators of participants' lesson planning, the frequencies for cognitive and socio-cognitive learning goals were analyzed separately. Because the distributions were heavily skewed, the frequencies were recoded into binary codes indicating whether the respective functional aspect was contained in the mental model (code = 1) or not (code = -1; for descriptive statistics see Table 4.2). To characterize the average *content* of the mental models with regard to the emerging categories, the percentages for the occurrence of each category were computed (see Figure 4.2).

4.2.3.3 Assessing TPCK task performance

Based on the theoretical considerations in Chapter 2, the current definition of the TPCK construct as a meta-conceptual awareness would afford a respective instrument to tap these meta-cognitive aspects. Although there are approaches from the area of research considering TPCK and pre-service teachers' self-regulated learning (SRL, Kohen & Kramarsky, 2012; Kramarsky & Michalsky, 2010), it is important to mention that these measures also cannot be considered tests assessing TPCK. Instead they focus on (pre-service) teachers' performance in tasks that request them to consider technology, pedagogy and content simultaneously. Taking this into account, however, this approach still can be considered the most appropriate for the approach to TPCK suggested in the present dissertation. Thus, the approach by Kramarski and Michalsky (2010) to assess pre-service teachers' performance in an *evaluation* and a *design* task for a given content (historic news reel) and a given technology (WebDIVER) was adapted. With regard to the design tasks, additionally, a distinction was made between more general ideal and more concrete intended uses of WebDIVER in class. As has been shown in Study 1, this measure differs from the intended use in such a way that mental models seem to have a more direct link to this part of lesson planning. On a more concrete level, the purpose of using these indicators was to focus on the quality of the intended use of video tools, not on the mere intention to use technology or not (a measure common in studies following the Technology Acceptance Model, e.g., Teo, 2009b). Therefore, as an additional indicator, the subscale assessing the specificity of technology affordances described in pre-service teachers' lesson plans of the TPCK-SRL coding scheme suggested by Kohen and Kramarsky (2012) was also adapted (see Table 4.2).

Ideal use of WebDIVER and barriers. Participants' ideas for ideal uses of a WebDIVER in class were considered to be an indicator of whether they understood the initial potential this specific technology provides. Here the participants were free to choose any content they deemed fit. Methodologically, the answers to this prompt should be less confounded with personal and technological barriers and constraints normally imposed on teachers by the educational system and colleagues. Ideal instructional uses proposed by participants were coded with regard to whether they contained cognitive or socio-cognitive functions, similarly to the procedure for coding their mental models. Rater-agreement was good for the socio-cognitive category, Krippendorff's α = .87, and relatively low for the cognitive category, Krippendorff's α = .55. In order to tap into whether the goals of participants' ideal lesson plans mapped the specific affordances of WebDIVER, the technology sub-category of the TPCK-SRL coding scheme proposed by Kohen and Kramarsky (2012) was adapted and answers were coded on a 0 to 3 scale (see Table 4.2). Inter-rater reliability was also satisfactory for this indicator, Krippendorff's α = .71.

Table 4.2

Coding scheme for specificity of affordances described in lesson plans.

Category	Definition	Example
0	*no tool affordances*	„Spontaneously I cannot think of anything“
1	*general tool affordances*	„Presenting parts of a movie of theatre play without having to present the whole video.”
2	*at least one affordance specific to WebDIVER*	“Referring to filmic style features by selecting parts of the video” OR “Adding comments and instructions that will challenge the students to discuss”
3	*two or more affordances specific to WebDIVER*	“Students elaborate on specific topics […] by creating presentations consisting of still images and sequences” AND „Because all students have worked with the same software, they can praise each other and provide feedback”

With regard to the barriers participants named as potential obstacles for implementing their proposed ideal uses, the coding scheme was based on emerging categories from participants' answers that were created by two independent trained coders and then merged. Finally, a coding scheme was created consisting of seven categories:

Technological Equipment, Time costs, Pedagogical issues, Usability issues, School system, Legal issues, Lack of professional knowledge. Participants' answers were coded by two independent raters with good rater-agreement, Krippendorff's $\alpha = .83$. To categorize the barriers described by participants, the percentages for the occurrence of each category were computed.

Evaluation Task. An example lesson plan for using WebDIVER in a collaborative setting was described in a short vignette (see Appendix Table B.3). The topic of the lesson plan dealt with news reels as propaganda instruments in post-war Germany and it had been used in earlier research by Zahn and colleagues with students in the field of history and language arts learning (Zahn, Krauskopf, et al., 2010; Zahn, Pea, et al., 2010b). First, participants watched a clip (1.5 minutes) from the video material used in the lesson plan, namely, a digitized version of an historical newsreel originally produced by the Allied Forces (US/Great Britain) during the Berlin blockade in 1948. On average participants took $M = 2.8$ minutes ($SD = 2.4$) to watch this clip. The time spent on watching was not correlated to the respective dependent variables, $p \geq .54$.Then, they read the vignette, which contained the learning goals, the class level, the sequence of subtasks, and the general instructions students had received. Participants took on average $M = 3.1$ minutes ($SD = 1.4$) to read the example lesson plan vignette. The reading time was not correlated with the task evaluation ratings, $p \geq .37$.

Subsequently, participants rated on one item the likelihood that they would implement this example lesson plan in their own teaching. Then they rated on two scales to what extent they thought this task would support individual learning (six items for *cognitive learning goals*, example item: "Supports understanding of learning content") and collaborative learning (six items for *socio-cognitive learning goals*, example item: "Supports referring to ideas and concepts that have already been developed during collaboration"), respectively. For all ratings, a 6-point Likert scale was used (1 = *completely disagree,* 6 = *completely agree*). The two scales were sufficiently reliable, cognitive, Cronbach's $\alpha = .75$, and socio-cognitive $\alpha = .81$. This task was not completed by the full sample ($n = 21$); however, independent sample *T*-tests showed no significant differences between respondents and non-respondents to this task with regard to their pedagogical knowledge, technological knowledge, lesson plan quality, or computer experience, ps $\geq .06$.

Design Task. As a second measure to tap into participants TPCK, participants were asked to briefly describe a lesson plan that they would devise for using the newsreel together with WebDIVER in class. In this lesson plan, they were supposed to specify how they intended to use this video tool, which learning goals they would address with their plan, and which role the video tool would play. Participants' answers were coded in two steps. First, a coding scheme of emerging categories was created with regard to the different instructional aspects that the lesson plans contained. The coding scheme for the aspects that participants had covered in their lesson plans was based on emerging categories from participants' answers created first by two independent trained coders and then merged. The final coding scheme consisted of 13 categories: *Content Elaboration*, *Detail Perception*, *Empathy*, *Exchange*, *Historic Comparison*, *Lesson Start*, *Material Preparation (Teacher)*, *Motivation*, *Shortening Movies*, *Students' Media Literacy*, *Students' Productive Use*, *Teacher Presentation*, and *Vividness* (for coding examples see Appendix Table B.4). Based on the assumption that a better lesson plan for using WebDIVER would contain more different valid aspects, a score was computed that represented *lesson plan quality* by counting the number of different codes for participants' intended use of WebDIVER (for an overview of constructs and for means and standard deviations see Table 4.2).

Second, the lesson plans were coded again for the transformation of cognitive and socio-cognitive learning goals in a similar manner to the procedure for coding participants' mental models (see Section 4.2.3.2). Rater-agreement was satisfactory for the emerging categories, median of Krippendorff's $\alpha = .75$, as well as the theoretically derived categories, cognitive Krippendorff's $\alpha = .74$ and socio-cognitive Krippendorff's $\alpha = .83$. Differences in codes were again resolved by discussion. Parallel to participants' ideal uses, we coded the lesson plans for the specificity with which affordances of WebDIVER for learning had been described (see Table 4.2). This measure also showed satisfactory inter-rater reliability, Krippendorff's $\alpha = .84$. All four measures, lesson plan quality, cognitive, and socio-cognitive learning goals were considered indicators of participants' performance in the TPCK design task.

4.2.4.5 Control Variables.

The control variables assessed were gender (0 = *male*, 1 = *female*) and age in years. Both of these variables were not correlated with the dependent variables of the analyses, $p \geq .27$.

Subject-specific pedagogical beliefs. These beliefs were assessed in order to be able to differentiate between knowledge and more global pedagogical assumptions to follow up on the scientific discourse (e.g., Law, 2008). Given the results of Study 1, in this study a subject-specific measure was chosen and participants rated items on two subscales adapted from Souvignier and Mokhlesgerami (2005). *Constructivist orientation* (example item "Students should be allowed to explore their own ways of dealing with texts and films before you show them how to approach a text or a film.") and *explicit instruction orientation* (example item "Students learn how to deal with texts and films most effectively when you provide them with instructions on how to go about working with texts and films.") were each measured by three items and rated by participants on a 4-point Likert scale (1 = *completely disagree,* 4 = *completely agree*). Both scales showed sufficient internal consistencies, Cronbach's $\alpha \geq .74$, and were negatively correlated, $r(24) = -.48$, $p < .05$. Parallel to Study 1 a difference score was computed with positive values indicating a relatively more constructivist orientation and negative scores a relatively more explicit instruction orientation.

4.3 Results Study 2

4.3.1 Qualitative Analyses

4.3.1.1 Mental models of WebDIVER functions.

The average length of the answers describing the most important functions of WebDIVER was M = 17.8 words (SD = 17.2). Results for the coding of theoretically derived categories show that slightly more participants represented socio-cognitive (25%) than cognitive (21%) functions in their mental models. Only two participants' considered both functional aspects, whereas the other participants considered either one (29%) or none (63%). That only about one third of the participants referred to one of the two categories shows that most of them considered other aspects. For the most part, participants either did not give their own reasons for prioritizing the functions presented in the video-tutorial (e.g. "I think that these are the central functions because this is what was presented in the tutorial.") or they showed that they had understood WebDIVER to be more an editing tool in the sense of producing new video files, as professional programs would (e.g. Adobe Premier).

4.3.1.2 Ideal use of WebDIVER and barriers

Coding the answers with emerging categories showed that the most prominent aspects (> 20%) were S*tudent's Productive Use, Exchange, Detail Perception*, and *Shortening Movies* (see Figure 4.2). Although there were aspects specific to the affordances of the video tools present ("Autonomous use of film material by students", "Pointing out visual stylistic devices by cutting out", "Having students work [with the video tool] themselves, and letting them discuss the videos/films via the software") more prominent was the approach for teachers to use the tool for preparing video material for them to present in class ("Editing videos, so that they are not too long for class [...]", "Showing sequences from films and theatre plays without the need to show the whole film. Overall, the suggested ideal uses often contained very general aspects of how video or film can be used in class rather than specifying an added-value by using the functions of the video tool ("You could discuss the emotions of a person when reading a text and then look at an interpretation of the text in a film", "You could show parts of theatre plays (Faust, The Beggar's Opera by Brecht) to get a better impression", "Short sequences of films could be used as catalysts for writing [own texts]").

From the coding with theoretically derived categories, it was found that, in contrast to their mental models, more participants mentioned one or more cognitive aspects (62.5%) than socio-cognitive ones (29%).

The answers of the participants regarding the perceived barriers which would keep them from implementing their proposed ideal use of the exemplary video tool WebDIVER were concerned mainly with the technological equipment (46%) of schools or classrooms and the time (42%) they felt it would take to prepare. Other issues of the school system (13%), the perceived usability of the software (13%), and legal issues (8%) were mentioned less often. Issues related to participants' pedagogical expertise were also seldom mentioned: pedagogical reasons for not using the technology at all (17%) or the perceived lack of relevant knowledge (4%).

4.3.1.3 Lesson planning for using WebDIVER with students.

Participants' *evaluation* of the example lesson plan indicated slightly higher agreement with this task providing support for cognitive learning goals rather than for socio-cognitive learning goals (for descriptive statistics see Table 4.3). For more precise analyses of this variable see Section 4.3.2.1.

Design task. Coding these answers with the emerging categories revealed that the four most prominent aspects covered by the lesson plans were generally unspecific to the affordances of the video tool (≥ 40%), such as Content Elaboration, Students' Media Literacy, Students’ Productive Use of WebDIVER, and Lesson Preparation (for percentages see Figure 4.2). Content elaboration was mostly concerned with supporting the individual student in understanding selected aspects of the newsreel such as the stylistic devices of news and propaganda, good rhetoric, stimulating the students own thinking by showing (parts of) the newsreel in new ways, trying to foster the integration of prior knowledge, answering questions by selecting adequate pictures and sequences, or for the teacher to give the video material a structure that (presumably) supports the students’ information uptake. Especially comparison tasks were mentioned as a particular aspect of elaboration. Ideas related to students’ productive use included both specific uses of tool functions such as creating a new message by selecting and arranging sequences of the newsreel differently, as well as simply using WebDIVER as a video player with the possibility to re-watch the material on demand. Students’ media literacy was basically connected to general aspects such as developing web research competencies.

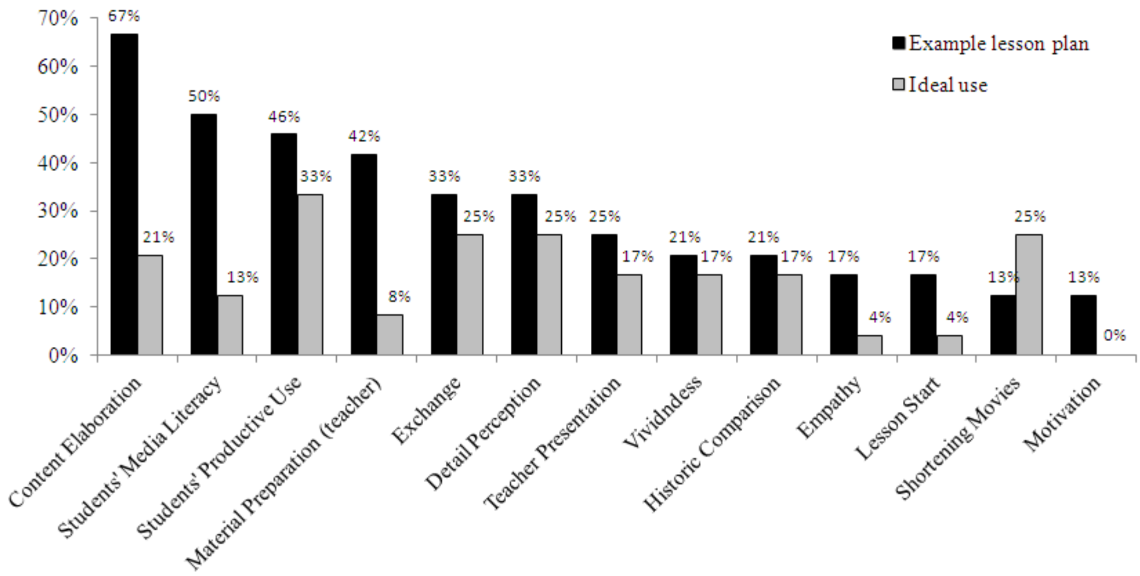

Figure 4.2. Frequencies for aspects in lesson plans, intended and ideal instructional use of WebDIVER.

However, aspects specific to the cognitive (Detail Perception) and socio-cognitive functions (Exchange) of the video tool were mentioned each in approximately one third of the lesson plans. What is noticeable is that mostly Exchange was more related to students working in groups in general or discussions in the plenum unrelated to the technology or to the results from the analyses using it. Two aspects representing the established use of video in the classroom (Teacher Presentation and Vividness) were addressed in up to one quarter of the lessons plans. Two more concrete aspects, which referred to the specifics of the content (newsreel as post war propaganda) as well as the specifics of the technology, were the comparison between the making of films in the past in comparison to the present (Historic Comparison) and the consideration of the emotions and atmosphere displayed in the newsreel by making use of the video tool features to focus on faces, mimics, and gestures (Empathy).

Overall, the lesson plans reflected certain recurring pedagogical approaches (teacher presents film sometimes edited with the software, students answer questions that the teacher has implemented in the software beforehand, cutting out or editing the video material as catalyst for plenum discussion or text production outside the software), which were mostly general and only seldom integrated content and technological affordances. Nevertheless, there were a few lesson plans that implemented this integration by applying specific tool functions to help students reach a certain learning goal (supporting the perception of details of the newsreel such as facial expression by zooming in on the details in order to gain emotional access to this historic source or choosing a controversial sequence of the video, providing it online, and having students discuss it using the functions of WebDIVER over an extended period of time before they present the results of this discussion in the plenum). Coding the lesson plans with the theoretically derived categories revealed that 96% of the lesson plans named cognitive learning goals (range 1-5), whereas only 29.2% named socio-cognitive goals (range 1-3). For descriptive statistics see Table 4.3.

4.3.2 Quantitative Results – discriminant effects of PK and mental models

Zero-order correlations were computed, which showed significant correlations between prior PK, TK, participants' mental models of the functions of WebDIVER, and different indicators of participants' lesson planning (see Table 4.3). Because there were no significant correlations between PK and participants' representation of cognitive or socio-cognitive functions in their mental models (a-path to the potential mediators), mediation analyses was not considered an appropriate approach for further analyses.

However, because there were some significant correlations between prior knowledge and aspects of proposed ideal uses and lesson plans for WebDIVER as well as correlations between the mental model indicators and these dependent variables, their discriminant predictive validity was investigated by means of hierarchical linear regression. In a first step, indicators for participants' prior knowledge (PK and knowledge of the presented video tool, TK) were entered into the regression. In the second step, indicators for the representation of cognitive and socio-cognitive functions of WebDIVER in participants' mental models (dichotomized, -1 = *not represented*, +1 = *represented*) were entered as two separate predictors. Three sets of dependent variables were regressed on these predictors: the indicators for proposed ideal uses (see Table 4.4), the evaluation of the example lesson plan vignette (see Table 4.5), and indicators for participants' self designed lesson plans (see Table 4.6). Collinearity diagnostics showed that the interaction terms between prior PK and mental model indicators contained redundant information. Therefore, the interaction terms could not be entered into the regression and moderating effects of participants' mental models could not be investigated. For complete hierarchical regression tables see Appendix Table B.3.1 through B.3.13. The type I error level for all analyses was set to $\alpha = .05$.

Table 4.3

Zero-order correlations, means (M) and standard deviations (SD) for scales and coded open answers.

	2)	3)	4)	5)	6)	7)	8)	9)	11)	12)	13)	14)	15)	16)	17)	18)	19)	*M*	*SD*
1) Pedagogical knowledge[c]	.34	.00	.02	-.15	.13	.14	.06	.09	.11	.10	**.56****	.16	**.51***	.38	.35	.24	.10	13.96	7.14
2) Technological knowledge[e]		-.07	.38	.24	.37	.28	.18	.06	.15	-.05	.35	.01	**.47***	.32	**.43***	.06	-.07	3.63	1.35
3) Constructivist orientation[d]			-.02	.31	-.09	-.11	-.16	.06	-.05	.03	.22	.04	-.12	.08	-.28	.01	-.02	1.03	0.80
4) Mm WebDIVER (cog)[a]				.18	**.68****	**.53****	**.59****	.31	**.48***	-.17	-.14	**-.51***	.30	-.10	.13	.31	-.08	.21	.41
5) Mm WebDIVER (soc-cog)[a]					.29	.20	.03	.24	.22	-.38	.15	.34	.18	.11	.14	-.17	.35	.25	.44
Ideal instructional use																			
6) Elaborateness (in # of words)						**.75****	**.53****	**.57****	**.74****	-.09	-.36	-.39	**.59****	.01	.38	.17	.34	17.63	12.92
7) Overall quality							**.69****	**.53****	**.84****	-.35	-.26	-.42	.24	-.10	.24	-.15	.25	2.04	1.33
8) Cognitive goals								.07	**.69****	-.11	-.28	-.33	.13	.02	.16	.16	.14	0.79	0.72
9) Socio-cognitive goals									**.51****	-.03	-.12	-.32	.34	-.01	.29	-.03	.23	0.38	0.71
11) Affordance specificity										-.25	-.42	-.42	**.46***	.11	**.44***	.02	.35	1.29	1.00
TPCK evaluation task																			
12) Implementation likelihood[d]											.29	.32	-.09	.23	.08	.26	.01	2.81	0.93
13) Cognitive goals[d]												**.62****	-.07	.37	.14	.14	-.01	4.73	0.66
14) Socio-cognitive goals[d]													-.08	.34	.21	.09	.36	4.56	0.87
TPCK design task																			
15) Elaborateness (in # of words)														**.54****	**.81****	**.49***	**.45***	48.67	32.68
16) Overall quality															**.66****	**.57****	**.49***	4.71	1.57
17) Cognitive goals																**.45***	**.61****	2.63	1.56
18) Socio-cognitive goals																	.23	0.38	0.71
19) Affordance specificity																		1.29	0.62

Note. WD = WebDIVER, mm = mental model, cog = cognitive, soc-cog = socio-cognitive.

[a]Sum score weighted with certainty ratings, [b]sum of recalled WebDIVER functions, [c]difference score, higher values indicate a more constructivist orientation, [d]binary coding, -1 = not represented in mental model, 1 = represented in mental model. * $p < .05$, ** $p < .01$.

4.3.2.1 Ideal use of WebDIVER.

For the indicators characterizing participants' suggested ideal use of WebDIVER hierarchical multiple regression analysis overall showed no significant effect for the knowledge variables PK and TK, $p \geq .11$, but only effects for participants' mental models of the functions of WebDIVER. In detail, the analyses revealed cognitive aspects in participants' mental models were a positive predictor for elaborateness , $\beta = .63$, $t(23) = 3.62$, $p = .002$, for the overall quality, $\beta = .51$, $t(23) = 2.45$, $p = .02$, the number of cognitive learning goals, $\beta = .62$, $t(23) = 3.06$, $p = .01$, and the specificity of affordance descriptions, $\beta = .49$, $t(23) = 2.31$, $p = .03$. Participants who represented cognitive functions in their mental models of the video tool also wrote more elaborate descriptions of an ideal use of WebDIVER in the classroom, included more different aspects, referred to more cognitive learning goals, and described the affordances of the sample technology more specifically. However, there were no significant effects of the representation of socio-cognitive functions in participants' mental models, $p \geq .27$. For regression statistics see Table 4.4.

4.3.2.2 TPCK evaluation task: Rating a lesson plan vignette

Regression analyses predicting participants' ratings of the presented lesson plan vignette showed no significant effects for participants' ratings of the likelihood for implementing the example lesson plan in their own future classroom, $p \geq .10$. With regard to participants' ratings of the potential of the example lesson plan to support cognitive learning goals, both PK and the representation of cognitive functions of WebDIVER in their mental models showed significant effects. Higher PK was associated with higher ratings the potential support of cognitive goals, $\beta = .57$, $t(20) = 3.07$, $p = .01$, whereas the representation of cognitive functions in participants' mental models was associated with lower ratings, $\beta = -.44$, $t(20) = -2.25$, $p = .04$. For the rating of socio-cognitive potentials of the example lesson plan, results showed also a significant negative effect for the representation of cognitive functions in participants' mental models, $\beta = -.63$, $t(20) = -3.11$, $p = .01$. Overall, participants with higher prior PK also rated the example lesson plan to exhibit a higher potential to support cognitive learning goals in students. However, controlling for this positive association with prior PK, the representation of cognitive functions of WebDIVER was associated with participants' considering the example lesson plan less likely to support both cognitive and socio-cognitive learning goals. For regression statistics see Table 4.5.

Table 4.4

Summary of hierarchical regression analysis for variables predicting indicators of participants' proposed ideal uses of WebDIVER (N *= 24).*

	Elaborateness (# of words)				Overall quality (# of emerging categories)				Cognitive goals				Socio-cognitive goals				Affordance specificity			
Step and predictor	*B*	*SE B*	β	ΔR^2	*B*	*SE B*	β	ΔR^2	*B*	*SE B*	β	ΔR^2	*B*	*SE B*	β	ΔR^2	*B*	*SE B*	β	ΔR^2
Step 1				.13				.08				.03				.01				.03
PK	0.25	.32	.14		0.03	0.04	.15		0.01	0.02	.06		0.02	0.02	.18		0.02	0.03	.17	
TK	0.33	1.84	.03		0.00	0.23	.00		-0.03	0.12	-.06		-0.10	0.13	-.19		-0.11	0.17	-.14	
Step 2				**.38****				.24				**.32***				.16				.25
Mm cog[a]	9.82	2.71	**.63****		0.82	0.33	**.51***		0.54	0.18	**.62****		0.29	0.20	.34		0.59	0.26	**.49***	
Mm scog[a]	2.80	2.48	.19		0.20	0.30	.14		-0.04	0.16	-.05		0.20	0.18	.25		0.22	0.24	.19	

Note: PK = pedagogical knowledge, TK = technological knowledge, mm = mental model.

[a]Binary coding, -1 = not represented in mental model, 1 = represented in mental model. **p* < .05. ***p* < .01.

Table 4.5

Summary of hierarchical regression analysis for variables predicting the TPCK evaluation task (n *= 21).*

	Implementation likelihood				Cognitive goals				Socio-cognitive goals			
Step and predictor	*B*	*SE B*	β	ΔR^2	*B*	*SE B*	β	ΔR^2	*B*	*SE B*	β	ΔR^2
Step 1				.02				**.35***				.03
PK	0.02	0.04	.15		0.06	0.02	**.57***		0.04	0.03	.28	
TK	0.08	0.19	.11		0.19	0.10	.36		0.08	0.14	.12	
Step 2				.18				.16				**.44****
Mm cognitive[a]	-0.28	0.29	-.24		-0.36	0.16	**-.44***		-0.69	0.22	**-.63****	
Mm socio-cognitive[a]	-0.43	0.25	-.41		0.03	0.14	.04		0.30	0.19	.30	

Note: PK = pedagogical knowledge, TK = technological knowledge, mm = mental model.

[a]Binary coding, -1 = not represented in mental model, 1 = represented in mental model. **p* < .05. ***p* < .01.

4.3.2.3 TPCK design task: Lesson plan for sample newsreel and WebDIVER

For the indicators characterizing participants' own lesson plans for implementing the WebDIVER with the sample video material in the classroom only two significant effects were found (see Table 4.6). Prior PK showed a significant positive effect on the elaborateness of participants' lesson plans, $\beta = .66$, $t(23) = 2.74$, $p = .02$, with higher pedagogical knowledge being associated with more elaborate lesson plan descriptions. The second effect was revealed for the specificity of the affordance descriptions in the lesson plans. Here the representation of socio-cognitive functions of WebDIVER in participants' mental models was a significant positive predictor, $\beta = .46$, $t(23) = 2.12$, $p = .047$. Overall, while prior PK proved to be associated with more elaborate lesson plan descriptions in general, only representing socio-cognitive functions of WebDIVER was associated with more specific descriptions of affordances, that is, of how the technology was assumed to affect students learning in the lesson plans. There were no other significant effects, for knowledge, $p \geq .08$, or mental models, $p \geq .10$, respectively.

Table 4.6

Summary of hierarchical regression analysis for variables predicting indicators of participants' lesson plans (TPCK design task, N *= 24).*

	Elaborateness (# of words)				Overall quality (# of emerging categories)				Cognitive goals				Socio-cognitive goals				Affordance specificity			
Step and predictor	*B*	*SE B*	β	ΔR^2	*B*	*SE B*	β	ΔR^2	*B*	*SE B*	β	ΔR^2	*B*	*SE B*	β	ΔR^2	*B*	*SE B*	β	ΔR^2
Step 1				**.36***				.19				.23				.06				.02
PK	2.12	0.88	**.46***		0.07	0.05	.32		0.06	0.05	.26		0.03	0.02	.25		0.02	0.02	.25	
TK	4.92	5.10	.20		0.31	0.28	.27		0.37	0.28	.32		-0.07	0.13	-.13		-0.11	0.11	-.24	
Step 2				.06				.06				.01				.15				.19
Mm cog[a]	7.41	7.53	.19		-0.44	0.41	-.23		-0.04	0.41	-.02		0.33	0.19	.39		-0.05	0.17	-.07	
Mm scog[a]	6.29	6.89	.17		0.24	0.38	.13		0.19	0.37	.11		-0.14	0.18	-.17		0.33	0.15	**.46***	

Note: PK = pedagogical knowledge, TK = technological knowledge, mm = mental model.

[a]Binary coding, -1 = not represented in mental model, 1 = represented in mental model.

**p* < .05., ***p* < .01.

4.4 Discussion Study 2

The aim of this study was to investigate how pre-service teachers' understanding of the affordances of a newly encountered video technology impacts their lesson planning with this technology. This study was conducted using a sample video technology designed for collaborative learning scenarios (WebDIVER^{TM}) with a sample of history and language arts pre-service teachers. Qualitative results show that only a relatively small number of participants represented the specific cognitive and/or socio-cognitive functions of the tool in their mental models of this technology. In contrast to this, participants tended to understand WebDIVER as an editing tool for their own use instead of understanding it as a learning tool for their students. Furthermore, in their proposed ideal uses of WebDIVER in class and the lesson plans, which they had designed for historic sample video material, specific tool functions were only partly reflected and participants relied upon tool-unspecific uses of film and video. Quantitative analyses showed that participants' prior PK was a positive predictor for their evaluation of the potential of the example lesson plan to support cognitive learning goals, and the general elaborateness of their own lesson plans. In contrast, investigating participants' mental models as predictors revealed more differentiated results. When cognitive functions were represented in their mental models of WebDIVER, participants were more elaborate in their descriptions of an ideal use of WebDIVER in class, these descriptions were of better quality, they contained more cognitive learning goals, and descriptions of the technological affordances were more specific. At the same time, however, the representation of cognitive functions was associated with lower ratings of the example lesson plan's potential to support both cognitive and socio-cognitive learning goals. With regard to socio-cognitive functions of WebDIVER, participants who represented these functions in their mental models exhibited more specific descriptions of how they would leverage the technological affordances in their own lesson plans. In contrast to the results of Study 1, prior PK (or TK) did not predict participants' mental models of the functions of the sample technology. Thus, no mediating relationship was found. Overall, the statistical effects were of moderate size.

4.4.1 Mental models of video tool functions and lesson planning

While the results of this study revealed that participating pre-service teachers' prior PK did predict some aspects of their lesson planning with technology, participants' mental models of learning-relevant functions of the sample technology revealed themselves as better predictors for specific aspects of lesson planning. In line with this interpretation, for participants own lesson plans prior PK only predicted a very general indicator, the elaborateness of participants' descriptions, whereas their representations of socio-cognitive functions predicted the specificity of their descriptions of technological functions in relation to learning. Beyond this finding, however, it was participants representing cognitive functions of the sample technology being the strongest predictor. Given the fact that participants were only presented with technological information about the sample video technology, it is interesting that some participants focused more on its functions relevant for cognitive learning goals (focusing, attention direction, reordering), others focused more on those relevant for socio-cognitive learning goals (commenting, sharing, facilitating deixis), and a large part of the participating pre-service teachers described their understanding of WebDIVER only very generally. This shows that participants' understanding of WebDIVER was sometimes in line with, in contrast to, or neutral to the affordances conceptually provided by this video tool. This was reflected in the different directions participants' mental models were found to predict different aspects of lesson planning. Participants' representations of cognitive functions were a significant positive predictor for several indicators (elaborateness, overall quality, cognitive learning goals, and affordance specificity). At the same time, however, these representations were associated with the evaluation that the collaborative design task presented in the example lesson plan was less likely to support both cognitive and socio-cognitive learning goals. Taken together, this provides some initial support that also for newly encountered technology pre-service teachers' lesson planning is in part influenced by how they mentally represent the technology's function in relation to learning goals.

Parallel to the result of Study 1, these findings were more pronounced for participants' proposed ideal uses of WebDIVER in the classroom. This aspect was considered to be a measure assessing the potential that they saw in this technology without limiting themselves because of external constraints. In the light of this background, it is interesting that the ideal uses proposed by participants in this study emphasized more the cognitive learning goals; that is, the potential for socio-cognitive learning represented equally in their mental models was not carried over to the ideal aspect of lesson planning. In contrast, the existence of cognitive aspects in participants' mental models predicted cognitive aspects in their proposed ideal uses of WebDIVER in a lesson. Even though no functions for exporting or downloading edited versions of the source video were introduced, proposed ideal uses for the sample video technology nevertheless mentioned such applications repetitively. Moreover, participants' descriptions of who would benefit from the cognitive functions of the technology, the teacher or the students, were inconsistent. Mainly when talking about preparing classroom material, participants described how the technology would serve their own cognitive goals rather than what these would mean for the cognitive processes of students. This inconsistency with regard to the audience of the technology could explain why the rater-agreement for coding participants' proposed ideal uses of WebDIVER was somewhat lower.

These findings can also be explained in the light of classical findings from cognitive psychology, showing that people reported to having seen elements in an office space that were not there based on the schema they possessed of an office of the respective profession (Brewer & Treyens, 1981). Applied to this study, it is possible that participants represented technological functions that they would expect based on earlier software use, for example, their schema of video software in general or in the classroom. Such a fallacy would be in line with findings that show shared patterns (for the concept of shared mental models in small group research see e.g. Mohammed, Klimoski, & Rentsch, 2000) for video use in the classroom (Hobbs, 2006), which exhibit restricted pedagogical approaches with regard to actual learning from and with video. This would be furthermore in line with findings that suggest that teachers act within a limited number of patterns for using digital technologies in general (Schmotz, 2009). Additionally, there is initial evidence that in Germany, especially in history and the language arts, specific and limited ways of using video in the classroom in part originates from subject specific teacher training (Baskiewicz, 2011). However, further research would need to explicitly tap into the influence of shared mental models to substantiate this hypothesis.

In addition to an open *design task* for creating an ideal use and a lesson plan for sample material, in the present study, participants' performance in TPCK tasks was also assessed by the *evaluation* of an example lesson plan (cf. Kramarski & Michalsky, 2010). Results from these different measures revealed inconsistent findings. When evaluating the example lesson plan, which explicitly suggested socio-cognitive learning goals, analyses revealed that understanding the tool as mainly a cognitive one impeded the appreciation of the example lesson plan's *socio-cognitive* potential. What was surprising, the same effect was also found for participants' ratings of the example lesson plan's *cognitive* potential. This suggests that participants' understanding of the cognitive functions of WebDIVER did not match their understanding of the cognitive potential of the example lesson plan. This is especially interesting, because, prior PK was positively associated to this indicator, thus providing more evidence for the notion of mental models of learning-relevant technology functions being a distinct construct. This further suggests that when the functions of a technology for learning are mentally represented in a certain way, for example as a tool for the teacher to be used, these functions cannot easily be mapped onto the student-centered setting of the example lesson plan presented to participants in this study. In line with this, one participant's final remarks illustrate how such a mental model might form a barrier to certain ways of using it for teaching: "Only after reading the lesson plan vignette did I understand that WebDIVER is not only meant for teachers to use as a means of preparation but that it can be a tool for students during collaboration or for presentations. [...]"

There are several possible processes that could lead to such difficulties for (pre-service) teachers to map their understanding of the sample video technology onto the evaluation task. Participants could have indeed misrepresented the technology functions with regard to their potential for teaching-learning processes based on pervasive patterns of instructional use for the respective technology as suggested above. Alternatively, participants could have tended to evaluate the example plan lessons based on more general terms while not being very sensitive to the concrete technology at hand. Finally, it is also possible that the presented vignette described a collaborative learning setting participants were rather unfamiliar with, given the complex nature of the design task presented in the example lesson plan (cf. Zahn, et al., 2012). This would also be in line with the finding that there were no effects of participants' representation of socio-cognitive functions on the evaluation and ideal use task. Given the nature of the example lesson plan, this should be surprising. However, assuming that this task is very different from what they have encountered as collaborative learning settings, they might not be able to validly judge the presented vignette. Overall, due to the complexity of the matter it seems most likely that an interplay of these processes could offer a possible explanation for the results of this study. At the same time, these possible explanations support the claim for experimental research trying to investigate possible moderating effects.

4.4.2 Mental models and Technological Pedagogical Content Knowledge (TPCK)

For the integrated sub-domain Technological Pedagogical Knowledge (TPK), the results of this study add evidence to the approach to conceptualize the integrated components of teachers' knowledge proposed by the TPCK framework as mental models. In this study, the TPK component operationalized as mental models of learning-relevant functions showed a distinct influence above and beyond prior PK on participants' lesson planning. In this study, there were even no correlations between prior PK and mental models as TPK indicators. This suggests that indeed TPK is something different than a mere combination of prior TK and PK. Moreover, results provide initial evidence that understanding the affordances of a technology is a factor differentially influencing the evaluation and creation of learning scenarios with value added by technology. Taken together with the somewhat different evidence from Study 1, I would therefore argue that in order to understand the overall concept of TPCK, the proposed sub-domains need to be further specified and empirically scrutinized. One important aspect to focus on would be to investigate what leads to the construction of mental models of the specific learning-relevant functions of a given technology. In contrast to the findings of Study 1, which used familiar video technology (YouTube), in this study neither prior pedagogical knowledge nor factual knowledge about the tool could explain the construction of specific mental models - nor could the other variables assessed here either (pedagogical beliefs or teaching experience). Therefore, it further remains an open empirical question what else contributes to the construction of mental models of a video tool's (socio-) cognitive functions, that is, how TPK is constructed and which role prior PK might still play under certain circumstances.

From a methodological point of view, it is interesting that there were differences in predicting participants' performance in different tasks tapping into all sub-domains of TPCK: lesson plan *evaluation* and *design* (Kramarski & Michalsky, 2010). Theoretically the closed item format of the evaluation task should be easier because it resembles a recognition task. Additionally, creating a lesson plan involves more undefined variables to consider and most likely considerations about its implementation afterwards. In this study, which was interested in investigating participating pre-service teachers' understanding of a technology, explicitly designed for collaborative learning, results of the evaluation task did not show any connection to participants' representation of

WebDIVER as a socio-cognitive tool. As mentioned above, this might be connected to the current example lesson plan vignette being unfamiliar and therefore not as easy as expected. Thus, in the future it could be a promising approach to design different vignettes with pre-tested levels of difficulty and covering different content areas. This might also be a step into the direction of creating a measure closer to a TPCK test in contrast to the performance in open ended tasks.

4.4.3 Self-reported barriers to the optimal use of digital video in class

In line with earlier findings, participants named the lack of sufficient technological equipment on the classroom or school level as the main obstacle. This is a commonly reported barrier by (pre-service) teachers and while of course an evident problem, there is consensus in the literature that it is only one contributing factor (Ertmer, 2005; Law, 2008; Webb & Cox, 2004). And also the results of this study provide evidence that when technology is given, there are relevant differences in how it would be used. Participants named time costs second most often as a barrier to implementing their respective ideal idea for using WebDIVER in class. Taken together with participants' emphasis of WebDIVER as a tool to prepare classroom material rather than as a tool in students' hands, this finding is quite interesting. Although time costs need to be attributed partly to initial familiarization with software, understanding a technology as something to be used by me as a teacher rather than by the students creates very different views on time costs. According to the idea of using technology in such a way for teaching so that content can be accessed in a different manner and more easily and, therefore, more time should be freed up for the teacher to pedagogically guide learners through conceptual learning tasks (cf. Angeli & Valanides, 2009), emphasizing time costs as a problem could add to the plausibility of interpreting the results of this study pointing to the participating pre-service teachers' misunderstanding of the tool's functions. However, and also in line with earlier findings (Krauskopf, Zahn, & Hesse, 2012), participants in this study did not explicitly describe lack of knowledge or training as a significant barrier for using innovative video technology even though the data indicate a significant contribution of these factors.

4.4.4 Limitations

Besides the already mentioned points, there are limitations of this study that need to be discussed. Although research has shown that studies conducted online can be comparable in most ways to studies in the laboratory (e.g., Yetter & Capaccioli, 2010), the results have to be interpreted cautiously. In online studies, there is a higher probability of a selective sample over-representing technophile participants. This cannot be ruled out for this study, however, there were a number of participants who uttered concerns about using the video tool in instruction or even using technology in instruction at all, thus pointing at least to a mixed sample. Due to the small size of the sample and that it was an anonymous online sample, it is important to be careful with generalizing the results of this study to the general population of (German) pre-service teachers. Additionally, this was not a random sample. Members completing an online study that involves several steps might be overly motivated in general. Also, with a group of non-respondents of unknown size, in the present study, too, there is no information about which factors might have contributed to participants' decision to fill in the questionnaire. Even though the sample of this study was quite small, results showed a consistent pattern over (methodologically) different dependent variables and findings of qualitative and quantitative analyses convergence. Methodologically, this study was limited by its small sample size and collinearity issues that prevented the investigation of moderating effects of participants' mental models. In line with this, the current PK measure was also very short version that could be criticized given the complex attempts to assess this construct by other research groups (Tatto et al., 2008; Voss et al., 2011).

In sum, before formulating practical implications, these findings need replication and the relation to pre-service teachers' actual classroom practice needs to be investigated. Furthermore, studies are needed following a longitudinal approach including in depth qualitative data that could try to identify when and how pre-service teachers acquire shared patterns or extrapolate from private experience.

4.5 Conclusion of Study 2

In conclusion, this study provided initial evidence that when encountering a new technology, in this case a video tool for collaborative learning, pre-service teachers' spontaneous understanding of this tool's functions (mental model) in relation to teaching and learning influence different aspects of their respective lesson planning. Taken together with earlier findings on the role of mental models and lesson planning for a familiar video tool (YouTube), the approach to conceptualize the knowledge of teachers relevant for teaching with technology can be considered a fruitful elaboration of the proposed TPCK framework (Angeli & Valanides, 2009; Mishra & Koehler, 2006; Niess, 2005).

On a theoretical level, interpreting the results of this study against the background of different views on the TPCK framework (Angeli & Valanides, 2009) suggests that investigating the different sub-components of the TPCK concept is an important step in order to learn more about their interplay and the process of their cognitive development. When dealing with a familiar video technology, as could be shown in Study 1 pre-service teachers' mental models indirectly related abstract pedagogical knowledge to their lesson planning. In this study, for the case of encountering a new video technology it could be shown, the spontaneously constructed mental models of its functions predicted aspects of proposed ideal and intended uses as well as moderated how prior pedagogical knowledge was related to these aspects of lesson planning. Both these studies show that interpreting mental models of learning-relevant tool functions (affordances) as a distinct aspect can be empirically supported. Furthermore, using this notion to specify the TPK component to provide a more precise conceptualization of how teachers' knowledge most likely needs to be represented in order to be relevant on a practical level.

Often the hope is expressed that younger teacher generations will bring more frequent and more effective technology use to learning in the classroom. The current findings, however, suggest that pre-service teachers' understanding of digital technology is not automatically sensitive to its impact on learning and teaching. It even seems likely their respective mental models are shaped early on by unaccounted, private or professional experiences with technology and handed down practices of technology use (here digital video) in the classroom. This leads to the question of how it is possible to shape the specific understanding of technology in (pre-service) teachers and thus enable them to incorporate technology into lessons, sensitive to the strengths and weaknesses of a technology. To answer this question, mental models seem to be a compatible elaboration of the TPCK framework, which can provide a basis for hypotheses about how teacher training programs need to be created from a cognitive perspective. In order to further elaborate this approach, however, it will be necessary to provide experimental paradigms. These would enable us to investigate how to support (pre-service) teachers' cognitive integration of pedagogical and technological understanding of a given digital technology, which seems to be a relevant factor for transforming technological potential into specific learning environments. The study presented in the following chapter tackles this issue by suggesting an experimental paradigm that aims at testing the *integrative* and *transformative* view on TPCK proposed by Angeli and Valanides (2009) against each other.

5. Study 3: Supporting the Construction of Mental Models of Video Tools. An Experimental Approach to the Cognitive Integration of Technological and Pedagogical Knowledge.

The results of Study 2 suggest that whether pre-service teachers represent a technology as having cognitive, or socio-cognitive functions does make a difference for their respective lesson planning. Moreover, it could be shown that, to a smaller extent, this is also the case for whether they have higher or lower general pedagogical knowledge (PK). However, these two aspects (PK and mental models) are not spontaneously cognitively integrated, that is, when encountering a new (digital video) technology, pre-service teachers do not spontaneously tap into their prior pedagogical knowledge in order to construct mental models of the technology's functions. Instead, they tend to adhere to pervasive instructional patterns and unspecific uses of the technology that only create limited added-value for student learning by using this technology. These findings are in line with Angeli and Valanides' (2009) criticism of a (spontaneous) *integrative view* on TPCK. Translated to the notion of mental models introduced in this dissertation, this suggests that indeed (pre-service) teachers need specific support to construct more complex mental models of a technology and its instructional impact (cf. *transformative view*). Angeli and Valanides have formulated these two views as a dichotomy: The *transformative view* defines TPCK as a distinct body of knowledge by claiming that prior knowledge in the basic sub-domains (TK, PK, CK) does not suffice to build TPCK, but the construction of this knowledge needs to be explicitly supported. Vice versa the *integrative view* is described mostly as a negation of this: TPCK is defined as an additive compound developing spontaneously out of knowledge in the basic sub-domains. Hence, the theoretical foundation of the proposed dichotomy remains on a somewhat superficial level. More concretely, how the cognitive processes leading to TPCK as a distinct body of knowledge have not yet been described more specifically. Moreover, until now no experimental studies have actually tested the two views on TPCK against each other. Thus it remains also an open empirical question, whether these contrasting views hold against experimental standards.

The described dichotomization and the lack of conceptualizing the underlying cognitive processes have also lead to neglecting the question which role differences in prior knowledge in the basic sub-domains (TK, PK, and CK) might play for constructing

TPCK as a unique body of knowledge. This means the question whether prior PK enable teachers differently for solving TPCK tasks that demand the orchestrated consideration of technology, pedagogy, and content (cf. also the conception of TPCK as meta-conceptual awareness in Section 2.3.2) has not been addressed empirically. Considering the elaboration of the TPCK framework with regard to a process-oriented perspective and results or Studies 1 and 2, it is therefore important to also investigate what role prior PK plays in the efforts to support a complex understanding of technology for teaching.

As a result, the third study presented in this dissertation contrasts the *integrative* and the *transformative* view on TPCK by suggesting an experimental paradigm, and tackling the question of prior PK as a potential moderating variable.

5.1 Research Questions of Study 3

Complementary to Study 1 and 2, the present study first addresses the question of how the cognitive integration of technological (TK) and pedagogical knowledge (PK) can be guided in order to support (pre-service) teachers in the construction of more complex mental models of learning-relevant tool functions (TPK; cf. arrow c in Figure 2.2). Second, it is investigated how different ways of guiding teachers' cognitive integration of TK and PK influence their respective lesson planning, and whether mental model characteristics mediate potential effects. Third, prior PK is investigated as a moderating variable for the potential effects of the experimental manipulations.

To answer these questions, an experimental paradigm was designed that aimed at operationalizing the contrast between the *integrative* versus the *transformative view* on a concrete level, namely, applying pedagogical considerations to a specific tool. Angeli and Valanides (2009) suggest a general approach (technology mapping, TM) to support teachers' instructional design with technology. However, TM is specified on a rather coarse grained level and emphasizes teachers' individual contexts. Therefore, following this dissertation's perspective of teachers' mental models of learning-relevant tool functions, it is necessary to specify interventions closer to the level of the teacher's cognition. Thus, transferring the *transformative view* to this level, it should be assumed that teachers will not map their pedagogical reasoning on a technology they encounter spontaneously. Instead, it would be necessary to model the cognitive integration of pedagogical information about instructional approaches applicable to a technology while encountering this technology. Neither would it be sufficient to model exemplary uses of technology in class (cf. Angeli & Valanides, 2005). Instead, it would be necessary to model how to map technological functions onto relevant learning goals (and topics). Thus, teachers would be guided how to construct complex (initial) mental models that should, in turn, guide their lesson planning. Moreover, teachers should then also transfer this to how they will approach different technologies in the long run.

In sum, these assumptions can be broken down into concrete hypotheses for the present study: Following the *integrative view* (a) it is expected that (compared to a control group with only technological information) it should suffice to provide technological and pedagogical information separately to support pre-service teachers in the construction of complex mental models of the technology. Accordingly, also their lesson planning for using this technology should improve. In contrast, following the *transformative view* (b) it is expected that only providing an introduction to a technology that models how to cognitively integrate technological and pedagogical information will improve pre-service teachers' construction of mental models and respective lesson planning. For visualizations of the two competing hypotheses see Figure 5.1. Moreover, to gain a more specific understanding about the interrelations between the sub-domains proposed by the TPCK framework, the role of prior PK as a moderator is also investigated in this study, bearing in mind that Studies 1 and 2 both showed specific variance attributable to prior PK. Finally, a transfer task introducing another web-based video technology (VideoANT) is included in this study to test, whether modeling the cognitive integration of TK and PK for one technology would have a long-term effect generalizing (at least) to a similar technology.

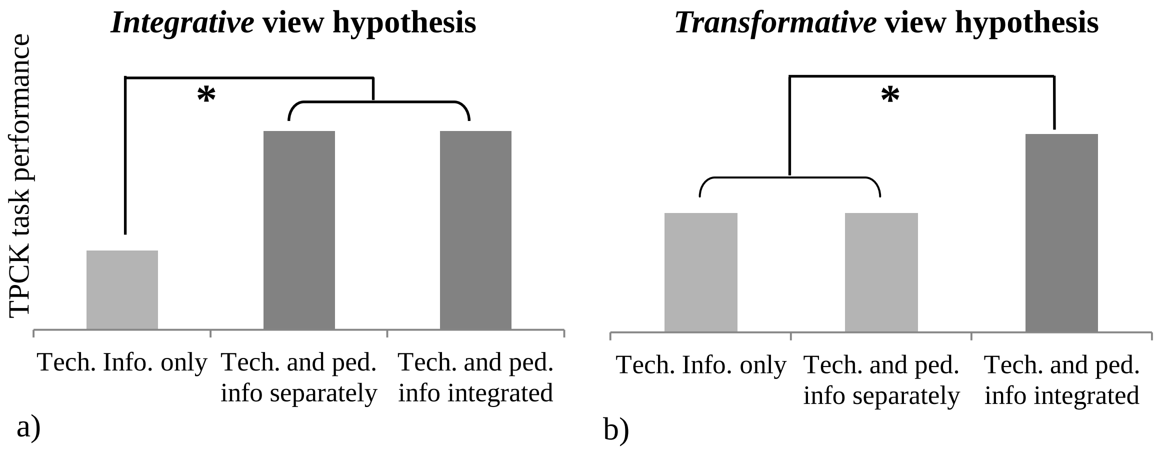

Figure 5.1. Visualization of contrasting hypotheses: a) providing technological and pedagogical information separately or modeling their cognitive integration will similarly improve pre-service teachers' performance in TPCK tasks compared to a control group with only technological information; b) only modeling the cognitive integration of technological and pedagogical information will improve pre-service teachers' TPCK task performance.

5.2. Method

5.2.1 Sample

Pre-service teachers of all subjects that had completed their 4th semester were recruited via the mailing list of the University of Tübingen. The final sample consisted of *N* = 74 pre-service teachers (age *M* = 24.6 years, *SD* = 2.7, semesters *M* = 8.9, *SD* = 2.4, high school graduation grade average, 1 = *best*, 6 = *worst*, *M* = 2.2, *SD* = 0.5, 60 female and 14 male). All were enrolled in the teacher training programs of the University of Tübingen to become secondary educators (Gymnasium level). 96% had already completed internships as assistant teachers with an average length of *M* = 14.0 weeks, *SD* = 6.3, where they themselves had taught M = 34.6 hours per week (SD = 2.7). Concerning the subjects (in Germany usually 2 subjects per teacher), 53% of participants studied German language arts, 34% sciences, 18% history, 11% mathematics, and 59% other subjects, respectively. As compensation, participants who completed all three measurement points received a compensation of 25€ and general information on the study's results.

5.2.2 Procedure and study design

Throughout the study, an anonymous code created by participants was used to match the data from all three measurement points and to enable participants to revoke their consent if necessary. For detailed descriptions of measures see Section 5.2.4 below.

Pre-measurement. Prior to being introduced to the sample technology WebDIVER in the lab, participants completed an online questionnaire. They provided demographic information (age, gender, high school graduation grade average), information about their teacher training (semester, pedagogical beliefs, teaching internship), and technology experience (computer use frequency, YouTube rating). Additionally, they completed a test assessing their prior pedagogical knowledge (PK), and another assessing their prior knowledge (CK) in the content area of the example lesson plan (Berlin Blockade and Air Lift). They also provided possible dates to come to the laboratory and provided their e-mail address, which was saved in a separate database.

Manipulation and post-measurement. About two weeks later (M = 15.6 days, SD = 5.3) participants came to the laboratory, where they were randomly assigned to one of three conditions. In the control condition (TK only), participants received a written introduction into only the technological functions of WebDIVER. In the first experimental condition (TK+PK), participants were presented a short text about the potential of web-based video tools as cognitive tools for learning before they were presented with the same introduction to WebDIVER as in the control condition. In the second experimental condition, all aspects that were mentioned in the text about the potential of web-based video tools were matched with the individual functions of WebDIVER. Participants were thus presented with an introduction to WebDIVER that contained information about the technological functions in relation to their possible impact on learning processes (for more details see Section 5.2.3.1 and Table 5.1). Immediately after reading the written information, participants were asked to recall the functions of WebDIVER that they remembered (theoretical maximum was limited to 10 items by number of text fields). Subsequently, they were provided with a personal username and password for WebDIVER and explored the software for ten minutes (system paced time limit). Subsequently, participants rated the amount of effort they had put into the exploration and how interesting the technology seemed to them at this point.

Then, participants completed two tasks tapping into their mental models of WebDIVER. Parallel to Studies 1 and 2, participants were asked to describe, which functions of WebDIVER they considered the most important for instruction. In addition, in the present study participants were given five minutes (system paced) to draw a concept map with the title “WebDIVER and instruction”.

Subsequently, participants worked on three lesson planning tasks that involved all aspects of the TPCK framework (TPCK tasks). First, participants were asked to design a lesson plan for using WebDIVER for a content of their choice stemming from one of their subjects. Second, they were presented with the example lesson plan vignette also applied in Study 2 and were asked to evaluate its potential to support cognitive and socio-cognitive learning goals, as well as the likelihood of implementing this lesson plan in their own future classroom. Finally, in a comprehension task participants were asked to reason about how they thought specific changes to the technology and pedagogy of the example lesson plan, respectively, would impact student learning. This order of tasks was again chosen so that participants would not be influenced by the example lesson plan when designing their own lesson plans. Further descriptions and results, however, will be presented in the order evaluation, comprehension, and design task following the increasing efforts needed to complete the tasks. After completing this measurement at the laboratory, they were thanked and reminded of the follow-up measurement, which they would be invited via e-mail to online.

Follow-up-measurement. After about 10 days (*M* = 11.9 days, *SD* = 5.0) participants completed another online measure. Participants watched a 3-minute video tutorial introducing only the technological functions of another web-based video tool (VideoANT) and were asked to recall its functions (theoretical maximum was limited to eight items by number of text fields). Subsequently, they were asked to describe how VideANT differed from WebDIVER with regard to the potential of the technological functions for instruction. After completing all measures, participants received a final e-mail informing them about how to pick up their compensation.

5.2.3 Experimental conditions

For all conditions, the written introduction to WebDIVER consisted of eight HTML pages and covered the same technological functions as the video tutorial used in Study 2 including screenshots (see Figures C.1.1 through C.18 in the Appendix): (1) P*lay* and pause a video, selecting (2) *still images* and (3) *sequences* (= creating *DIVE panels*), (4) *zooming* in on details before cutting out, annotating cut outs with (5) *titles*, (6) *commenting* on own and other users' cut outs, (7) *copying & pasting* selections already made, (8) *reordering* cut outs via drag & drop, (9) *sharing* a link to one's annotated selections via e-mail to other users, and (10) *embedding* these selections on other websites. After a short overview the layout of WebDIVER's graphical user interface (see Figure 4.1) and its general features, each of the technological function was introduced in more detail. The three conditions differed with regard to whether and how pedagogical information was given together with the technological information about WebDIVER.

In the control condition (TK only), participants read the text segments introducing only the technological functions of WebDIVER (1348 words). This was parallel to the video tutorial in Study 2 and was considered a baseline condition that only supported the construction of technological knowledge about WebDIVER explicitly. In Experimental Condition 1 (TK+PK), participants additionally read two text segments before being introduced to the technological functions (1726 words). These text segments contained information about the general potential of web-based video tools to support users' cognitive and socio-cognitive processes (PK and TPK), however separate from the concrete functions of WebDIVER and their potential impact on learning. This condition was based on the *integrative view* (cf. Angeli & Valanides, 2009) that assumes fostering teachers' technological and pedagogical knowledge separately is sufficient, because teachers will spontaneously integrate their knowledge when planning to use a technology for instruction. Finally, in Experimental Condition 2 (TPK) participants read an adapted version of the text segments introducing WebDIVER in which the description of technological functions were mapped onto cognitive and socio-cognitive functions (1482 words). The mapping of technology and (socio-) cognitive functions was based on the conceptual background of the tool and prior research. Because WebDIVER was especially designed for collaborative learning scenarios it supports the creation of new points of view and guiding others attention to these (facilitating deixis and initiating negotiation), focusing attention to notice details for establishing common ground (facilitating deixis), and saving isolated and annotated details in separate collections (group memory). However, the impact on detail perception, the creation of a personal view on a source video, and saving artifacts stemming from prior work with a video can also be equally considered relevant for an individual's cognitive processes (cf., Zahn, et al., 2012). This condition was based on the transformative view on TPCK (Angeli & Valanides, 2009) that assumes that the development of the independent sub-domains is not sufficient for teachers to develop the unique basis of knowledge about technology relevant for teaching as TPCK is defined in this line of research. Thus, when the integration of knowledge is not specifically fostered, teachers will fail to design learning scenarios with an added-value of technology. Angeli and Valanides (2009) suggest an approach called technology mapping, which they describe as an interaction technique supporting participative instructional design emphasizing the individual teacher's context. However, the focus of the current study is on pre-service teachers' cognitive integration of technological and pedagogical knowledge and the construction of complex mental models of learning-relevant technology functions. Therefore, the instruction to WebDIVER in this condition modeled how to sensibly map a specific technological function and their potential impact on individual learners or collaborating learners. On the text level this was operationalized by modal conjunctions and modal clauses (e.g., in order to, thus, in that way, then, because of) connecting technological descriptions and pedagogical functions. For an example of how the material in the three conditions looked like, see the respective descriptions of the zooming function in Table 5.1. Overall, this experimental paradigm poses a more conservative test to the transformative view, because in Experimental Condition 1 (TK+PK) not only abstract pedagogical information was provided, but general to web-based video tools were included.

Table 5.1

Examples of information material provided in the three conditions.

Control Condition (TK only)	Experimental Condition 1 (TK+PK)	Experimental Condition 2 (TPK)
	[…] This is because [these tools] only possess a small number of specific functions that afford specific ways of approaching the content of a video. **For example, they support analysis**, comparison, or interpretation of videos. […] On the other hand, different technological functions influence [the user's] attention [allocation] differently: **Zooming in on details can also focus a person's perception and attention.** […]	
The yellow frame inside the video (see figure below) can be used for zooming. *With its help it is possible to select and record smaller areas within a video.* When taking screenshots of still images or recording sequences, only the area within the frame will be recorded. Size and position of the frame can be manipulated and it can be moved through the video like the lens of a virtual camera. […]	The yellow frame inside the video (see figure below) can be used for zooming. *With its help it is possible to select and record smaller areas within a video.* When taking screenshots of still images or recording sequences, only the area within the frame will be recorded. Size and position of the frame can be manipulated and it can be moved through the video like the lens of a virtual camera. […]	The yellow frame inside the video (see figure below) can be used to **select relevant areas in order to focus on details and emphasize them.** When taking screenshots of still images or recording sequences, only the area within the frame will be recorded. Size and position of the frame can be manipulated and it can be moved through the video like the lens of a virtual camera. **Thus, moving objects can be observed in greater detail, for example, processes of change and other developments can become subject to the analysis and interpretation of the video as well.** […]
		

Note. Sequences describing pedagogical impact of technology in bold. Descriptions of technology functions using modal conjunctions and clauses in a content neutral way set in italics. Bold type and italics were not included in stimulus material.

In order to keep the length of the text-based manipulation as similar as possible across conditions, the text in the control condition (TK only) contained additional neutral information, such as “click with the left button of the mouse” instead of “click” that can be considered not to have a specific affect in a sample of university students familiar with technology. Furthermore, in order to balance out the comprehensibility of the texts, similar modal conjunctions and clauses were used to connect neutral information or irrelevant technological information in more detail, such as “This then leads then to the panel turning turquoise”, instead of “The panel turns turquoise”.

To also empirically investigate possible differences in text comprehensibility between the conditions, the respective Flesh Reading Ease scores were computed. The eight segments describing technology functions (TK only and TK+PK condition) exhibited an overall score of 57, which is considered an indicator of average comprehensibility. The same was true for the text matching technological and pedagogical descriptions (TPK condition) with a score of 43. The text segment describing the pedagogical potential of web-based video technology separately (TK+PK condition), however, was more difficult with a score of 24. This indicates a text best understood by university students. Several revisions to make it easier to understand were not successful. Therefore, to make sure the text segment was sufficiently understandable in the context of the instructional material and for university participants similar to the designated population, the different texts were pre-tested in a pilot study with a sample of 45 students of the University of Tübingen (M = 24.0 years, SD = 3.24, 48% female, variety of subjects excluding student teachers). They were randomly given one version of the instructions to read (15 students each) and asked to rate them for several criteria. On a 6-point Likert-Scale (1 = *completely disagree*, 6 = *completely agree*) they rated the overall comprehensibility, how interested they were in WebDIVER after reading the instruction, and whether they felt prepared to explore the actual software. ANOVAs with the between subjects factor Condition (TK only, TK+PK, and TPK) revealed no significant differences between the three text versions with regard to these measures, Fs < 1.15, $p \geq .32$. Additionally, paired-samples t-tests were run comparing the comprehension rating for the text segments describing technological functions with the ratings of the text describing the pedagogical potential of web-based video tools within the TK+PK condition. The results revealed that the text on the pedagogical potential was significantly more difficult to comprehend (M = 4.27, SD = 0.96) than the average of the technology descriptions (*M* = 5.02, *SD* = 0.65), *t*(14) = -3.11, *p* = .01. However, it was not rated to be more difficult than the most difficult rated section of the technology descriptions (user interface of WebDIVER, *M* = 4.20, *SD* = 1.47), *t*(14) = 0.19, *p* = .85. Moreover, the comprehensibility rating for the pedagogical text segment was still above average. As a result, the material was considered adequate to be used for implementing the manipulation in the main study.

5.2.4 Measures

5.2.4.1 Control Variables.

The control variables assessed were gender, age in years, duration of studies in semesters, and high school graduation grade average (1 = *best grade*, 6 = *worst*). With regard to their teacher training experience participants indicated whether they had completed a teaching internship and how many weeks it had lasted. To tap into participants' experience with digital technology, they reported how often they used a computer during the week on a 5-point Likert scale (1 = *less than once a week*, 5 = *daily*). To have a measure closer related to the technology of this study, participants also rated the potential of YouTube functions (10 items based on the emerging categories of Study 1, Cronbach's α = .78) on a 6-Likert scale (1 = *completely disagree*, 6 = *completely agree*). Time on task for the laboratory session and follow-up measurement were also computed using log-data. *Subject-specific pedagogical beliefs* as another control variable were assessed with short version of the items used in Study 2 (adapted from Souvignier and Mokhlesgerami, 2005). Participants indicated their pedagogical beliefs on two scales, *constructivist orientation* (three items) and *explicit instruction orientation* (two items) on a 4-point Likert scale (1 = *completely disagree*, 4 = *completely agree*). Both scales showed sufficient internal consistencies, Cronbach's α ≥ .74. Parallel to Study 1 and 2 a difference score was computed with positive values indicating a relatively more constructivist orientation.

5.2.4.2 Pedagogical, content, and technological knowledge

To assess declarative aspects of participants' general *pedagogical knowledge* (PK), a slightly shortened version of the measure used in Study 1 consisting of 18 items was applied (see Appendix Table A.2 and A.3). Considering the heterogeneity of the aspects touched on by the items, the internal consistency of the measure was satisfactory, Cronbach's α = .70.

To be able to control for participants prior knowledge in the specific historical *content* (CK) of the example lesson plan, a 12 item a multiple choice test was administered. This measure was adapted from a retention test for high school students (e.g., Zahn et al., 2012) and pretested with a sample of 39 pre-service history teachers who had *not* completed their 4th semester to ensure they were not eligible for participation in the actual study (M = 21.0 years, SD = 1.1, 72% female, M = 2.2 semesters, SD = 1.0). The items were selected ensure an adequate difficulty (M = .67, SD = .16) for a pre-service teacher sample. Internal consistency was satisfactory, Cronbach's α = .71.

To assess participants' prior *technological knowledge* (TK), the number of recalled WebDIVER functions were counted by using and MS Excel 2007 formula indicating, whether at least one of a number of keywords characteristic of the respective function was present (e.g. play or watch or rewind or start for Play). These dichotomous codes (0 = *function not recalled*, 1 = *function recalled*) were summed up into a sum score with a theoretical maximum of 10. For a full overview over the keywords and Excel syntax see Appendix Table C.1.

5.2.4.3 Mental models of WebDIVER functions

To tap into participants' mental models of the learning-relevant functions of the video tool WebDIVER, that is, their technological pedagogical knowledge of the tool (TPK), the same (a) *text-based* procedure applied in Studies 1 and 2 was followed (cf. Azevedo & Cromley, 2004). In addition, to tap in to structural aspects of their mental models, participants were asked to draw (b) *concept maps* representing WebDIVER and instruction. The instruction included a concept map for a neutral example topic (eco system forest, see Appendix Figure C.19 for the task instruction).

Content indicators. The content of participants' text-based answers as well as nodes and relations represented in concept maps was coded. Both data sources were coded with the coding scheme representing the theoretically derived categories for learning goals mapped on technology functions for instructional use (see Studies 1 and 2, Tables 3.1 and 4.1). Parallel to Study 2 (see Section 4.2.3.2), due to the specific affordances of WebDIVER for individual and collaborative learning only the categories *cognitive* and *socio-cognitive* were coded. Categories were not exclusive and one answer could receive more than one code. Rater-agreement[8] was satisfactory for coding the written answers, cognitive Krippendorff's α = .97, and socio-cognitive, α = .69, as well as the concept maps. Differences in codes were resolved by discussion.

Concept maps were coded (0 = not represented as node, 1 = represented as node) with regard to whether they contained representations of the TPCK basic sub-domains in terms of *technology* (WebDIVER), *pedagogical* agents (teacher, student), and the *content* to be taught. All concept maps were coded by two independent raters, showing high agreement for all categories, teacher, Krippendorff's α = .96, student, α = .89, WebDIVER, α = .96, and content, α = .84. Based on these codes an indicator representing the completeness of participants' mental models with regard to the TPCK sub-domains was computed that focused on the representation of students as most relevant elements. A conditional sum score was computed indicating how many elements (WebDIVER, teacher, content) were contained in a concept map, given the necessary conditions that students were also represented. This score thus ranged from 0 (*incomplete* = students not contained, independent of other elements contained) to 4 (*complete* = students and the three other elements contained). For example, if a concept map contained a node representing the teacher and WebDIVER this indicator was assigned the value 0, if, however, teacher, WebDIVER, *and* student were contained a value of 3 was assigned.

Structure indicators. The concept map measure made it possible to also infer information about the structure of participants' mental models of the learning-relevant functions of WebDIVER by looking at the represented elements (nodes) and the links between them (edges). Based on ideas of social network analysis, parameters can be computed that indicate how much an element is tied into a network (degree centrality of a node) and to what extent the overall network is interconnected (degree centrality of a graph). The necessary information was extracted from participants' concept maps by listing all represented elements along with the number of links connecting each element. Because there was no coherent use of directed and undirected edges between participants, all links were treated as undirected for this analysis.

The degree centrality of a node, and a graph, respectively, is a measure of graph structure ranging from 0 to 1 (Clariana, Draper, & Land, 2011). The degree centrality C_D of a node v is computed by dividing the degree (number of edges) of this node $deg(v)$ by

[8] For all coding schemes 20% of the respective answers in each condition were double coded by a second independent rater.

the total number of edges n minus one (see Formula 1). Higher values signify a greater interconnectedness within the graph, that is, if the node representing students has a higher centrality, there are more in- and outgoing links relative to all links in the graph. For example, node a in the linear structure in Figure 5.2 has a degree centrality of C_D (v) = .20, whereas node a in the hierarchical structure has a degree centrality of C_D (v) = .60. Thus, if students were to be represented like node a in the hierarchical network example, this would signify a more important role in this graph as a connector for the other instructional elements and a higher interdependence among these. Degree centrality was computed for nodes representing students, teachers, and the technology WebDIVER. If there were more than one node representing one of these elements, the average was computed. Based on this, the degree centrality C_D of a graph G is computed by first computing the difference between the degree centrality of each node v_i and the highest degree centrality of a node within the graph v^*, and dividing this difference by the total number of edges n minus two. Then, the sum of these values for all nodes from i to V is computed (see Formula 2).

$$C_D(v) = \frac{deg\ (v)}{(n-1)} \tag{1}$$

$$C_D(G) = \sum_{i=1}^{V} \frac{C_D(v^*) - C_D(v_i)}{(n-2)} \tag{2}$$

With regard to how the shape of a graph is represented by its degree centrality, a value of $C_D(G)$ = .10 represents a ‘linear’ form, $C_D(G)$ = .40 a ‘hierarchical’ or ‘tree’ form, $C_D(G)$ = .60 representing a ‘network’ form, and $C_D(G)$ = 1.0 representing a ‘star’ or ‘hub and spoke’ form (see Figure 5.2; cf. Clariana et al., 2011). Thus, a pre-service teachers’ concept map with low graph centrality would indicate a linear representation of how the sample technology and other elements in the classroom are linked, which constitutes a rather low complexity assuming no feedback processes. In contrast, a networked representation of the technology in the classroom context would mean more complex relations with technology, people and other elements showing a higher interdependence.

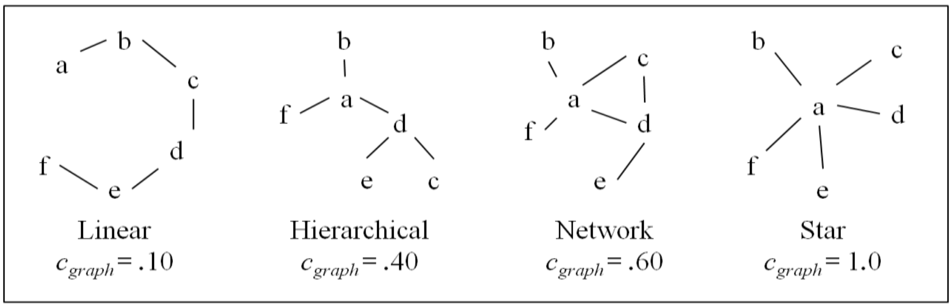

Figure 5.2. Visualization of degrees of centrality for different network structures, adapted from Figure 1 in Clariana et al. (2011).

Table 5.2

Overview over the indicators tapping into participants' mental models of WebDIVER.

Data Source	Aspect	Indicator
(a) Text-based measure		
	Content	Elaborateness (word count)
		Cognitive functions
		Socio-cognitive functions
(b) Concept map measure		
	Content	Cognitive functions
		Socio-cognitive functions
		Completeness (Conditional sum score)
	Structure	Overall graph
	(degree centrality)	Student node(s)
		Teacher node(s)
		WebDIVER node(s)

5.2.4.4 Assessing TPCK task performance

Parallel to Study 2 and based on the theoretical considerations in Chapter 2, participants' performance in tasks that demand considering technology, pedagogy and content simultaneously were chosen following Kramarski and Michalsky (2010) as the most appropriate measure to tap into their TPCK.

Evaluation task. The example lesson plan for WebDIVER in a collaborative setting covering the topic of news reels as propaganda instruments in post-war Germany from Study 2 was again used in this study (see Appendix Table B.3). Because in this Study participating pre-service teachers studied a variety of subjects and not only history and German language arts, their prior knowledge with regard to this era of the German history was assessed in the CK test described above. The scales participants rated the lesson plan on were short versions of those used in Study 2: Rating of the likelihood that they would implement this example lesson plan in their own teaching (one item), and the extent they thought this task would support *cognitive learning goals* (three items) or *socio-cognitive learning goals* (two items), respectively. For all ratings, a 6-point Likert scale was used (1 = *completely disagree,* 6 = *completely agree*). The reliability was lower than in Study 2 but still acceptable, cognitive, Cronbach's $\alpha = .65$, and socio-cognitive $\alpha = .70$.

Comprehension task. A task was created following items from research on mental models of mechanical systems (e.g., Hegarty, 1992; Hegarty & Just, 1993). Such items are based on the idea that in order to make correct inferences about the consequences of changes to a previously presented mechanical system, participants need to have constructed functional mental models of this system. Translating this idea to the current research, in order to make predictions about how changes to a previously presented lesson plan affect this lesson plan's potential, teachers need a functional mental model of the elements relevant to this plan. Based on these assumptions, participants were presented with a question about the potential impact of a change to the use of *technology* ("How would it impact the students' learning, if they only discussed about the film material instead of using WebDIVER to accomplish this task?), and, complementarily, to the *pedagogy* of the example lesson plan ("How would working individually on this task impact the students' learning with WebDIVER?).

The number of words participants had written to address the impact of each alteration to the example lesson plan were counted and answers were coded with two subscales of the TPCK-SRL coding scheme suggested by Kohen and Kramarski (2012). Parallel to Study 2, the technology sub-category was adapted to assess how specific participants described the impact of the technological affordances on student learning and the answers to the added-value question were coded on a 0 to 3 scale (see Table 4.2 in Chapter 4). Inter-rater agreement was satisfactory, Krippendorff's $\alpha = .69$.

Because on average participants' answers in this study were more elaborate on average, they were coded with regard to their self-regulated learning considerations. This coding scheme is based on the idea that another dimension to the descriptions of how technology, pedagogy and content interrelate is that teachers should also justify their reflective decision making with regard to teaching with technology. Following this assumption, on the lowest level teachers only indicate *what* technology tools, pedagogical approaches, or topics are included in a lesson, on the medium level teachers also reflect on *how* these should be implemented and in which sequence (*when*), and, finally, on the highest level, teachers are also explicit about *why* they combine technology affordances with specific pedagogical approaches and select specific content. For coding levels and examples see Table 5.3. Inter-rater reliability was satisfactory for both subtasks, change in pedagogy, Krippendorff's $\alpha = .67$, and change in technology, Krippendorff's $\alpha = 1.0$

Table 5.3
TPCK-SRL assessment scheme adapted from Kohen and Kramarski (2012) for teachers' integration of self-regulated learning (SRL) considerations into TPCK tasks.

Coding level	Excerpts from comprehension and lesson planning task	Mapping SRL question	Benchmark
Specific mapping of all TPCK components (T, P, and C) with full SRL considerations (*what*, *how* / *when*, and *why*)	"Without WebDIVER it would be more difficult to separately speak about a certain scene, because you would need to constantly pause the video. Moreover, only few students need to contribute to the discussion. Furthermore, it would be more difficult to consider the whole film as an arrangement of individual scenes, because cuts and transitions could not be emphasized."	What? How? What? What? Why?	High 3
Specific mapping of all TPCK components (T, P, and C) with partial SRL considerations (*what* and *how*, or *what* and *when*, without justification of why)	"[The] students would not watch the film as carefully, in comparison to selecting sequences by themselves and would not actively deal with the content."	What? How?	Middle 2
General mapping of TPCK components (T, P, and C) without SRL considerations (only what should be achieved)	"Focusing on specific content elements would be less pronounced."	What?	Low 1

Note. T = Technology, P = Pedagogy, C = Content.

Design task. Participants were asked to design a lesson plan that they would devise for using WebDIVER in class with content of their choice. Because participants studied various subjects they were not asked to design a lesson plan for the topic of propaganda in post-war Germany as in Study 2. In this lesson plan, they were asked to explicitly specify in separate text-fields the content of the lesson, the learning goals and processes they aimed, the concrete task instruction, the procedure, and the support they would provide as teacher. These five aspects were based on models of lesson planning used in German teacher education (Kiper & Mischke, 2009). Furthermore, participants were asked to separately describe the role WebDIVER played in their lesson plan and the added-value it would bring to its pedagogical potential.

The number of words participants had written to address each aspect were counted and answers were coded in two steps. First, the teaching approaches present in participants' lesson plans were assessed with a coding scheme that consisted of nine categories based on the emerging categories from Study 2. For more pronounced analyses these were grouped into five broader categories and mean scores were computed, when applicable: *Teacher-Centered* (Material Preparation (teacher), Shortening Movies (teacher), and Teacher Presentation), *Student-Centered* (Students' Media Literacy, Student Motivation, and Students' Productive Use), *Attention Guidance Focus* (Detail Perception and Focusing Attention), *Comprehension Focus* (Empathy and Comparison), and *Collaboration Focus* (Exchange). For a more objective coding procedure an MS Excel formula was used to count the occurrence of a number of keywords defined for each of the categories (e.g. group, discuss, exchange, and discussion for Collaboration Focus). The keywords were created by two independent raters and subsequently combined. Excel syntax was double checked with regard to spelling errors and verb inflection occurring in participants' answers. For a full overview over the keywords and Excel syntax see Appendix Table C.2.

Second, lesson plans were also coded with the two subscales of the TPCK-SRL coding scheme suggested by Kohen and Kramarski (2012), specification of technology affordances and SRL considerations. Inter-rater reliability was satisfactory for all indicators, Krippendorff's ranging from α = .70 to 1.0. See Table 5.4 for an overview over all dependent variable indicators including follow-up measures.

Table 5.4
Overview over dependent variable indicators.

Task	Subtask	Indicator
Example lesson plan evaluation		
	Learning goal support	Cognitive goals
		Socio-cognitive goals
	Implementation	Likelihood
Comprehension task		
	Consider change in *pedagogy*	Elaborateness
		SRL consideration
	Consider change in *technology*	Elaborateness
		SRL consideration
		Affordance specification
Lesson plan design		
	Lesson content	Elaborateness
		SRL consideration
	Learning goals/processes	Elaborateness
		SRL consideration
	Task instruction	Elaborateness
		SRL consideration
	Procedure	Elaborateness
		SRL consideration
	Teacher role /guidance	Elaborateness
		SRL consideration
	Added-value of technology	Elaborateness
		SRL consideration
		Affordance specification
	Teaching approach	Teacher-centered
		Student-centered
		Attention guidance focus
		Comprehension focus
		Exchange focus
Transfer task		
	Comparison to WebDIVER	Elaborateness
		Cognitive functions
		Socio-cognitive functions
		SRL consideration
		Affordance specification

Note. SRL = self-regulated learning.

5.2.4.4 Transfer task – mental model of a second video tool

In order to assess, whether potential effects would carry over to participants understanding of another video technology, a transfer task was designed. The focus of the transfer was on how they would construct a mental model of this new tool. In order to create a not too difficult task, another web-based video tool was chosen as stimulus material. Thus, this can be considered a near transfer task. However, the transfer task was applied as a delayed follow up measure.

The video tool VideoANT, created by the University of Minnesota (http://ant.umn.edu/) and was chosen, because the graphical user interface has a similar layout (source video on the left and worksheet on the right, see *Figure 5.3*), which makes the two tools more comparable. With regard to technological functions, on the one hand, VideoANT does not provide features for zooming and actually selecting still images or sequences, but only for marking moments in a video that can then be annotated. On the other hand, it additionally has a timeline, which provides an overview over the markers. Parallel to WebDIVER, VideoANT also allows users to share a links to an annotated video (with and without rights for further editing), however there is no possibility for more users to collaborate on one VideoANT file.

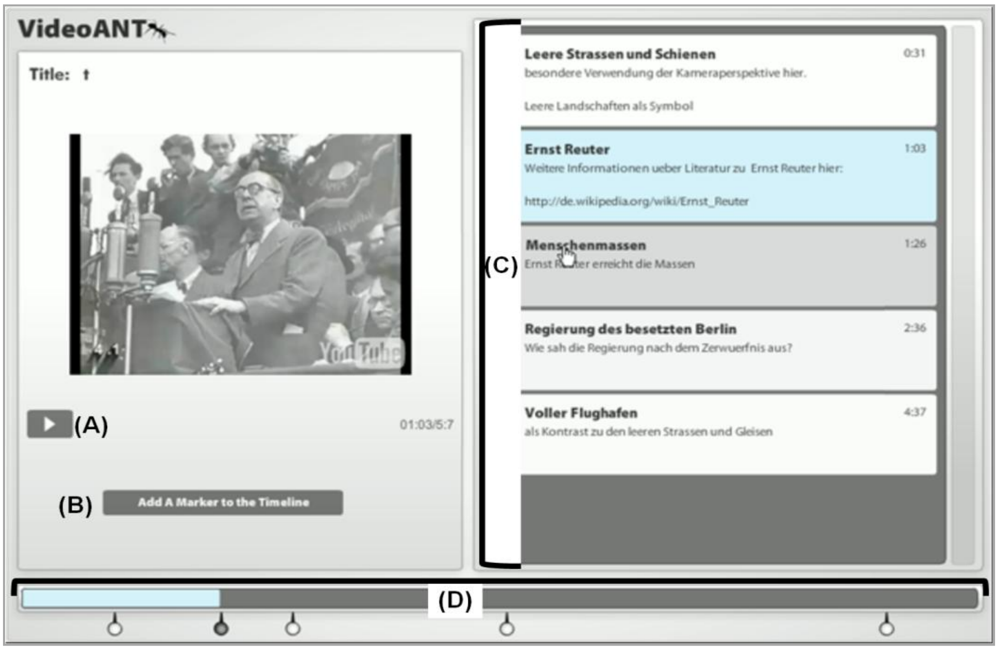

Figure 5.3. Screenshot of the graphical user interface of VideANT. With functions for (A) play and pause, (B) adding markers, (C) the worksheet for annotating marked video segments, (D) and the timeline with pins indicating the position of marked segments. http://ant.umn.edu/.

All participants watched a 3-minute video tutorial that introduced the basic technological functions of VideoANT: (1) P*lay* and pause a video, (2) setting *markers* to specific moments in the video, (3) *annotating* these markers, (4) *editing* the annotations, (5) *reordering* annotations by drag & drop, (6) using pins in the *timeline* to navigate, (7) *sharing* one's marked and annotated video via e-mail. First, participants were asked to recall the functions that had been introduced in the tutorial. Parallel to the coding procedure for recalling WebDIVER functions an MS Excel formula was used to indicate, whether at least one of a number of keywords characterizing the respective function was present (e.g. "play", "watch", or "rewind" for Play). In addition to the seven functions introduced in the video, (8) the misrepresentation of *cutting out* parts of the video was also coded as an indicator of an incorrect transfer from WebDIVER. These dichotomous codes (0 = *function not recalled*, 1 = *function recalled*) were summed up into a sum score with a theoretical maximum of 8. For a full overview over the keywords and Excel syntax see Appendix Table C.3.

Then, in the actual transfer task, participants were asked to compare VideoANT to WebDIVER with regard to their potential for instruction, to tap into participants mental models of this new technology. The number of words participants had written to this comparison task were counted as an indicator of elaborateness and answers were coded with regard to three aspects: first, whether cognitive and socio-cognitive functions had been addressed, second, with regard to their level of SRL considerations, and, finally, with regard to the specification of affordance descriptions. Inter-rater reliability for all measures was satisfactory, cognitive functions, Krippendorff's α = .85, socio-cognitive functions, Krippendorff's α = .99, SRL considerations, Krippendorff's α = .77, and affordance specificity, Krippendorff's α = 1.0, respectively. For an overview over indicators of the follow-up measure see Table 5.4.

5.3 Results Study 3

5.3.1 Statistical analyses

Due to the aim of contrasting the two hypotheses based on the competing views on TPCK described above, contrast analyses were run. The analytic procedure followed the suggestions made by Niedenthal and colleagues (Niedenthal, Brauer, Robin & Innes-Ker, 2002; see also Abelson & Prentice, 1997). The *integrative view* hypothesis corresponds to the Contrast A (-2 1 1), meaning that following this view, it was expected that participants in both the TK+PK and the TPK condition would show higher scores in the mental model indicators and perform better in the TPCK and transfer tasks than participants in the control condition (TK-only) without significant differences between the TK+PK and TPK condition. In contrast, the *transformative view* hypothesis corresponds to a significant Contrast B (0 -1 1) without Contrast A being significant, meaning that following this view, it was expected that only participants in the TPK condition would show higher scores in the mental model indicators and perform better in TPCK and transfer tasks. Given that there were only three experimental groups, no further contrasts to capture any residual systematic variance were necessary. A result was considered consistent with the *integrative view* hypothesis when Contrast A was statistically significant, and Contrast B was not. Vice versa, a result was considered consistent with the *transformative view* hypothesis when contrast B was statistically significant, and contrast A was not. For a visualization of the expected results pattern see Figure 5.1

In addition to the main effects tested by these contrasts also possible moderating effects of prior PK were tested. Following Aiken and West (1991), the sum scores of the PK test were z-standardized, and the interaction terms were computed by a multiplication of the PK z-scores and the contrast codes (Interaction A and Interaction B). A significant result for Interaction A (without a significant result for Interaction B) would indicate that differences in prior PK moderated the effect of the manipulation in both the TK+PK and TPK conditions but not in the control condition (TK-only). A significant result for Interaction B (without a significant result for Interaction A) would indicate that only in the TPK condition, differences in prior PK moderated the effect of the manipulation. Significant interaction terms were followed up with simple slope analyses (following Aiken & West, 1991).

All independent variables (two contrasts and two interaction terms) were entered in a multiple regression analysis. Given no significant differences in prior PK between the conditions (see Section 5.3.1), this variable was not entered into multiple regressions to avoid collinearity issues. The level of significance for all analyses was set to .05.

5.3.2 Comparability of conditions

One-factorial analyses of variance (ANOVAs) with the between subjects factor condition (TK-only vs. TK+PK vs. TPK) revealed no significant differences between conditions with regard to control variables assessed prior to the manipulation, age, high school graduation grade, semester, PK, CK, constructivist orientation, duration of teaching internship, frequency of computer use, and ratings of YouTube functions, all *F*s $\leq$ 1.99, all *p*s $\geq$ .15. Neither did χ^2-tests reveal any significant differences for the categorical variables, gender, teaching internship, or study majors (German, history, sciences, mathematics, and others), all *p*s $\geq$ .34. Furthermore, a number of post manipulation variables were also investigated to ensure comparability of conditions after the manipulation, especially given the differences in text difficulty described above. One-factorial ANOVAs again did not show any significant differences between conditions with regard to the time participants spent on the second measurement (manipulation and post-test), their TK (recall of WebDIVER functions), the effort they invested during the exploration of WebDIVER, their situational interest in WebDIVER, and the time participants spent on the follow-up-test (VideoANT tutorial and transfer task), all *F*s $\leq$ 1.65, all *p*s $\geq$ .20. For descriptive statistics see Table 5.5.

Table 5.5

Means (M) and Standard Deviations (SD) of control variables.

	TK (n = 25)		TK+PK (n = 24)		TPK (n = 25)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Demographics						
Age	25.08	2.91	24.63	3.23	24.12	1.56
High school grade average[a]	2.24	0.38	2.14	0.43	2.12	0.60
Semester	9.12	2.52	8.92	2.67	8.68	1.99
Female	80%		83%		80%	
Teaching related variables						
PK[b]	9.08	2.77	9.08	2.00	9.48	1.98
CK[c]	5.32	1.86	5.67	1.40	5.56	1.56
Constructivist orientation[d]	0.91	1.91	0.93	2.04	1.84	1.66
Teaching internship (weeks)	13.9	5.92	15.0	7.73	13.0	5.43
Technology related variables						
Computer use frequency[e]	4.96	0.20	4.92	0.41	4.96	0.20
YouTube rating	4.19	0.74	3.88	0.72	3.88	0.71
Post manipulation						
Time on post-test (min.)	54.50	16.17	55.37	11.17	55.79	9.35
TK[g]	7.72	2.07	6.88	2.11	6.76	2.42
Effort during WD exploration	4.88	0.97	4.63	1.17	5.16	0.94
Situational interest in WD	4.89	0.80	4.69	1.06	5.00	0.92
Time on follow-up test (min.)	11.32	3.98	11.51	3.32	12.33	5.68

Note. WD = WebDIVER. [a]German Abiturnote, 1 = *best grade*, 6 = *worst grade*, [b]theoretical maximum 18, [c]knowledge about the topic of the examples lesson plan: Berlin Blockade and Air Lift, theoretical maximum 12, [d]difference score with values above 0 indicating a constructivist orientation over an explicit instruction orientation, [e]1 = *less than once a week*, 5 = *daily*, [g]theoretical maximum 10.

5.3.3 Mental models of WebDIVER

Content indicators. Multiple regression analyses were conducted in which the indicators derived from participants' text-based descriptions of their mental model of

WebDIVER and instruction were regressed on the two contrasts (see Figure 5) and two interaction terms. Results revealed that Contrast A (see figure 5.1a) was statistically significant for elaborateness, $F(1, 73) = 7.27$, $p = .01$, R^2change = .09, and the representation of socio-cognitive functions, $F(1, 73) = 6.95$, $p = .01$, R^2change = .09. For these indicators, both experimental groups did not differ significantly from each other (Contrast B, see figure 5.1b), and there were no significant interaction effects with prior PK, Fs < 1. Hence, in comparison to participants in the control condition, participants in the two experimental conditions answered more elaborately to the text-based item tapping into participants' mental models and their answers contained more socio-cognitive functions (for descriptive statistics see Table 5.6). With regard to cognitive functions specified by participants there were no significant effects, Contrast A, $F(1, 73) = 2.41$, $p = .13$, R^2change = .03, Contrast B, $F < 1$, Interaction A, $F < 1$, and Interaction B, $F(1, 73) = 2.05$, $p = .16$, R^2change = .03.

Multiple regression analyses with mental model indicators derived from participants' concept maps as dependent variables revealed a significant effect of Contrast A, $F(1, 73) = 7.23$, $p = .01$, R^2change = .09, for cognitive functions being represented in the concept maps. Contrast B and both interaction terms were not significant, Fs < 1. This means that participants in both experimental conditions specified more cognitive functions than participants in the control group. There were no significant effects for the representation of socio-cognitive functions in the concept maps, Contrast A, $F(1, 73) = 2.16$, $p = .15$, R^2change = .03, all other Fs < 1. For the indicator of completeness of participants' mental models with regard to the TPCK sub-domains, Contrast B, $F(1, 73) = 4.62$, $p = .04$, R^2change = .06, and Interaction B, $F(1, 73) = 4.38$, $p = .04$, R^2change = .05, were significant. Contrast A, $F(1, 73) = 1.67$, $p = .20$, R^2change = .02, and Interaction A, $F(1, 73) = 2.08$, $p = .15$, R^2change = .03, were not significant. These results indicate that only participants in the TPK condition created more complete concept maps in comparison to participants in both the control group and the TK+PK condition. However, simple slopes analyses following up significant Interaction B indicated that, this was only the case for participants with higher PK ($\beta = .50$, $p = .003$), but not for those with lower PK ($\beta = -.03$, $p = .86$).

Structure indicators. Multiple regression analyses with structural indicators derived from concept maps as dependent variables revealed a significant Contrast A for the centrality of WebDIVER, $F(1, 73) = 7.17$, $p = .01$, R^2change = .09, without a significant Contrast B, $F < 1$, Interaction A, $F < 1$, or Interaction B, $F(1, 73) = 1.49$, $p = .23$, R^2change = .02. For the degree centrality of nodes representing teachers Contrast B was significant, $F(1, 73) = 5.91$, $p = .02$, R^2change = .08, as it was for the degree centrality of nodes representing students, $F(1, 73) = 9.02$, $p = .004$, R^2change = .11. For the degree centrality of student nodes there was also a marginally significant Interaction B, $F(1, 73) = 3.81$, $p = .05$, R^2change = .05. There were no further significant effects for degree centrality of teacher nodes, all Fs ≤ 1.11, and degree centrality of student nodes, Fs < 1, respectively. These results indicate that the nodes representing the technology WebDIVER in the concept maps of participants in both experimental conditions exhibited higher degree centrality, that is, a higher degree of interconnectedness (for descriptive statistics see Table 5.6.). However, only participants in the TPK condition represented teachers and students more centrally. For the degree centrality of student nodes, simple slope analyses showed that this effect was only present for participants with higher PK ($\beta = .58$, $p = .001$), but not for those with lower PK ($\beta = .08$, $p = .63$). There were no significant effects for the overall degree centrality of the graphs (concept maps), Interaction B, $F(1, 73) = 2.74$, $p = .10$, R^2change = .04, all other Fs < 1.

Taken together, in comparison to the control group participants in both experimental conditions were more elaborate in their descriptions of WebDIVER's learning-relevant functions and specified more socio-cognitive functions within these. Furthermore, they specified more cognitive functions in their concept maps, and nodes representing WebDIVER were represented in a more interconnected way. Above and beyond, only the concept maps created by pre-service teachers in the second experimental condition (TPK) showed more complete representations, and more interconnected representations of teachers and students within the concept maps. However, mostly it was participants with higher prior PK who exhibited this incremental effect of introducing the functions of WebDIVER in relation to their potential instructional impact in the TPK condition.

Table 5.6
Means (M) and Standard Deviations (SD) of mental model indicators.

	TK (n = 25)		TK+PK (n = 24)		TPK (n = 25)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Content indicators						
Elaborateness	42.80	25.48	71.17	51.90	73.12	47.35
Cognitive functions	1.28	1.14	1.67	0.92	1.72	0.98
S.-cog. functions	0.12	0.33	0.46	0.66	0.56	0.71
Cognitive functions (cm)	0.80	0.82	1.62	1.24	1.40	1.04
S.-cog. functions (cm)	0.24	0.66	0.46	0.59	0.48	0.59
Completeness (cm)	2.44	1.42	2.50	1.44	3.24	0.72
Structure indicators (degree centrality)						
Overall graph	.27	.12	.31	.21	.28	.14
WebDIVER node(s)	.23	.23	.37	.25	.41	.22
Teacher node(s)	.24	.20	.17	.16	.29	.15
Student node(s)	.26	.19	.22	.16	.36	.14

Note. S.-cog. = socio-cognitive, cm = concept map.

5.3.4 TPCK task performance

5.3.4.1 Evaluation task

With regard to the evaluation of the example lesson plan, Interaction A was significant for socio-cognitive learning goals, $F(1, 73)$ =5.64, p = .02, R^2change = .07, without Contrast A or B, Fs < 1, or Interaction B being significant, $F(1, 73)$ =1.20, p = .28, R^2change = .02. The results of simple slope analyses indicated that in both experimental conditions participants with higher PK (β = .36, p = .03), but not those with lower PK (β = -.13, p = .88) rated the potential of the example lesson plan to support socio-cognitive goals higher. For descriptive statistics see Table 5.7.

Table 5.7
Means (M) and Standard Deviations (SD) of TPCK evaluation task.

	TK (n = 25)		TK+PK (n = 24)		TPK (n = 25)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Implementation likelihood	4.92	1.04	4.63	1.06	5.04	0.94
Cognitive learning goals	5.23	0.69	5.00	0.73	5.01	0.84
S.-cog. learning goals	4.62	1.00	4.71	0.91	4.96	0.83

Note. S.-cog. = socio-cognitive.

5.3.4.2 Comprehension task

Multiple regression analyses with the indicators derived from participants inferences about the potential impact of changes to the example lesson plan showed a significant Contrast A for the elaborateness of participants' answers to the pedagogy subtask, $F(1, 73) = 5.68$, $p = .02$, R^2change = .07, without Contrast B or the interaction terms being significant, Fs ≤ 1. With regard to the change in technology subtask, Contrast A was only marginally significant, $F(1, 73) = 3.59$, $p = .06$ R^2change = .05, as was Interaction A, $F(1, 73) = 3.50$, $p = .07$, R^2change = .05, while Contrast B, $F < 1$, and Interaction B, $F(1, 73) =1.75$, $p = .19$, R^2change = .02, were not. These results indicate that participants in both experimental conditions wrote longer descriptions of the potential impact of changing the collaborative setting to an individual one and had the tendency to do so for the potential impact of omitting the use of WebDIVER in favor of students only discussing about the example lesson plan video. Additionally, this effect tended to be moderated by prior PK, with simple slope analyses showing that meaning that participants with higher PK described the impact of changing the technology more elaborately ($\beta = .41$, $p = .01$), but not participants with lower PK did not ($\beta = .02$, $p = .88$). For descriptive statistics see Table 5.8.

With regard to the indicators taping into the quality of participants answers, there was no effect for the SRL considerations in both subtasks: pedagogy, Contrast B, $F(1, 73) =3.12$, $p = .08$, R^2change = .04, all other Fs < 1, and technology, all Fs < 1, respectively. However, for the specificity of affordance descriptions in the technology subtask Contrast A was significant, $F(1, 73) =4.68$, $p = .03$, R^2change = .06, without Contrast B, $F(1, 73) =2.57$, $p = .11$, R^2change = .03, or the interaction terms being significant, Fs < 1. Thus, for the indicators tapping into the quality of participants' comprehension task performance, results show that there were no significant differences between conditions with regard to SRL considerations, however, participants in both experimental conditions were more specific about the technology affordances in the technology subtask.

Table 5.8
Means (M) and Standard Deviations (SD) of TPCK comprehension task.

	TK (n = 25)		TK+PK (n = 24)		TPK (n = 25)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Elaborateness						
Pedagogy subtask	27.52	14.67	40.67	19.28	35.64	20.97
Technology subtask	28.48	15.54	35.38	13.39	35.84	20.46
SRL consideration						
Pedagogy subtask	2.20	0.76	2.54	0.66	2.16	0.65
Technology subtask	2.16	0.80	2.17	0.82	2.16	0.80
Specification of affordances						
Technology subtask	1.32	0.69	1.54	0.66	1.88	0.78

5.3.4.3 Lesson plan design task

Multiple regression analyses with the indicators for participants' performance in the lesson plan design task revealed a significant Contrast B for the elaborateness of participants' descriptions of the learning goals/processes tackled by their lesson plans, $F(1, 73) = 9.34$, $p = .003$, R^2change = .11, and the concrete task instruction they planned to provide for students, $F(1, 73) = 6.16$, $p = .02$, R^2change = .08. There were no other significant effects for these variables: learning goals/processes, Contrast A, $F(1, 73) = 2.81$, $p = .10$, R^2change = .03, Interaction A, $F(1, 73) = 1.84$, $p = .18$, R^2change = .02, and Interaction B, $F < 1$; task instruction: all Fs < 1. Interaction A was significant for the elaborateness of the descriptions addressing the added-value of using WebDIVER, $F(1, 73) = 6.20$, $p = .02$, R^2change = .08, without Contrast A, $F(1, 73) = 2.13$, $p = .15$, R^2change = .03, Contrast B, or Interaction B being significant, Fs ≤ 1. There were no other significant effects for the elaborateness of participants' descriptions of the other aspects of their lesson plans: content, all Fs < 1, the classroom procedure, $F(1, 73) = 1.30$, $p = .26$, R^2change = .02, all other Fs < 1, and the teacher's role, all Fs $\leq$ 1.1. For descriptive statistics see Table 5.9.

Thus, results regarding quantitative aspects of pre-service teachers' lesson plans indicate that only participants in the second experimental condition (TPK) described the learning goals and processes more elaborately that they aimed at in their devised lesson plans. Furthermore, they also provided more elaborate task instructions to be given to the students. In contrast, with regard to the added-value of using WebDIVER, simple slope analyses showed that in both experimental conditions, participants with higher prior PK provided more elaborate descriptions ($\beta = .42$, $p = .01$), however, participants with lower PK did not ($\beta = -.09$, $p = .55$).

Multiple regression analyses with SRL considerations in participants' lesson plans as dependent variables showed a significant Interaction A for the added-value of WebDIVER use, $F(1, 73) = 4.15$, $p = .045$, R^2change = .06, without Contrast A being significant, $F(1, 73) = 2.04$, $p = .16$, R^2change = .03, or Contrast B and Interaction B, Fs < 1. There were no significant effects for participants' SRL considerations concerning the other aspects of the lesson plans: content, Interaction B, $F(1, 73) = 2.38$, $p = .13$, R^2change = .03, all other Fs ≤ 1, learning goal / process, Contrast B, $F(1, 73) = 1.34$, $p = .25$, R^2change = .02, Interaction B, $F(1, 73) = 1.21$, $p = .27$, R^2change = .02, other Fs < 1, task instruction, all Fs ≤ 1.1, classroom procedure, Interaction B, $F(1, 73) = 1.40$, $p = .24$, R^2change = .02, other Fs < 1, and teacher role, Contrast B, $F(1, 73) = 1.68$, $p = .20$, R^2change = .02, Interaction A, $F(1, 73) = 1.73$, $p = .19$, R^2change = .02, other Fs < 1, respectively. With regard to how specific participants described the affordances of WebDIVER Contrast A was marginally significant, $F(1, 73) = 3.87$, $p = .05$, R^2change = .05, without any other significant effects, Interaction A, $F(1, 73) = 1.29$, $p = .26$, R^2change = .02, other Fs < 1.

These results for indicators tapping into specific qualities of participants' lesson plans show that in both experimental conditions participants were more specific about the affordances of the technology. Additionally, simple slope analyses showed that participants with higher prior PK provided more self-reflective descriptions about what they considered the added-value of the technology ($\beta = .38$, $p = .02$), however, participants with lower PK did not ($\beta = -.05$, $p = .75$).

Table 5.9
Means (M) and Standard Deviations (SD) of elaborateness, SRL considerations, and specificity of affordance descriptions, TPCK design task.

	TK (*n* = 25)		TK+PK (*n* = 24)		TPK (*n* = 25)	
Lesson plan aspects	*M*	*SD*	*M*	*SD*	*M*	*SD*
Elaborateness						
Content	15.32	12.92	14.46	11.76	17.52	20.80
Learning goal / processes	23.68	15.04	23.54	14.01	38.56	22.25
Task instruction	35.60	16.54	30.29	20.71	50.00	41.00
Classroom procedure	37.32	24.27	37.63	15.21	45.80	29.52
Teacher role	18.96	11.86	23.46	20.66	23.32	21.68
Technology added-value	31.44	19.74	35.96	17.63	38.20	15.89
SRL considerations						
Content	1.44	0.51	1.33	0.48	1.48	0.71
Learning goal / processes	1.72	0.89	1.75	0.90	2.04	0.98
Task instruction	1.88	0.44	1.88	0.61	1.96	0.73
Classroom procedure	1.96	0.73	2.00	0.59	2.00	0.71
Teacher role	1.48	0.59	1.38	0.65	1.64	0.81
Technology added-value	2.24	0.93	2.46	0.72	2.56	0.71
Specification of affordances						
Technology added-value	1.12	0.78	1.46	0.83	1.64	1.04

Multiple regression analyses with the indicators describing the teaching approaches applied in the designed lesson plans showed a significant Contrast B for student-centered approaches , $F(1, 73) = 4.01$, $p = .045$, R^2change = .06, without any further significant effects, all other *F*s < 1. Contrast B was also marginally significant for teacher-centered approaches, $F(1, 73) = 3.87$, $p = .05$, R^2change = .05, without any further significant effects, *F*s < 1. For a participants focusing on students' comprehension in their lesson plans Contrast A was significant, $F(1, 73) = 4.42$, $p = .04$, R^2change = .06, without any further significant effects, *F*s ≤ 1.1. There were no significant effects for focusing on students' attention guidance, Contrast B, $F(1, 73) = 1.51$, $p = .22$, R^2change = .02, other *F*s < 1, or focusing on collaborative exchange, Contrast A, $F(1, 73) = 1.39$, $p = .24$, R^2change = .02, other *F*s < 1. For descriptive statistics see Table 5.10.

These results indicate that participants in both experimental conditions showed a stronger focus on comprehension tasks for students in their lesson plans compared to the control condition. However, only participants in the second experimental condition (TPK) described more student-centered and less teacher-centered classroom scenarios for using WebDIVER in their instruction.

Table 5.10
Means (M) and Standard Deviations (SD) of teaching approaches, TPCK design task.

	TK (n = 25)		TK+PK (n = 24)		TPK (n = 25)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Teacher-centered	0.09	0.18	0.14	0.22	0.04	0.11
Student-centered	0.91	0.75	0.76	0.85	1.27	0.99
Attention Guidance Focus	0.34	0.66	0.35	0.43	0.18	0.28
Comprehension focus	0.08	0.19	0.33	0.79	0.38	0.53
Exchange focus	1.40	1.35	1.83	1.61	1.88	1.62

5.3.4.4 Transfer task

Multiple regression analyses with the indicators derived from the task of comparing WebDIVER with another video tool (VideoANT) about a week after the intervention revealed a significant Interaction B for the number of cognitive functions they referred to, $F(1, 73) = 4.99$, $p = .03$, R^2change = .06, the SRL considerations reflected in the answers, $F(1, 73) = 4.79$, $p = .03$, R^2change = .06, and the specificity of affordance descriptions, $F(1, 73) = 5.17$, $p = .03$, R^2change = .07. All other effects for these variables were not significant: cognitive functions, other Fs < 1, SRL considerations, other Fs < 1, and affordance specificity, Contrast B, $F(1, 73) = 1.27$, $p = .27$, R^2change = .02, other Fs < 1, respectively. There were no further significant effects: elaborateness, Interaction B, $F(1, 73) = 1.39$, $p = .24$, R^2change = .02, other Fs < 1, and socio-cognitive functions, Contrast A, $F(1, 73) = 1.42$, $p = .24$, R^2change = .02, other Fs < 1, respectively. For descriptive statistics see Table 5.11

These results for the transfer task indicate, that only participants in the second experimental condition (TPK) with higher prior PK specified more cognitive functions ($\beta = .37$, $p = .04$), in comparison to participants with lower PK ($\beta = -.23$, $p = .21$). Participants with higher prior PK in this condition also reached a higher benchmark regarding their SRL considerations ($\beta = .37$, $p = .04$), than participants with lower PK ($\beta = -.22$, $p = .22$). Moreover, participants with higher prior PK also were more specific when describing the affordances to the two technologies (β = .43, *p* = .02), than participants with lower PK (β = -.17, *p* = .34).

Table 5.11
Means (M) and Standard Deviations (SD) of transfer task performance indicators.

	TK (*n* = 25)		TK+PK (*n* = 24)		TPK (*n* = 25)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Elaborateness	40.60	29.58	50.46	40.04	44.20	25.78
Cognitive functions	0.32	0.48	0.33	0.48	0.44	0.58
Socio-cognitive functions	0.32	0.48	0.13	0.34	0.24	0.52
SRL considerations	2.12	0.83	2.00	0.83	2.16	0.80
Specification of affordances	1.60	0.76	1.50	0.88	1.80	0.96

5.3.4.5 Additional analyses – mental models as mediators

In order to test whether the effects on the dependent variables (TPCK tasks and transfer task) could be explained by differences in participants' mental models of WebDIVER, mediation analyses were run following Preacher and Hayes (2008) with 5000 bootstrap samples. Given that some of the effects on participants' mental models (the potential mediators), as well as effects on the dependent variables were moderated by prior PK, the procedure proposed by Preacher, Rucker, and Hayes (2007) for moderated mediation analyses was applied, and high and low levels of prior PK were operationalized as one standard deviation above and below the mean score (parallel to simple slope analyses reported above).

TPCK Evaluation task. Mediation analyses showed a significant effect for the degree centrality of WebDIVER nodes in participants' concept maps as mediator and ratings of socio-cognitive goals in the example lesson plan as dependent variable (*b* = .04, *SE* = .03, CI α = .05 [.001; .12]). Participants in both experimental condition showed more central representations of WebDIVER in their concept maps (β = .31, *p* = .01), and degree centrality, in turn, tended to foster a positive evaluation of the example lesson plan with regard to socio-cognitive learning goals (β = .23, *p* = .06; see Figure 5.2). In addition, the conditional direct effect for participants with higher prior PK in both experimental conditions (TK+PK and TPK condition; β = .36, *p* = .03) significantly decreased when the mediator centrality of WebDIVER nodes was included in the analysis (β = .27, p = .09). No other indicators tapping into participants' mental models were significant mediators, all confidence intervals including 0.

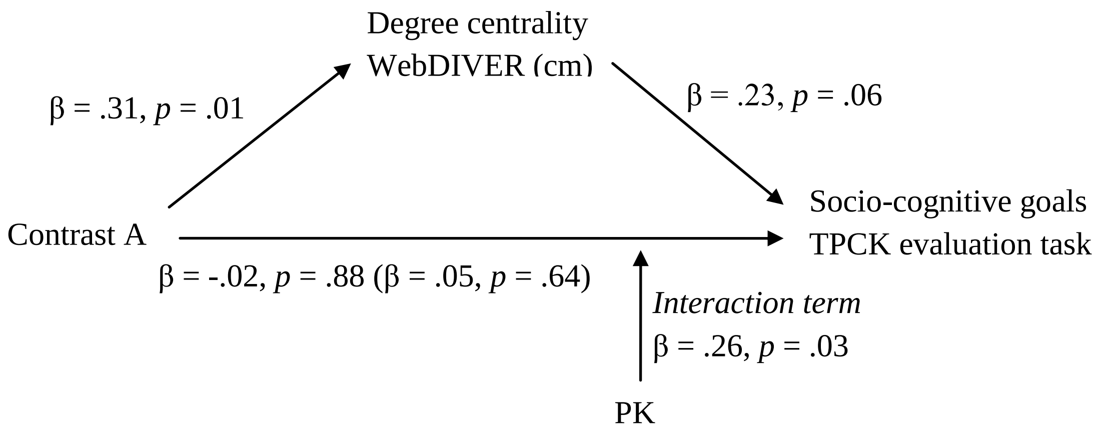

Figure 5.4. Mediation effects for degree centrality of WebDIVER node (cm = concept maps) mediating the conditional direct effect of both experimental interventions (Contrast A, moderated by prior pedagogical knowledge, PK) on the evaluation of socio-cognitive goals in the example lesson plan.

TPCK Comprehension task. Mediation analyses revealed that the elaborateness of participants descriptions of their mental models significantly mediated the effect of both experimental interventions (Contrast A) on the elaborateness of participants reflections about changes in pedagogy would impact the instructional potential of the example lesson plan (b = 1.24, SE = .58, CI α = .05 [0.24; 2.49]), and the marginal effect for changes in technology (b = 1.41, SE = .60, CI α = .05 [0.54; 2.94]), respectively. With regard to the technology subtask the representation of socio-cognitive functions in participants mental models (open answer item) also proved to be a significant mediator (b = .75, SE = .44, CI α = .05 [0.01; 1.77]). However, mediation analysis including both mediators (elaborateness of mental model description and representation of socio-cognitive goals) at the same time revealed that the elaborateness of participants' mental model descriptions remained a significant mediator (b = 1.29, SE = .71, CI α = .05 [0.67; 3.27]) whereas the representation of socio-cognitive functions did not (b = .0.43, SE = .41, CI α = .05 [-0.30; 1.33]). In sum, participants in both experimental conditions described their mental models of learning-relevant functions of WebDIVER more elaborately (β = .30, p = .01), and elaborateness of their mental model descriptions, in turn, fostered more elaborate considerations of pedagogical (β = .30, p = .01; see Figure 5.2), and technological changes to the example lesson plan (β = .36, p = .003; see Figure 5.3), respectively. In addition, the direct effect of both experimental conditions (Contrast A) on the elaborateness in the pedagogy subtask (β = .27, p = .02) significantly decreased when the mediator elaborateness of mental model descriptions was included in the analysis (β = .17, p = .14). Moreover, the conditional direct effect on elaborateness in the technology subtask for participants with higher prior PK in both experimental conditions (β = .41, p = .01) significantly decreased when the mediator elaborateness of mental model descriptions was included in the analysis (β = .28, p = .07). All analyses for the technology subtask accounted for the condition direct effect of the interventions (moderator prior PK). No other indicators tapping into participants' mental models were significant mediators, all confidence intervals including 0.

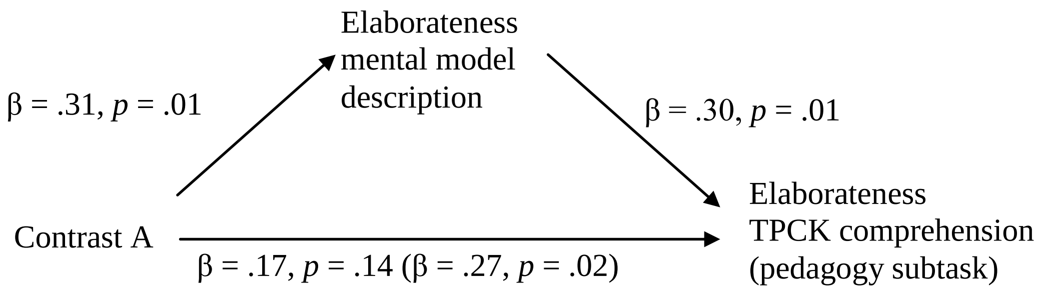

Figure 5.5. Mediation effects for elaborateness of mental model descriptions mediating the effect of both experimental conditions (Contrast A) on the elaborateness of the pedagogy subtask of the TPCK comprehension task.

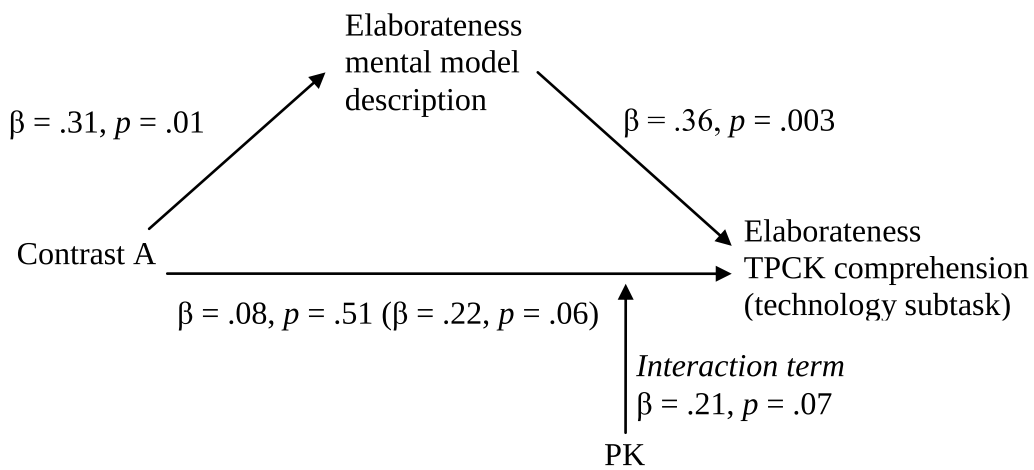

Figure 5.6. Mediation effects for centrality for elaborateness of mental model descriptions mediating the conditional direct effect of both experimental interventions (Contrast A, moderated by prior pedagogical knowledge, PK) on the elaborateness of the pedagogy subtask of the TPCK comprehension task. Effects are controlled for the non-significant mediator representation of socio-cognitive functions.

TPCK Design task. Mediation analyses revealed that the representation of cognitive functions in the concept maps tapping into participants' mental models significantly mediated the positive effect of both experimental interventions (Contrast A) on a comprehension focus in participants' own lesson plan designs (b = .03, SE = .02, CI α = .05 [.008; .08]). Participants in both experimental conditions represented more cognitive functions in their concept maps elaborately (β = .31, p = .01), and the representation of cognitive functions, in turn, increased participants' focus on the students' comprehension in their lesson plans (β = .26, p = .03; see Figure 5.4). In addition, the direct effect of both experimental conditions (β = .23, p = .046) significantly decreased when the mediator elaborateness of mental model descriptions was included in the analysis (β = .15, p = .20). There were no further significant mediation effects, all confidence intervals including 0.

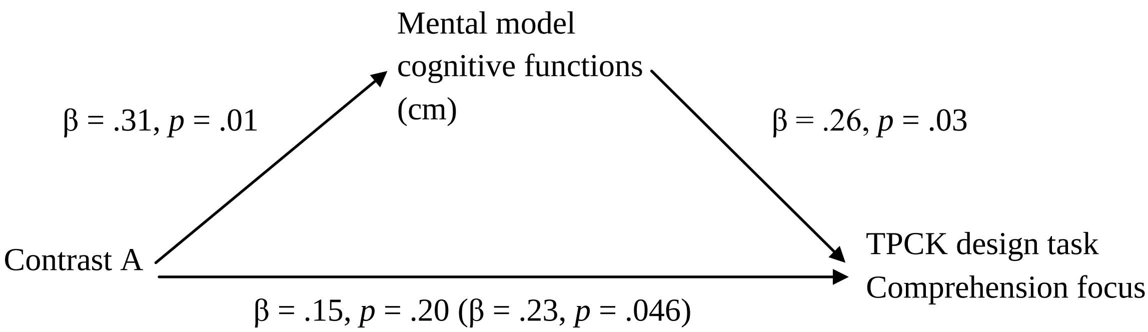

Figure 5.7. Mediation effects for cognitive functions represented in participants' mental models (cm = concept map) mediating the effect of both experimental conditions (Contrast A) on the focus on students' comprehension in lesson plans, TPCK design task.

Transfer task. With regard to participants' performance in the transfer task moderated mediation analyses showed an indirect effect of the TPK condition (Contrast B) on the description of cognitive functions in the transfer task mediated by the completeness of mental models, that is, the representation of the learners together with other instructional elements in the concept maps (indirect effect of highest order interaction, b = -.05, SE = .03, CI α = .05 [-.13; .008]). Results revealed that the conditional indirect effect of presenting technological and pedagogical in an integrated way (TPK conditions) on the number of cognitive functions referred to in the comparison between WebDIVER and another video-tool (VideoANT) was negative and significant when prior PK was high (*b* = -.10, *SE* = .05, CI α = .05 [-.22; -.02]), but was not significant when prior PK was low (*b* = .002, *SE* = .02, CI α = .05 [-.04; .06]). This means, participants with higher PK in the TPK condition showed more complete mental models (β = .51, *p* = .003), more complete mental models, in turn, lead to less references to cognitive functions when participants compared the two technologies (see Figure 5.5). However, the conditional direct effect of the TPK condition for participants with higher prior PK (β = .37, *p* = .04) remained significant and became even larger (β = .53, *p* = .004), suggesting a suppressor effect of completeness.

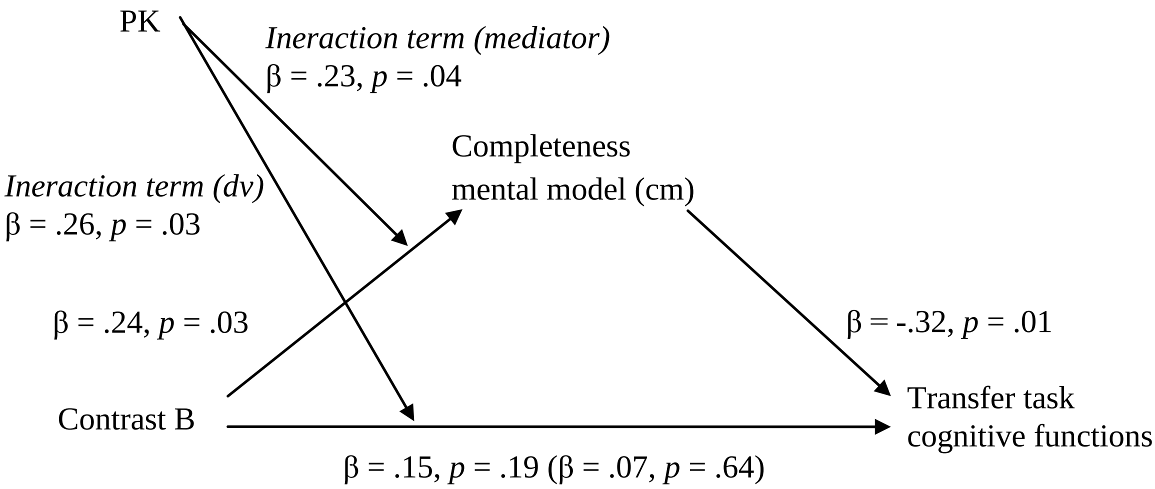

Figure 5.8. Mediation effects for the mediator completeness of mental models (cm = concept maps) and the moderator prior pedagogical knowledge (PK) mediating the conditional direct effect of the TPK condition on the reference to cognitive functions in the transfer task.

Taken together, results with regard to participants' performance in the TPCK and transfer tasks show for some indicators that, compared to the control group (TK only condition), pre-service teachers in both experimental conditions (TK+PK and TPK condition) showed a better performance. They wrote more elaborate answers to the comprehension task asking to infer the impact of specified changes to the pedagogy of the example lesson plan. They were also more specific in describing the affordances of WebDIVER in this task, as well as in the lesson plans they created themselves. Additionally, in these lesson plans they put a greater emphasis on students' comprehension. Moreover, significant interaction effects show that participants with high (versus low) prior PK in both experimental conditions differed in their performance from the control group. These participants rated the example lesson plan higher on socio-cognitive learning goals, and they described the potential impact of changes to the technology of the example lesson plan more elaborately. Furthermore, higher PK in both experimental conditions led pre-service teacher to be more elaborate and more reflective on their pedagogical reasoning when describing the added-value that WebDIVER brought to their own lesson plans.

However, there were other indicators which were only affected by presenting technological and pedagogical information in an integrated way in the TPK condition, compared to the control group and the TK+PK condition. Only pre-service teachers in the TPK condition described the learning goals and process they addressed in their lesson plans as well as the task instructions more elaborately. In addition, the teaching approaches presented in these descriptions were less teacher- and more student-centered. Moreover, in pre-service teachers with high (versus low) prior PK also exhibited better performance in the transfer task: they referred to more cognitive functions in the tool comparison task, exhibited a higher level of reflection on their pedagogical reasoning, and described technology affordances more specifically.

Furthermore, there were mediating effects for particular characteristics of participants' mental models of the learning-relevant functions of WebDIVER. A more interconnected representation of WebDIVER mediated the positive conditional direct effect of both interventions on participants' ratings of socio-cognitive goals in the example lesson plan. The positive effects on the elaborateness of participants' answers in the comprehension task were instead mediated by the elaborateness of their mental model descriptions. With regard to a stronger focus on students comprehension in the lesson plans of pre-service teachers both experimental groups it was the representation of cognitive functions of WebDIVER that mediated this relationship. Additionally, there was a negative indirect effect for the completeness of mental models showing that pre-service teachers with higher prior PK in the TPK condition exhibited more complete mental models, which, in turn, reduced references to cognitive functions in the transfer task. For an overview over the significant effects ordered by hypotheses (Contrast A and B) and moderating effects of prior PK (Interaction A and B) see Table 5.12.

Table 5.12
Overview over significant contrasts and interactions supporting the integrative *versus the* transformative *view on TPCK.*

Task	Indicator	*Integrative view* hypothesis **TK < PK+TK = TPK**		*Transformative view* hypothesis **TK = PK+TK < TPK**		Mediator (mm)
		Contrast A	Interaction[a] A	Contrast B	Interaction[a] B	
TPCK evaluation task						
Learning goal support	Socio-cognitive goals		+			Degree centrality WD (cm)
TPCK comprehension task						
Change in *pedagogy*	Elaborateness	+				Elaborateness
Change in *technology*	Elaborateness	+	+			Elaborateness
	Affordance specification	+				
TPCK design task						
Learning goals/processes	Elaborateness			+		
Task instruction	Elaborateness			+		
Added-value of technology	Elaborateness		+			
	SRL consideration		+			
	Affordance specification	+				
Teaching approach	Teacher-centered			-		
	Student-centered			+		
	Comprehension focus	+				Cognitive functions (cm)
Transfer task						
Comparison to WebDIVER	Cognitive goals				+	Completeness (cm)
	SRL consideration				+	
	Affordance specification				+	

Note. **+** = positive effect, **-** = negative effect, TK = Technological knowledge, PK = pedagogical knowledge, TPK = Technological Pedagogical Knowledge, TPCK = Technological Pedagogical Content Knowledge, WD = WebDIVER, cm = concept map, mm = mental model, SRL = self-regulated learning.
[a]Prior PK as moderating variable.

5.4 Discussion Study 3

The *transformative view* on TPCK, in contrast to the *integrative view* (Angeli & Valanides, 2009; Graham, 2011), claims that TPCK as complex knowledge is not spontaneously constructed by (pre-service) teachers on the basis of prior knowledge in the relevant sub-domains, technology, pedagogy, and content. This means that possessing such prior knowledge should not suffice for teachers to solve tasks that demand an orchestrated integration of all these aspects, such as lesson planning for added-value of technology. However, this claim has not been investigated in experimental settings and the two views on TPCK have not been empirically contrasted. Thus, the aim of this study was to investigate how pre-service teachers can be supported in the construction of mental models of a (digital video) technology that integrate its pedagogical impact (TPK); whether this can be achieved by providing pedagogical information separately or integrated into the encounter with a new technology.

Based on this, an experimental paradigm was created to contrast the two views on TPCK. Compared to a control group that received only technological information, pre-service teachers in one experimental condition (TK+PK) that operationalized the *integrative view* received information on how web-based video technology can impact the users learning before encountering a sample tool (WebDIVER). Pre-service teachers in another experimental condition (TPK) that was based on the *transformative view* were introduced to the same sample tool while simultaneously receiving information about its impact on learning, that is, the cognitive integration of technological and pedagogical information was modeled. Using contrast analyses it was tested, whether data supported one or the other view. Moreover and following up on the results of Study 1 and 2, prior PK was considered as a possible moderating variable. Additionally, the measures tapping into participants' mental models were complemented by a concept mapping task, and a transfer task was included to test, whether modeling the cognitive integration of technological and pedagogical information for *one* technology would have a long-term effects generalizing to *another*, similar technology.

Results with regard to pre-service teachers' mental models showed different effects for different indicators. On the one hand, there were effects of providing pedagogical information irrespective of whether it was presented separately (TK+PK condition) or in an integrated way (TPK condition). This was the case for the elaborateness of participants descriptions of their mental models, in which they also represented more cognitive (concept map) and socio-cognitive functions. Also the sample technology WebDIVER was represented in a more interconnected way. On the other hand, however, only pre-service teachers who had received the pedagogical information mapped onto the technological functions (TPK condition) exhibited more interconnected representations of pedagogical elements (students and teachers) as well as more complete mental models centering on the students' role. Moreover, the incremental effects of modeling the cognitive integration of technological and pedagogical information were specific to mental models as represented in the concept map data. Having higher prior PK moderated some of these effects and consistently lead to positive effects.

With regard to participants' performance in TPCK tasks, that is, the evaluation, comprehension and design of lesson plans that implement technology to create an added-value for student learning (TPCK tasks), results also differed for particular indicators. Compared to the control group, pre-service teachers in both experimental conditions rated an example lesson plan (collaborative scenario) higher for socio-cognitive goals. They were also more elaborate in inferring the potential impact of changes to the example lesson plan, and more specific in describing technology affordances in both their reasoning about the example lesson plan and their own lesson plans. Both experimental groups' lesson plans also focused more on the comprehension of students in comparison to the control group. However, only pre-service teachers who received in introduction to the sample technology that modeled the integration of technological and pedagogical information (TPK condition) exhibited better performance with regard to the pedagogical aspects framing the use of the sample technology: More elaborate descriptions of learning goals and processes, and task instructions that were also less teacher- and more student-centered. Moreover, only in this condition there were transfer effects, which attach additional value to these findings. In line with the findings for the mental model indicators that showed more complete representations centering on the students' role as well as more interconnected representations of teachers and students. Again, prior PK was a significant moderator for some of these effects; especially all effects on the transfer task introducing another video technology a good week later were only present for pre-service teachers with higher prior PK.

With regard to the question whether indicators taping into participants mental models of WebDIVER mediated the effects on the performance in TPCK and transfer tasks there were mixed findings. They did not show consistent effects for one indicator, and effects on lesson plan design and the transfer task in TPK condition could not be explained.

In sum, findings indicate that overall providing pedagogical information about a family of technologies prior to encountering an exemplar of this technology already supported a more complex understanding of the technology and impacted more general aspects of respective lesson planning tasks. However, more specific and longer lasting effects were only found, when the integration of pedagogical information was modeled during the encounter with the technology exemplar. Thus, overall the results are more in line with the *transformative view* on TPCK, however, the role of prior PK as moderating variable, especially regarding transfer, suggests that this perspective on TPCK also does not sufficiently capture the complexity of the issue. It was especially interesting that it does seem to be an important indicator how pre-service teachers represented and planned the role of the students. This furthermore coincides with the claim of Angeli and Valanides (2009) that the learners' role has to be specified by the TPCK framework. As a result and in line with the theoretical considerations discussed in Chapter 2 the conceptualization of the interrelations among the proposed TPCK sub-domains is relevant and demands further effort to develop a more process-focused TPCK framework.

5.4.1 Supporting the construction of mental models of tool functions

With regard to all effects, it is important to keep in mind that in the TPK condition all the effects that were significant for the TK+PK condition as well, plus additional effects. Thus, there were not trade-off effects and with regard to participants' mental models of WebDIVER this means that above and beyond more complex representations for more general indicators, pre-service teachers specifically showed more interconnected understanding with regard to pedagogical aspects. That these effects only concern indicators derived from concept maps, and are thus more structure related, shows that modeling the cognitive integration of pedagogical and technological information was indeed reflected by these results. These findings are, however, not trivial and clearly exceed a manipulation check, because of the different external representations used in manipulation(= text) versus the assessment (= drawing), and because in the manipulation teachers, students, and their roles and activities were not explicitly addressed. It can be concluded that, in addition to a text-based measure, which were also used in Study 1 and

2, it is important to also include measures that allow researchers to infer structural information about teachers' representations of the elements relevant for effectively teaching with technology should be further investigated. In the present dissertation it was especially important to also include such a measure because mental models are defined as representations of elements *and* their interrelations. Still, further research is needed to investigate which indicators derived from such measures are most appropriate. This will need to be complemented by more in-depth analyses of the concept-map data and trying different instructions for creating concept maps. The instructions for pre-service teachers in the current study were rather constrained by showing an example (for a neutral topic). This might have prevented participants from choosing shapes and symbols than participants would have under less constrained circumstance. Based on such research, it will be important to address the question, whether the conceptualization of TPK as mental models of technology in relation to cognitive, socio-cognitive, meta-cognitive, and motivational learning goals is sufficient. Current findings suggest, that structural measures need to be included in these considerations and that in these the role and network position of the pedagogical agents in relation to the technology should be included.

5.4.2 *Integrative* versus *transformative* view on TPCK

In the present study an experimental paradigm was suggested to operationalize more concrete hypotheses based on the *integrative* versus the *transformative view* on TPCK than it has been done in the related research so far. Overall, results show that the suggested manipulations were appropriate, and that modeling the cognitive integration of pedagogical and technological information can be conceptualized as an important aspect of transforming the understanding of technology for teaching. Even though the confusion that might be evoked by naming the process specifying the *transformative* view cognitive integration in opposition to the *integrative view*, there has been no need to call the process cognitive transformation, especially given the early stage of the theoretical development of the TPCK framework. What the results with regard to the moderating effects of prior PK suggest, however is that also the transformative view as formulated in the literature so far does not capture the processes in building a complex understanding of technology defined as a unique body of knowledge, namely TPCK. Therefore, future research should not focus on the dichotomy of the two opposing views on TPCK. Instead, present results suggest focusing more on the question of concrete interrelations between the knowledge sub-domains as suggested in Chapter 2. Empirically, the findings of this study need to be replicated for other technologies and also far transfer to different technologies needs to be shown. Additionally, other subject-specific issues will need to be addressed, for example by more closely examining prior CK similarly to it was done in this study with PK.

5.4.3 Mental models and lesson planning

Results of Study 1 and 2 suggested that pre-service teachers' mental models of a technology and its pedagogical impact have specific predictive validity for lesson planning. However, in those studies the findings were clearer for ideal ways of using the sample technology WebDIVER in comparison to actually intended and more concrete uses. In contrast, the present study focused on these concrete plans instead, which can be considered tasks that are closer to the later professional practice of participants. A major strength of this study was that the manipulations did produce meaningful effects on participants' concrete lesson planning and transfer task performance. However, given the more detailed measures tapping into both the mental models and lesson planning, it becomes more complicated to match indicators on both levels to scrutinize the potential function of the mental models as mediators.

For example, the elaborateness of mental model descriptions mediated effects on the elaborateness of answers to the comprehension task, but not those on the elaborateness of the designed lesson plans, which is surprising given the common methodological variance. On the other hand, it is interesting, because it suggests that lesson plan evaluation, comprehension and design as operationalized in this study seem to assess empirically separable aspects. The distinctness of the different TPCK tasks is further emphasized by the more specific findings, such as that a more interconnected representation of the video technology mediated the effect on socio-cognitive goal ratings in the example lesson plan, however the representation of cognitive functions in the concept maps mediated the effect of a higher focus on students' comprehension in both experimental groups. While both these effects are plausible, they do not form a coherent pattern. The most important challenge that remains is to identify the processes that lead to putting the student in the focus, because mental model indicators that theoretically could have acted as mediators, completeness and student centrality, did not do so in this study. An answer to this might be connected to the issue mentioned in Section 5.4.1, that more studies are needed to find the appropriate indicators to be derived from concept maps (and text-based items) in the study of TPCK.

An aspect that furthermore remains challenging to fit into the greater understanding of teaching with web-based video tools is the role of cognitive learning goals in this research using a sample video-tool that was designed for collaboration. For the transfer task there was an additional indirect negative effect showing that more completeness of mental models lead to less mentioning of cognitive functions when comparing WebDIVER and the transfer video-tool VideoANT. Although, higher prior PK in the TPK condition lead to more complete mental models and to the mentioning of more cognitive functions in the transfer task. The indirect effect could not help to explain these effects but rather acted as a suppressor. This shows that above and beyond these positive effects of the intervention and prior PK, a more complete mental model of WebDIVER situated in the classroom leads to focusing less on individual learning. However, it does not relate to a greater focus on collaborative learning, which could have been expected. Hence, this shows how complex the cognitive processes involved in the pedagogical reasoning about leveraging technology for teaching is, and that future research will need to adapt to this.

In conclusion, however, the present study provides a good starting point to continue a research agenda based on the assumption that mental models of technology in relation to its instructional impact are mediating factors in an overall TPCK process-model. And as always with regard to research on teaching classroom and student data will be needed in the long run to validate the actual importance to the lesson planning aspects affected by the manipulations in this study.

5.4.4 Limitations

Besides the limitations already mentioned there are some aspects that need discussion with regard to the validity and generalizability of the results. A major strength of this study in comparison to Studies 1 and 2 was that a sample of pre-service teachers was invited to the laboratory and by the recruiting process their status as pre-service teachers could be ensured. However, with regard to a study addressing teachers technology related competences it is likely that participants with positive attitudes toward and experiences with technology were overrepresented the sample. This is also suggested by the on average daily use of computers reported by participants. Therefore, results have to be interpreted carefully with regard to pre-service teachers less prone to using technology, and, of course, with regard to (older) in-service teachers.

Furthermore, the task instructions were rather constraining and limited, for example, the possibility of participants to omit certain aspects when describing a lesson plan, because separate text fields were provided for each target aspect. Similarly, the form of the concept maps was constrained by a concept map example. Even though this might mean a more conservative test, because all participants had the chance to provide specific answers, using such restrictive tasks could have thus lead to the missing of actually important parts of their reasoning, such as completely omitting aspects that they were forced to consider in these tasks. Another aspect with regards to the measures applied, was that the example lesson plan focused on scenarios more comment in the social sciences, which might explain less pronounced results in the evaluation and comprehension task in the present sample of pre-service teachers for a variety of subjects. In addition, the pedagogical setting of the example lesson plan (collaborative design task for historic newsreels), remains an uncommon setting within the current everyday life in German schools. As a result, there is need for joint effort in developing a taxonomy of TPCK measures that also consider task difficulty and subject specificity.

5.5. Conclusion of Study 3

For the example of digital video-tools, the findings of the current study indicate that modeling the cognitive integration of technological and pedagogical information for a specific technology can foster the construction of more complex mental models of the learning-relevant functions of this technology, and lesson planning for it. Given higher prior PK pre-service teachers in this study could also transfer this to a more pedagogical understanding of another technology. Furthermore, this studied showed that this is definitely the case for more general aspects, such as more elaborate and more specific answers, in comparison to only introducing technological information. But what is more interesting, this was also the case for more specific pedagogical considerations, such as the roles of students and teachers, in comparison to giving more abstract pedagogical information separately. Moreover, a very important finding for the further development of the TPCK framework was that prior PK of participants significantly played a consistent role as moderating variable. Higher knowledge about general pedagogical aspects of instruction, thus, seems to prepare future teachers for interventions that aim at developing their teaching relevant understanding of technology. In conclusion, this study could provide more specific empirical evidence for the *transformative view* on TPCK, but, at the same time, further supported the claim that there is ample need to study the interrelations of the professional knowledge sub-domains, that is, focusing on a more process-based model of the notion of TPCK.

6. General Discussion

Given continuously emerging digital technologies, the complexity of the task of teaching is being amplified. Teachers are put in charge of re-purposing these ubiquitous technological tools in order to turn them into tools for learning. Therefore, teachers have to thoroughly understand the learning-relevant functions of these technologies and have to relate these functions to the other domains of their professional knowledge. In the current research literature the Technological Pedagogical Content Knowledge (TPCK) framework (Mishra & Koehler, 2006) is a promising approach to describe this extended conceptualization of teachers' technological understanding. However, above and beyond characterizing the content of the proposed knowledge sub-domains of different combinations of technological, pedagogical and content knowledge, researchers invested in the TPCK approach have neglected to provide a theoretical basis for more concrete and confutable assumptions. As a result, there are still issues that remain unattended. There is a lack of clear definitions of how knowledge in the proclaimed sub-domains is mentally represented and how the different sub-domains presumably interrelate. Is knowledge in some sub-domains a pre-supposition for more complex knowledge in others or are the sub-domains independent? Furthermore, it also remains an open issue whether TPCK as a construct defines a unique knowledge representation or a combination automatically arising from knowledge in the sub-domains (cf. *transformative* versus *integrative* view of TPCK, Angeli & Valanides, 2009). And, if it is unique, what makes it unique? Finally, in this context there are no systematic empirical studies trying to assess the influence of teachers' prior knowledge on their understanding of technology and ultimately their intentions of using technology in their teaching. Based on these considerations two broader questions guided the work of the present dissertation:

1. *How can the TPCK framework be elaborated to focus on the underlying cognitive processes by employing the concept of mental models in order to derive assumptions about the proposed knowledge representations of the sub-domains and their interrelations?*
2. *Can empirical studies provide initial evidence for the assumption that mental models of learning-relevant technology functions impact (pre-service) teachers' lesson planning for emerging technology, in this case web-based digital video tools? What is the role of prior pedagogical knowledge (PK) in this?*

6.1 Summary of main findings

To tackle the first, theoretical question, a more general overview over the TPCK framework was provided in Chapter 1, and then presented an approach to fill the gap in the theoretical specifications of the TPCK framework in Chapter 2. In the current literature, authors most frequently propose seven knowledge sub-domains: Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK), and the central construct of Technological Pedagogical Content Knowledge (TPCK). Simultaneously, they claim that the TPCK construct needs to be considered a unique body of knowledge. However, until now there have been no elaborate conceptualizations of the knowledge representations proposed by the framework. I proposed to conceptualize teachers' understanding of technology in the light of the affordances they perceive the respective technology provides. More concretely I defined the notion of perceived affordances as *mental models of the learning-relevant functions of a technology*. Mapping this definition onto the TPCK framework, two levels of cognitive integration characterizing the development of TPCK were proposed (cf. Table 1.1), which also lead to a suggestions for a clearer definition of the TPCK construct. On the first level, the transformation of knowledge of the basic sub-domains (TK, PK, CK) into knowledge of the integrated sub-domains (PCK, TPK, TCK) is defined as the construction of mental models (Brewer, 1987; Johnson-Laird, 1980, 1983). For the second level of integration, referring to the construction of TPCK, considerations from the conceptual change literature (Clark et al., 2011; diSessa et al., 2004; Ioannides & Vosniadou, 2002; Vosniadou, 1994) were followed and TPCK was conceptualized as meta-conceptual awareness of the teaching task, the teachers own knowledge in the integrated sub-domains, and the context. In the light of this, TPCK as a scientific normative framework has to be conceptualized as a coherent structure of basic underlying assumptions (cf. framework theories, Vosniadou, 1994) that, in turn, constrain the construction of mental models in concrete situations. Nevertheless, it was discussed that novices in using technology for teaching might establish a fragmented understanding of using technology for teaching that would innately inhibit the development of a meta-conceptual understanding. Thus, the transition from such a fragmented toward a coherent understanding of TPCK can be considered a crucial incident for teachers to develop technology-related competences. In line with this, expertise in TPCK was defined as adaptive. This referred to the idea that possessing a well developed meta-conceptual awareness of what one requires to teach effectively with technology presents a foundation for adjusting to changing contexts, such as new emerging technologies.

To tackle the empirical shortcomings in the current research literature the second question was addressed in three empirical studies. With regard to the methodological approach the presented studies complement the empirical research documented in the literature by explicitly examining the relations between the proposed constructs via the application of regression analytic techniques (Studies 1 through 3) and an experimental paradigm (Study 3). As a basis for doing so, and for the first time in this line of research, a pedagogical knowledge test and recall measures of technology functions were applied to assess the PK and TK constructs instead of self-reported confidence measures (e.g., Schmidt et al., 2009). Furthermore, a concrete and distinct operationalization of TPK as mental models of the learning-relevant functions of a technology (in this case digital video tools) was provided, and lesson plans for specific subject matter content as indicators for the ability to solve TPCK tasks. Moreover, introducing an experimental paradigm Study 3 made it possible to contrast hypotheses derived from the *integrative* versus the *transformative view* on TPCK. Finally, conducting an experimental study also enabled investigating the role of prior knowledge in a basic sub-domain, here PK, as a moderator for pre-service teachers' understanding of technology, thus, addressing the claim that the interrelations between the TPCK sub-domains are a relevant issue for further developing the framework. Overall, this made it possible to sensibly investigate the relation among these selected constructs, in contrast to earlier studies that used fuzzily conceptualized self-report measures. Another aspect that was addressed by the present dissertation for the first time is that measures of pedagogical beliefs were included that have been claimed and shown to be an important factor for how teachers use technology, but never investigated together with the TPCK framework.

With regard to a sample technology, it was made use of digital video technology as an exemplar for emerging technologies. The reason for this was that research has shown that video technology indeed provides interesting potential for individual and collaborative learning. At the same time, research has shown that the effective use of these technologies requires an adequate pedagogical framing, which does not exist for the use of video in general. This contradiction between established patterns of video use and the potential of emerging technologies made it especially interesting to investigate how pre-service teachers would mentally represent the technologies functions and intend to apply these in class.

The aim of Study 1 was to investigate whether in a sample of pre-service teachers of various subjects their PK can predict the complexity of their mental models of the learning-relevant functions of a known digital video technology (YouTube); and, in turn, to investigate whether that complexity predicted two aspects of planning the use of YouTube with students in class: The intended use and an ideal use. Also the perceived barriers that might prevent participants from implementing their ideas for ideal instructional applications of YouTube were explored. The results were in line with the expectation that the mental models participants possessed of the functions of YouTube had a distinct influence on their lesson planning. In detail, higher prior PK positively predicted the quality of participants' lesson planning for YouTube. However, this influence was mediated by the complexity of their mental models of YouTube for the proposed ideal instructional applications of YouTube, and showed a marginal indirect effect for its intended use. Overall, the statistical effects were of moderate to small size. In their lesson plan ideas for instructional use of YouTube, participating pre-service displayed rather conservative applications of YouTube, focusing on YouTube as an audio-visual medium, and as a searchable database with some additional Web 2.0 features.

Based on the findings from Study 1, the aim of Study 2 was to investigate how pre-service teachers' understanding of the learning-relevant functions of a newly encountered video technology impacts their lesson planning for this technology. A sample video technology software was chosen that was designed for collaborative learning scenarios and that has been tested in previous research, WebDIVER™. Furthermore, the subjects of participating pre-service teachers were constrained to history and language arts. With regard to lesson planning, the concrete topic of propaganda in post-war Germany was provided as a sample topic to reduce variability with regard to participants' CK. In addition to designing an own lesson plan for this sample content I provided a sample lesson plan that was evaluated by participants. Qualitative results show that participants represented the specific socio-cognitive functions of the tool in their mental models. In contrast to this, participants also tended to understand WebDIVER as an editing tool for their own use instead of understanding it as a learning tool for their students. Furthermore, in their designed lesson plans, specific tool functions were only partly reflected and participants relied upon tool-unspecific uses. Quantitative analyses showed that participants' mental models of the functions of WebDIVER predicted their proposed ideal uses of the video tool and their ratings of an example lesson plan. Furthermore, investigating participants' mental models as predictors revealed differentiated results: when cognitive functions were represented in the mental models there was generally a positive association with indicators for the proposed ideal uses of WebDIVER. In contrast, there was a negative association with ratings of the example lesson plan's potential to support both cognitive and socio-cognitive learning goals. The representation of socio-cognitive functions, on the other hand was related to more specific concrete lesson plans. In contrast to the results of Study 1, prior PK (or TK) did not predict participants' mental models of the functions of the sample technology. Thus, no mediating relationship was found. Furthermore, a more constructivist orientation (pedagogical beliefs) did not predict any dependent variables and were also not related to PK and mental models. In sum, the assessed constructs showed distinct predictive validity and facilitating as well as inhibiting associations with TPCK tasks. Overall, the statistical effects were of moderate size.

Study 2 showed that providing only technological information about a new (video) technology did not seem to foster the spontaneous construction of complex mental models of this technology. Additionally, prior PK also did not predict mental model indicators, in contrast to Study 1. Therefore, complementing these two studies, the third study attempted to investigate different ways of supporting the construction of adequate mental models of the same video-tool (WebDIVER) with regard to instruction. It addressed the question of how the cognitive integration of technological (TK) and pedagogical knowledge (PK) can be guided in order to support (pre-service) teachers in the construction of more complex mental models of learning-relevant tool functions (TPK; cf. arrow c in Figure 2.2). To answer these questions, an experimental paradigm was designed that aimed at operationalizing the contrasting *integrative* (Experimental Condition 1 = technological and pedagogical information separately) versus *transformative view* (Experimental Condition 2 = modeling the integration of technological and pedagogical information) on the concrete level of applying pedagogical considerations to a specific tool. Additionally, prior PK was investigated as a potential moderator. Two tasks were added in comparison to Study 2. A comprehension task was constructed based on the same sample lesson plan. In order to explicitly tap pre-service teachers comprehension based on a functional mental model of the video tool, the respective items asked participants to infer the potential impact of changing the pedagogy, and technology of the example lesson plan, respectively. Also, a transfer task was added in which participants had to compare WebDIVER with another web-based video tool in a follow-up measure.

Overall, results of Study 3 showed that that in comparison to a control group (only technological information), more general characteristics of participants' mental models of WebDIVER (elaborateness or centrality of WebDIVER in concept maps) could be supported by both experimental manipulations, that is, presenting pedagogical information and technological information regardless of is form (providing pedagogical information separately versus modeling its cognitive integration) supported more complex mental models of WebDIVER with regard to its pedagogical impact. The same was true for the TPCK evaluation, comprehension and design task. However, only the explicit modeling of how to integrate information about technological functions and their pedagogical impact (Experimental Condition 2) lead to a more complete mental models, and more central representation of the pedagogical agents (students and teachers). In line with this, pre-service teachers in this condition created more student-centered and less teacher-centered lesson plans for WebDIVER. An important finding was that for many indicators the effects were only present for participants with higher prior PK. Especially with regard to transfer task performance, only participants with higher prior PK in the second experimental condition provided comparisons indicating a deeper pedagogical understanding of web-based video tools a good week later.

Comparing the results of the studies, an important difference between Study 1 and 2 was that in Study 1 PK was a significant predictor for the complexity of participants' mental models of YouTube, whereas none of the assessed constructs significantly predicted the different aspects of participants' mental models of the functions of WebDIVER. There are methodological differences between the studies that make it difficult to directly compare between the two studies, for example, in Study 1 there pre-service teachers taught many different subjects, and they were asked about a video tool they also used in their private lives. In this case, the more participants had prior PK the more complex was their understanding of YouTube functions. In contrast, in Study 2, participants did not know WebDIVER in advance and only learned about it in a study for which they were explicitly recruited in their role as pre-service teachers. Therefore, even though some participants in Study 2 also mentioned ideas for using WebDIVER privately, it seems that it was not their prior PK that influenced their immediate understanding of the technology's functions. Furthermore, participants all had a history and language arts background; both areas that are as school subjects not inherently open to technological developments. Finally, WebDIVER also provides more specific affordances with specific influences of the different aspects represented in the mental models (cognitive versus socio-cognitive in Study 2) rather than just more or less complex mental models with regard to the representation of more or less learning goals addressed (Study 1).

Study 3 differed from Study 2, because this study took a slightly different approach by focusing on the manipulation of the construction of mental models of the learning-relevant functions of WebDIVER and not only looking at the interrelations among the different variables without any external support. This was done, because in line with the results of Study 2 and the transformative view on TPCK the integration of prior knowledge (here PK) alone does not support the understanding of a new technology. However, what Study 3 was also able to do, was showing the role of prior PK as a moderating variable for encountering new (video) technology. This had not been possible in Study 2 due to methodological limitations in Study 2. Comparing the results of Study 1 and 3, the claim of Cox' (2008) and Graham (2011) that when emerging technologies become transparent the differentiation of TPCK becomes less imperative, and the knowledge about its use for instruction might become part of a teacher's more basic knowledge might explain why PK was related to mental models of YouTube, but not WebDIVER. For the latter external support was needed. For leveraging this support, however, prior PK again played an important role.

In conclusion, however, the theoretical elaborations presented in Chapter 2 provided a fruitful basis for investigating concrete assumptions in initial empirical studies following the present conceptualization of the TPCK framework. All empirical studies were able to provide initial support for the hypothesis that (pre-service) teachers' mental models of learning-relevant functions of technology have a distinct influence on their lesson planning for this technology. This influence was clearer and stronger when participating pre-service teachers were asked to describe ideal ways of using the respective video technology prompted in Study 1 and 2. However, the more fine graded lesson planning tasks in Study 3 could also show some effects of mental models characteristics on more concrete lesson planning. With regard to the influence of prior PK, results overall show that this knowledge seems to play a role for planning the use of technology in class. This influence is, however, not a simple and direct one. Instead, the influence of the rather abstract PK is indirect through mental models of tool functions (Study 1), or on the other hand, qualifies attempts to support the construction of complex mental models (Study 3). Furthermore, and in line with prior assumptions, simple knowledge of technological functions (TK) did not contribute to pre-service teachers' lesson planning. Another important finding of both studies was that pedagogical beliefs can be distinguished from the investigated knowledge constructs and, thus, a further integration of both aspects into future research is recommendable.

In the following sections the strengths and limitations of the current dissertation will be discussed in more detail and present directions for future research and implications for teacher education at this point.

6.2 Strengths and Limitations

6.2.1 The current elaboration of the TPCK framework

A major strength of this dissertation is the attempt to clarify what is meant by knowledge in the context of the TPCK framework. This is a unique theoretical contribution to the discussion of whether all sub-domains proposed by this framework have a distinct value for explaining what teachers need to know in order to leverage the potential of emerging technologies and thus create added value for student learning. So far, there have only been efforts to define the *content* of the different TPCK sub-domains more precisely (Cox & Graham, 2009, 2009; Graham et al., in press), however, the representational *form* of the knowledge in these areas has not been addressed. By introducing two levels of necessary cognitive integration into the TPCK framework, it became possible to disentangle the fuzzy boundaries between the different sub-domains: The basic sub-domains pedagogy, and content, represent independent bodies of knowledge that are not sufficient to solve the task of teaching with technology, yet they are likely to be pre-requisites for constructing more complex forms of knowledge. At this level, the role of representational format for teaching is still open for discussion, however, based on the reported concern that knowledge that is being delivered in teacher education programs is innate (Gruber & Rehrl, 2005), it can be assumed following Shulman (1986) that this basic knowledge is for the most part propositionally represented. Before this background, my assumption is that on a first level of cognitive integration the development of knowledge in the sub-domains of PCK, TPK, and TCK has to be connected to the transformation of prior, most likely propositional knowledge, into mental models of the respective sub-domains. The notion of mental models as analogous cognitive representations of relevant elements and their interrelations is in line with the idea that these integrated sub-domains are conceptualized as more complex knowledge bases already serving to solve sub-tasks specific to teaching with technology. The assumptions proposed in this dissertation are congruent with the established conceptualizations of PCK by Shulman (1986, 1987) and also more recent lines of research that have supported them empirically (Blömeke et al., 2010; Krauss et al., 2008; Kunter et al., 2007). TPK was defined as mental models of technological functions with regard to their impact on cognitive, socio-cognitive, meta-cognitive, and motivation educational goals. In contrast, there is still a lack of a more generic conceptualization of TCK, which was further left unaddressed in this dissertation. Because, however, the idea that emerging technologies provide unique access to content, such as the development of electron microscopes that have enabled the visualization of single atoms, seems central to the scientific development of the disciplines the school subjects are based on. Thus, this construct needs to be included into future research more explicitly.

With regard to the still only vaguely specified notion of TPCK as a unique body of knowledge (cf. the *transformative* view of Angeli & Valanides, 2009) a second level of cognitive integration was proposed that defines TPCK as a teacher's meta-conceptual awareness of the teaching task, the teachers' own professional knowledge in the other sub-domains, and the contextual constraints. This conceptualization is on the one hand in line with Shulman's argument (1986) that the teacher's awareness of his or her own knowledge is a definitive aspect of being a professional. On the other hand, this is line with the literature on conceptual change that conceives of the development of meta-conceptual knowledge as an important part of the development from the naïve understanding of a novice to the scientific understanding of the experienced professional (diSessa et al., 2004; Hatano & Inagaki, 1986). Therefore, TPCK as a scientific normative framework, has to assume a coherent structure of basic underlying assumptions (cf. framework theories, Vosniadou, 1994) that constrain the construction of mental models in concrete situations rather than fragmented, unconnected knowledge in pieces that innately inhibits the development of a meta-conceptual understanding. In the case of TPCK, the underlying framework theories were not explicitly addressed in this dissertation and still need to be extrapolated from theory and qualitative research. This complementary consideration of theoretical approaches as well as concepts emerging from qualitative analyses of teachers' own reasoning was applied in the present dissertation exemplarily for the integrated sub-domain TPK. On one side, four aspects of educational goals, cognitive, socio-cognitive, meta-cognitive, and motivational, were considered central for determining the potential of a technology. On the other side, this theoretically driven approach was complemented with the categories that emerged from participants' descriptions of the potential of YouTube and WebDIVER (Studies 1 and 2), respectively. Moreover, in the Study 3 analysis of a concept map measure also showed to tap into structural aspects of participants' mental models of the video-tool regarding its impact on instruction and learning. Here, the representation of students was revealed as a relevant indicator that seems to differentiate a more complex understanding of technology in this context. The importance of the representation of students in the visualization of the TPCK framework has been claimed by Angeli and Valanides (2009), however, there was no empirical evidence supporting this claim. Moreover, the present results also suggest that adding students as another separate factor into the framework does not seem to be most important. Instead, it is the question of whether and how teachers consider students within their representations of the sub-domains. In conclusion, further theoretical developments will need to try and integrate this issue into a generic, structural definition of TPK. Furthermore, a more solid validity of these aspects regarding lesson planning and teaching have to be established.

In the empirical studies both these approaches could successfully be operationalized and applied to pre-service teachers' answers. Combining these two perspectives can be considered another strength of this dissertation, because this way generic and specific aspects of technology in the educational context can be tackled simultaneously.

A limitation with regard to the connection between the theoretical assumptions explained as an answer to the first research question is that in the empirical studies at this point, the definition of TPCK as a meta-cognitive construct was not explicitly addressed. However, there is initial empirical evidence showing that self-regulatory support, as an aspect of meta-cognition, has a positive effect on the evaluation and the design of lesson plans for utilizing technology (Kramarski & Michalsky, 2010).

6.2.2 Blind spots entailed by the TPCK framework

Although the introduction of the TPCK framework has sparked an increasing number of research studies and conceptual papers (Voogt et al., 2012), there are blind spots that are not addressed when following only this approach. A strength of this dissertation was to tackle one such blind spot, namely, the neglect of teacher beliefs and to provide evidence that this construct has discriminant validity and calls for further integration into the TPCK framework. Attaining this amendment was possible because several lines of research were considered to complement my proposed elaboration of the TPCK framework. A body of literature that was deemed important to consider stems from research on teacher competence in general that focuses on four related aspects. First, general Pedagogical Knowledge and Pedagogical Content Knowledge (Baumert & Kunter, 2006; Ben-Peretz, 2011; Blömeke et al., 2008, 2010; Klusman et al., 2008; Krauss et al., 2008; Kunter et al., 2007; Tatto et al., 2008; Voss et al., 2011), second, teachers' beliefs (Dubberke et al., 2008; Maggioni & Parkinson, 2008; Souvignier & Mokhlesgerami, 2005; Staub & Stern, 2002), third ,teacher reasoning and lesson planning (Blömeke et al., 2006; Calderhead, 1996; Clark & Yinger, 1979; Kiper & Mischke, 2009; Peterson, Marx, & Clark, 1978; Shavelson & Stern, 1981; Yinger, 1980), and, finally, expertise in teaching (Berliner, 1992, 2001; Leinhardt & Greeno, 1991). Furthermore, research on teacher beliefs was considered in relation to their use of technology (Anderson & Maninger, 2007; Chen et al., 2009; Ertmer, 1999, 2005; Law, 2008; Teo, 2009a, 2009b; Teo et al., 2008). With regard to the empirical research presented in this dissertation, a major strength that resulted from extending my reading beyond the core TPCK literature was that methodological approaches from these lines of research were adopted that have not been applied to TPCK-related research so far. First, the application of knowledge tests instead of self-reported confidence measures, second, the simultaneous investigation of knowledge and belief measures, third, the use of regression analytic techniques investigating mediating and moderating relations among the different construct, and, finally, an experimental paradigm to test more concrete hypotheses derived from the elaborated TPCK framework. Another strength was the consideration of discussions in the conceptual change literature discussed above (Clark et al., 2011;

diSessa et al., 2004; Hatano & Inagaki, 1986; Ioannides & Vosniadou, 2002; Vosniadou, 1994). However, there are still further aspects that were not integrated at his point, such as motivational aspects of teachers' technology-related competences.

Teacher motivation and technology use

With regard to motivational aspects, teachers' self-efficacy for using technology is a construct that has more prominently been discussed. This is interesting because thus the strength of this dissertation to try and tap into teachers' knowledge with operationalizations avoiding the frequently used TPCK self-efficacy scales (e.g., Schmidt et al., 2009) lead to the tradeoff of neglecting this aspect. Findings from empirical studies not related to the TPCK approach show that higher self-efficacy in teachers leads to an increase in the intention to use digital technologies in their classroom teaching (Compeau, Higgins, & Huff, 1999; Sang, Valcke, Braak, & Tondeur, 2010). In accordance with these findings, research applying expectancy x value models of motivation show that the *expectancy* to successfully utilize technology in their teaching exhibits significant predictive power for the self-reported actual use of digital technology for teaching (Wozney, Venkatesh, & Abrami, 2006). What is important to mention in this context is, that a relevant source for the expectation of success is being familiar with using technology. However, this familiarity mostly results from teachers' private technology use (Wozney et al., 2006) and only to a small extent from their professional training. This is a situation that is repeatedly criticized by teachers themselves (e.g., Smarkola, 2008). In spite of the importance of teachers' computer-related self-efficacy for the intended and self-reported use of digital technology in class, the perceived added-value of the respective technology for reaching educational goals (*value*-component) is another relevant factor (cf. Smarkola, 2008). A line of research that adheres to this assumption relies on the *Technology Acceptance Model* (TAM, e.g., Davis, 1989). Studies following this approach investigate the *perceived usefulness* of a technology as an important influence on teachers' intentions of using technology, next to the *perceived ease of use* and individual teacher characteristics. Teo (2009b), for example, could show in a survey study with 475 pre-service teachers that a technology's perceived usefulness exhibited both direct and indirect effects on participants' intentions of technology use.

In conclusion, further research is needed to compare and carve out the commonalities between the TPCK framework and these approaches to reach a more economic, overall conceptualization of teachers' technology related competences. Not to forget that this would also broaden the overall scope by shifting the focus more onto the question of whether teachers are planning to use technology at all, instead of how, based on their profession competence, they would use it. The most interesting way of integrating this aspect would be to investigate the question whether a more complex understanding of the potential of technology automatically leads to an increased motivation to use technology, or whether there are different, unrelated motivational factors in play.

6.2.3 The role of mental models of technology functions for lesson planning

Assuming that prior knowledge in the basic sub-domains is not sufficient for teaching with technology (*transformative view*) leaves the open question of whether this prior knowledge might still be a necessary pre-requisite. In the empirical studies of the present dissertation this question was investigated for the example of PK and TK as possible predictors for mental models in the domain of TPK, and the influence of all three of them on concrete lesson plans as indicators for TPCK. In Study 1, results showed a mediating effect of the mental models of participants for the relation between prior PK and lesson plans for YouTube. Even though this could not be shown for an encounter with technological information about a new technology in Study 2, results of Study 3 also showed mediating effects of mental model indicators, and also prior PK to be a moderator for the effects of differently introducing pedagogical information on TPCK task performance. These differences will need to be followed up by future research because mediation and moderation hypothesize different underlying processes.

Mediation analysis aims at testing a process hypothesis that assumes that an independent construct (PK), has an effect on a dependent construct (TPCK task), and that a transmitting variable (TPK) covaries with both these constructs such that it explains the influence of the independent on the dependent variable. Thus, a mediating effect of teachers' mental models of technology functions (TPK) suggests that PK and TPK covary in a way that the influence of abstract pedagogical knowledge is only relevant for lesson planning to the extent that it is integrated into the understanding of the mental models of learning-relevant functions of this technology. Moderation analysis on the other hand, aims at testing a hypothesis regarding the different ways of supporting knowledge construction (TPK) that affect a dependent variable (TPCK tasks) more or less depending on a moderating variable (PK). In this case the influence of the independent on the dependent variable is thought to depend on the state of another unrelated variable (cf. Jacoby & Sassenberg, 2011, p. 181). Thus, a moderating effect of teachers' prior abstract pedagogical knowledge (PK) on the construction of mental models of technology functions on their lesson planning (TPCK task) suggests that whether certain aspects are represented in teachers mental models (TPK) is not caused by their prior knowledge but the successful support in interventions depends on it.

As mentioned above, the three studies presented here differ with regard to a number of aspects that complicate direct comparison. At this point, the different results have to be considered mixed first findings until the effects have been replicated and substantiated in experimental studies. A major limitation of the first two studies is their correlational nature, especially with regard to the fact that mediation and moderation depend on experimental designs in order to truly test causal relations. Furthermore, Jacoby and Sassenberg (2011) even suggest experimental procedures to actually test mediation in experimental designs that statistically test moderation (interaction) effects. Thus, disentangling the nature of the underlying processes of what influences the construction of mental models in comparison to what these mental models, in turn, influence is only possible in more controlled experimental studies. For example, in order to tap into the construction of mental models, experimental are needed that interfere with the construction. The experimental paradigm introduced in Study 3 took a first important step in addressing this limitation. Results of Study 3 indicate that the control group (TK only) only providing technological information, parallel to Study 2, seems to already inhibit the construction of more complex mental models and the activation of prior PK. However, future studies would need to make sure that participants with the same information but without the possibility to combine them show the same detrimental effects. For this, however, indicators like those derived from concept maps need to be developed and improved to address such process oriented hypotheses are needed. In future studies when participants interact with the new technology process measures such as log files or even eye-tracking data should be assessed make this link.

Overall, the findings of all three studies have shown that—given the proposed operationalizations—the different knowledge constructs can empirically be discriminated and although modeling of the cognitive integration of pedagogical and technological information seems necessary (*transformative view*) prior knowledge (PK) plays a significant role to enable pre-service teachers to leverage certain learning opportunities.

Thus, although the present dissertation provides initial evidence that the suggested operationalizations and basic study designs provide a new starting point to further scrutinize this question.

The measurement of mental models

One strength of assessing participants' mental models of learning-relevant functions of the respective video technologies is that this operationalization of TPK clearly taps into a more complex understanding of technology than other measures of technological skills do (e.g. the INCOBI for students, Richter, Naumann, & Groeben, 2001). Additionally, combining a theoretical and an empirical approach for coding participants' answers to the question of what the most important functions of the respective technology makes it possible to gain comparable results across studies (coding the four categories cognitive, socio-cognitive, meta-cognitive, and motivational educational goals), as well as covering the specific aspects of the individual technologies (coding the categories that emerged from participants' answers, see also Section 5.2.5). Although this bifocal approach was applied to digital video technologies in the present studies, it is applicable to other technologies, and therefore provides a basis for future research and efforts to replicate the present findings.

Another major strength was the inclusion of a concept mapping task in Study 3 to assess also structural information about participants understanding of a technology. This addressed the limitation of the only text-based measures in the first two studies. Because the notion of mental models implies analogous representations visual or image representations more appropriate, or at least as important as content focused measures. A limitation to the present application of concept maps was the focus on only one structural parameter, centrality. Future studies could further leverage the potential of concept maps by using respective software and automated analyses (e.g., Clariana et al., 2011) to compute other statistical parameters based social network analysis.

A way to improve the text-based assessment in the present studies could be to compare participants' explications of their mental models to sophisticated or complete mental models of experts (e.g., Azevedo & Cromley, 2004). However, defining expert solutions in this context might prove difficult, because the relative nature of perceived affordances of emerging technologies render it difficult to determine whether a certain mental model has exhausted a technology's potential. In contrast, in the case of mathematics teachers, for example, it is possible to determine whether their representation of how to explain a mathematical "fact" or how to answer to different misconceptions of students is correct or not (cf. Krauss et al., 2008). Therefore, in the context of emerging technologies it seemed more appropriate to refrain from including external measures of correctness or quality of participants' mental models until the research base for determining the actual effects on student learning is better developed.

These considerations are another reason why WebDIVER and the Berlin Blockade lesson plan example were selected for the second and third study, because both have been rather intensely studied, and the beneficial effects on collaborative learning settings have an empirical foundation. Thus, it would be possible to come up with actual knowledge tests for teachers; however, given the number of technologies and the fast development – which constitutes part of the outset problem of this dissertation – would not be addressed by such a measure. Items would become obsolete very quickly. Thus I still consider the approach of assessing the perceptions of teachers based on widely established dimensions of educational goals more appropriate for answering to the challenge of changing technology (affordances).

A limitation with regard to the operationalizations of mental models in the empirical studies of this dissertation is that measures applied cannot distinguish between the construction of new mental models or the activation and modification of old ones. Following the notion of mental models argued here (cf. Brewer, 1987; Johnson-Laird, 1980, 1983), theoretically, teachers should construct a respective mental model when confronted with the situation to consider the functions of a technology. However, especially with regard to already familiar technology, such as YouTube, it is likely that the participants in Study 1 relied on examples of using YouTube for education from their past. Hence, future studies would benefit from assessing change in the assessed mental models over time in order to pinpoint the integration of new information rather than the activation of old information.

6.2.4 Lesson planning versus classroom teaching

According to Shavelson (1983, p. 401), the importance of lesson planning for teachers' classroom teaching cannot be overestimated. By creating plans on different time dimension (year, term, month, week, day), teachers provide frames for their actual, interactive behavior in the lesson. Overall, the central basic unit of lesson planning is the *task*. And, with regard to how teachers approach the planning of such instructional tasks Shavelson reports Yinger's (1977) findings that show: teachers themselves approach planning like a problem-solving task. While their solutions are likely to be greatly influenced by what they are used to actually do in class, teachers' lesson plans are considered a better estimate of the implicit theories teachers hold and against which they evaluate their actual performance (Clark & Yinger, 1979). In contrast, their actual behavior is considered to be concerned with classroom management issues. Thus, because in the focus of the present dissertation was on teachers' cognitions not, their classroom skills, assessing lesson plan ideas as the dependent variable is a major strength of the empirical studies of this dissertation. This notion was even elaborated by making a difference between ideal lesson plan ideas and actually intended ones.

However, even though planning with regard to educational objectives on the lesson level is explicitly advocated in teacher education (cf. Kiper & Mischke, 2009) and often prompted in laboratory settings (Shavelson, 1983), it is likely that teachers in the field revert to roughly distributing the obligatory content over given time periods. Thus, there clearly remains a gap also between the measures of this study and what participants might do in their classroom practice in the future. Nevertheless, lesson planning remains an important issue of teacher training, and therefore also provides material for reflected practice, which in turn is considered to be a means for establishing expertise in the long run. Moreover, qualitative studies have shown contingencies between planning and teaching. For example, in her dissertation Harrington (2008) followed three pre-service teachers through pre-, inter-, and postactive phases of teaching mathematics with the help of technology. She could show, even though the participants' reasoning grew more elaborate over time and contexts, their more abstract mental models (Harrington talks about conceptions) influenced their specific lesson plans and teaching activities. From my point of view this can be understood as initial findings showing that pre-service teachers' mental models of technology (here more abstract between *using* technology as teaching tool versus *doing* technology as part of the lesson content) also impact their behavior beyond lesson planning. Harrington furthermore reports that in one case in spite of unsuccessful lesson implementation this pre-service teacher's ideal of instructional use of technology was kept and even reinforced. Thus, this shows that the postactive reflection of a lesson seems another important source for teachers' mental models of what technology can do and their ideals of lessons integrating technology, pedagogy, and content that should be addressed in future studies.

Similar to the assessment of mental models, the quality of lesson plans in the sense of comparing to expert solutions or expert ratings was not assessed. These would be valuable additions in future research; however the confound of experts providing examples or coding with regard to what is the Zeitgeist of teaching at the time. The measures applied here stay within the teachers' own categories or those of the four proposed dimensions of educational objectives. Of course, there are possible frameworks in the literature that could be used as anchor points for more objective evaluations, such as the 12 basis models of teaching proposed by Oser and Baeriswyl (2001) based on general theoretical approaches to teaching. Also, a critical point could be that the coding in the presented studies does not specifically address the quality of the technology integration. The coding scheme devised by Harris, Grandgenett, and Hofer (2010) for example suggests to rate lesson plans on the four dimensions *alignment of curriculum goals and technology*, *technology support for instructional strategies*, *technology selection in line with curriculum goals and instructional strategies*, and the *fit between content, pedagogy, and technology*. Another example is provided by Raby (2011) who proposes four levels of pedagogical integration of technology possible analytic categories: *familiarization*, *exploration*, *infusion*, and *appropriation*. All these rubrics, however, tap very distal categories that also are inclined to be confounded with what is considered good teaching at the time. Nevertheless, the current operationalization of using the breadth of aspects in a lesson plan as an indicator of quality is debatable, because, for example, 20 ineffective ideas comprised in one plan do not make it a good plan. Future research will have to integrate several measures to tackle this issue.

There are two further issues that limit the use of lesson planning as dependent variable in the present dissertation. First, it is not clear whether (pre-service) teachers who devise better lesson plans will also perform better in class, or vice versa, do teachers only devise plans they are able to teach? The differences between the results for ideal uses and intended uses of the video tools in the present studies indeed suggests that thinking about what a teacher can constrain the development of tasks ideas. In this context, it is important to consider differences between expert teachers and novices that have to be expected with regard to approaches to planning (cf. Leinhardt & Greeno, 1991). Second, the ultimate standard lesson plans need to be tested against is the learning of students.

Thus, a great challenge remaining, from my point of view, is getting together factors on the teacher and the student side, which, first of all, means relating teachers' planning and implementing to students' mental models and behaviors (cf. Gerjets & Hesse, 2004). Although there is evidence showing that teacher knowledge predicts better task quality which, in turn, predicts better student performance in the context of regular mathematics instruction (Baumert et al., 2010), this connection has to be empirically established for the relations investigated in the present dissertation.

6.2.5 Utilizing digital video for teaching

The rationale behind using digital video tools such as YouTube and WebDIVER as sample technologies in the empirical studies of this dissertation was that they exemplify the tension between leveraging the concrete potential of a specific technology and the pervasive patterns of using traditional technology prior to this. For the case of video technology, empirical research was able to provide evidence that the affordances of new video tools can provide specific potential for learning in the classroom (e.g., Merkt et al., 2011; Zahn, Krauskopf, et al., 2010; Zahn, Pea, et al., 2010). At the same time research also showed that potentials need to be leveraged by teachers selecting and creating adequate tasks and instructional guidance (Caspi et al., 2005; Merkt et al., 2011; Zahn et al., in press). However, as Hobbs (2006) showed, with regard to utilizing video in instructional settings, teachers mostly revert to activities that are unrelated to learning.

In the present dissertation it was investigated how pre-service teachers' prior knowledge and mental models influence their lesson planning for digital video tools. Besides the results on the interplay between theses constructs, the results also provided more concrete insights into the tension between general and specific aspects in pre-service teachers' proposed uses of video technology for classroom instruction. Comparing the conceptualization of YouTube and WebDIVER on the level of the categories that emerged from participants' answers illustrate nicely how the lesson plans of participants mirror this tension (see Table 5.1). On the one hand, without regard to coding frequencies for each category, participants in both studies referred to a number of resembling goals video technology can serve in instruction. Of special interest here is, except one category (Students' productive use) all other common categories referred to aspects that would also apply to a TV set with a VHS player (Content Elaboration, Exchange, Lesson Start, Motivation, Students' Media Literacy, Teacher Presentation, Vividness [of Content]). On the other hand, there are categories that emerged specific to the technology: the potential use of YouTube was additionally characterized by its Accessibility, potential for Entertainment, as a tool for Foreign Language instruction, and as an Information Repository. Thus, besides Entertainment, these categories point to the conceptualization of YouTube's specific affordances as those of a database. The potential use of WebDIVER was additionally characterized by enabling Detail Perception, supporting Empathy for characters in the video, Historic Comparison[s], and for the teacher as tool for Material Preparation and Shortening Movies. Thus, the conceptualization of WebDIVER's specific affordances adhered more to that of an actual tool for working with video material, although strongly focused on the teachers as user. Furthermore, these specific differences also become apparent when—carefully—comparing the percentages of the common categories for the proposed ideal uses of both tools. This comparison also shows that WebDIVER was seen more as a tool for collaborative settings (Exchange), and student activities (Students' Productive Use) than YouTube, which was in turn seen more as a video library for the teacher (Teacher Presentation). Thus, overall pre-service teachers did respond to the specifics of the respective technologies. Nevertheless, (potentially inadequate) use patterns that are pervasive (cf. Schmotz, 2009) and might have been taught to them during training (cf. Baskiewicz, 2011) seem to play a specific role when pre-service teachers attempt to appropriate video technologies for their teaching. Future research will have to try to disentangle these influences and determine what other goals the reproduction of inherited patterns of technology use might serve, such as teachers' stress regulation or reacting to time constraints.

Table 6.1
Comparing emerging categories for coding lesson plans.

Emerging categories for coding YouTube lesson plans Study 1 (% for ideal use)	Emerging categories for coding WebDIVER lesson plans Study 2 (% for ideal use)
Content Elaboration (25%)	Content Elaboration (21%)
Exchange (8%)	Exchange (25%)
Lesson Start (8%)	Lesson Start (4%)
Motivation (7%)	Motivation (0%)
Productive Use (Students) (12%)	Students’ Productive Use (33%)
Students' Media Literacy (12%)	Students' Media Literacy (13%)
Teacher Presentation (32%)	Teacher Presentation (17%)
Vividness (35%)	Vividness (17%)
Accessibility (2%)	*Detail Perception (25%)*
Entertainment (3%)	*Empathy (4%)*
Foreign Language (5%)	*Historic Comparison (17%)*
Information Repository (28%)	*Material Preparation (Teacher) (8%)*
	Shortening Movies (25%)

Note. Categories are sorted in alphabetical order. Categories in italics could not be matched between the studies.

6.2.6 Generalizability of results

As mentioned in the discussion of the individual studies, there are limitations to the generalizability of the empirical results. First, with regard to Studies 1 and 2, although research has shown that studies conducted online can be comparable in most ways to studies in the laboratory (e.g., Yetter & Capaccioli, 2010), the results have to be interpreted cautiously. In spite of a number of participants who uttered concerns about using the video tool in both studies, there is a heightened probability for the over-sampling of technophile participants. Even though the larger part of Study 3 was conducted in the laboratory, the oversampling of technophile participants might still be true. However, in this study recruiting method could guarantee for their regular teacher student status. Second, due to the small size of the samples (especially Study 2), and the anonymity of an online study (Studies 1 and 2) it is important to be careful with generalizing the results to the general population of (German) pre-service teachers. Study

3 is less affected by the latter concern, yet still, all participants came from the University of Tübingen, and effects might be influenced by the specifics of technology and pedagogy related course work. Third, all samples were no random samples and participants completing a rather long (online) study might be overly motivated in general. Fourth, with a group of non-respondents of unknown size for Studies 1 and 2, in the present studies, there is no information about which factors might have contributed to participants' decision to fill in the questionnaire, although this might be relevant information. Finally, investigating only pre-service teachers also needs to be a considered a limitation to the generalizability of the results of the present study due to the expectable differences between novices and experienced teachers (maybe even experts) in lesson planning and actual teaching experience.

6.3 Implications

6.3.1 Implications for developing the TPCK framework

First, with regard to the fuzziness of the seven knowledge sub-domains of the TPCK framework (cf. Cox & Graham, 2009; Graham, 2011), a hierarchal structure was suggested by specifying not only the content of these sub-domains, but addressing the question of their representational form. Assuming that, on a first level, integrating the basic sub-domains (TK, PK, CK) has to happen by constructing mental models rather than memorizing propositional representations concretizes the claim of Angeli and Valanides (2009) that developing TPCK does not happen by studying the basic sub-domains separately. Moreover, assuming the construction of mental models also makes it possible to connect TPCK research to other lines of research on teacher knowledge (Baumert et al., 2010; Kunter et al., 2007; Voss et al., 2011) as well as more basic research on naïve conceptions and the development of expertise (Clark et al., 2011; diSessa et al., 2004; Hatano & Inagaki, 1986; Ioannides & Vosniadou, 2002; Vosniadou, 1994). Furthermore, assuming that TPCK on a second level of integration has to be developed as a meta-conceptual construct (cf. also Shulman, 1986) provides a more concrete theoretical foundation, thus it makes sense to assume this construct in addition to the integrated sub-domains (PCK, TPK, TCK). These considerations also provided a clearer language for talking about developing TPCK and developing expertise in TPCK. In sum, for the future theoretical development of the TPCK framework, these concretizations implicate the exchange of more concrete assumptions among researcher about the cognitive processes underlying the construction of teacher knowledge in this area of research. For example, in addition to qualitative ethnographic approaches to teachers' reasoning, that is, examining a teacher's argument and evaluating whether it explains technology use in the specific context, the notion of TPCK as a coherent theory can serve as a foundation to assemble more generic heuristics that teachers need in order to approach, that is, theoretically founding basic arguments that will lead to a more or less effective way of technology use.

Second, with regard to future empirical research, proposing concrete assumptions about how the different TPCK constructs differ in their form of cognitive representation provides new arguments for operationalizing these constructs and criticizing existing ones. For example, given the assumptions proposed the present dissertation it does not make sense to try to assess knowledge in the several sub-domains by sub-scales of the same format in a self-report questionnaire. Following this argument, the findings of the present studies provide initial empirical evidence that TPK operationalized as mental models of learning-relevant tool functions can be empirically distinguished from pedagogical and technological knowledge, and also from pedagogical beliefs. All these constructs showed unique relations to the central task of planning lesson with added-value of technology. Moreover, the experimental paradigm introduced in Study 3 provides a concrete example how to test specific hypotheses based on the TPCK framework and suggests a concrete operationalization that can be applied in future studies. Thus, these findings provide also a first answer to the claim to develop new ways of operationalizing and assessing the TPCK constructs formulated by Voogt and colleagues (2012) in their review of current TPCK research. Furthermore, the representation of the role of the students seems to be another point to continue empirical research. In conclusion, there are two concrete issues future research should follow up next. First, the findings of the present studies need to be replicated with samples that have actual firsthand experience with technology, including technologies other than video tools. With regard to the research designs future studies will have to apply experimental designs that enable the testing of actual causal hypotheses about the influence of prior PK and teachers' mental models of technology functions (TPK). If possible, future studies should include student data to go beyond the world of the teacher, however, this implies large scale projects that would for example have to be integrated in to larger studies such as PISA or ICILS, thus following the example of COACTIV. Second, the definition of TPCK as meta-conceptual awareness hast to be tested by empirical research. A first approach could be to build on research that has already started to consider pre-service teachers' self-regulation together with the TPCK framework (Kohen & Kramarski, 2012; Kramarski & Michalsky, 2010) and include measures for the development of TPCK as meta-conceptual awareness in future studies.

6.3.2 Implications for teacher training and teacher professional development

Regarding practical implications, the findings of this dissertation have to be treated with special caution before results have been replicated and disambiguated in further experimental and field studies. However, the theoretical considerations and findings provide a starting point for describing potential misconceptions of teachers who are training to use technology and for presenting a more concrete normative picture of what the goal of these training efforts might look like. Moreover, the experimental paradigm suggested in Study 3 can serve as an orientation for creating course materials that can then be evaluated in practice.

First, introducing the notions of mental models of tool functions and meta-conceptual awareness of the demands of the teaching task, available knowledge in the TPCK sub-domains, and the context provide a foundation for understanding why teachers might not use technology as expected or what their difficulties with regard to the educational use of technology are (*descriptive aspect*). For example, against this background it becomes apparent why the modeling of sample lessons alone is unlikely to impact teachers' future behavior (cf. Angeli & Valanides, 2005) or why the support of self-regulation with regard to teachers' own comprehension, connection, strategies, and reflection should enhance their performance in TPCK lesson planning tasks. On the other hand, discussing teachers' conceptualization of TPCK between the boundaries of coherence versus fragmentation also adds to the understanding of problems encountered in training and practice. Teacher trainers and professional developers can build on this conception and try to understand how their students tend to represent their experiences with technology in their teaching, whether and if, how they abstract from these experiences, and which basic framework theories guide their reasoning. In line with this, the results of the present empirical studies provide concrete examples for the use of video technology that can be introduced into teacher training by asking the following questions: Which potential of video do the teachers represent, are they unspecific, specific to video as a medium, or responsive to the specific video technology at hand? Do the teachers have ideal ideas of using video that show that, in principle, they do consider other aspects of their profession knowledge and to what extent do their ideals guide their actual classroom behavior? What are the constraints for using video technology in these ideal ways and what support do the teachers need to successfully complete their implementation?

Second, with regard to explicating a clearer picture of the knowledge that teachers should have, the theoretical considerations of the present dissertation—including the suggested alterations to the TPCK diagram—can provide a common ground in teacher training and professional development courses (*normative aspect*). On the one hand, if the goal is to support teachers in constructing mental models, teacher educators themselves have to plan their courses and tasks accordingly. For example, teachers should then not only be provided with lesson example vignettes or the design of these, but also be prompted to reflect what specific changes with regard to the potential of the lesson plan would occur if certain elements, such as the technology would be altered. Based on the results of Study 3, it seems to be helpful to model the cognitive integration of pedagogical considerations when introducing a concrete technology. With regard to better and longer-term effects, however, it seems relevant that pre-service teachers have acquired general pedagogical knowledge first. These findings are in line with to those of Graham and colleagues (in press) who suggest to introduce technology after establishing prior PK and CK. It remains an open question, whether similar considerations should be kept in mind for in-service teacher professional development.

On the other hand, providing a coherent understanding of TPCK as a meta-cognitive construct proposes a new perspective for teacher educators to structure their reading of the TPCK research literature and their own experiences to consider for the design of their courses. For example, exploring the idea of using TPCK as a meta-conceptual framework conflicting visualizations of the different sub-domains can be used as prompts for teachers' reflections on their actual and their goal states with regard to mastering technology for teaching (e.g., Foulger, 2012). Such an approach would also be sensitive to the different professional development needs over the career of teachers (cf. Richter et al., 2011).

To sum up, both these aspects of implications will need to be followed up by extensive research; however, they provide more concrete starting points than the TPCK framework seems to have provided until now.

6.4 Conclusion

How to effectively teach with technology remains a challenging task for present and future teachers and it presents many open issues for research. Although the TPCK framework has offered a common language for researchers to unite their efforts to investigate what teachers need to know in order to solve this task, the related theoretical and empirical work has come to a point where a number of shortcomings have to be addressed. By following the two research questions of the present dissertation theoretical and empirical approaches are suggested that help to tackle these shortcomings.

In sum, by elaborating on the representational form of the knowledge sub-domains proposed by the TPCK framework (Koehler & Mishra, 2008; Mishra & Koehler, 2006), it was possible in the present dissertation to lay ground for deducing more concrete hypotheses about their interrelations and to suggest an experimental paradigm for testing these. In line with this, the present empirical findings could provide initial evidence that indeed abstract pedagogical knowledge and mental models of tool functions as TPK indicator showed distinct influences on the lesson using the sample of digital video technology. With regard to how teachers plan the use of technology for teaching, their understanding of the technology's functions can foster or inhibit the pedagogical framing of this technology. Furthermore, an experimental study could, on the one hand, provide evidence supporting the *transformative view* on TPCK by showing the incremental effect of explicitly supporting the cognitive integration of pedagogical and technological information as a step towards a complex understanding of technology for teaching. However, on the other hand and in line with the theoretical considerations of this dissertation, the results also showed that the role of prior knowledge in the basic sub-domains (here PK) needs to be considered and that currently the *transformative view* on TPCK does not present a sufficient theoretical conceptualization of the framework. Thus, the claim for a more process-oriented elaboration of the TPCK framework was supported.

In conclusion, further developing the TPCK framework as a coherent theory has implications for improving research on how teachers reason about technology for teaching and how to support them in their development toward knowledge that enables them to professionally include continuously emerging technologies. In doing so, it will remain an important issue to be aware of the contrast to the transmission of established general patterns of using technology, such as video, that are likely to constrain the development of such an adaptive competence in teachers. In sum, the results of this dissertation contribute to the understanding of how (pre-service) teachers develop media-related competence. Simultaneously this dissertation creates a foundation for more specific operationalizations of assumptions underlying the TPCK framework that can now be tested in future experimental research.

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Appendix A: Test Items and Coding Schemes Study 1

Table A.1

Coding scheme for coding of pre-service teachers' lesson planning, intended and ideal instructional use of YouTube.

Category	Example answers, keywords in bold
Accessibility	"…, because you can find a lot of information, for example **about political events also on YouTube**." "… using **interviews** with **current** artists " "… to make church rituals **accessible** to students **as a video**"
Content elaboration	"… students **elaborate on content** in the form of video" "…**repeating** a presentation or **further** exercises…" " … **wrap up a lesson** series on poverty with a song that deals with this topic"
Entertainment	"Watching videos"
Exchange	"Video **competition** on a YouTube channel" "For example to **present** a project or a creative realization of my class **on the internet**" "… the students **added results** from their **group work** on other data carriers to this."
Foreign language	"I would use YouTube especially in **teaching English** [as a foreign language]" "Listening to **foreign languages** and getting accustomed to the 'sound' …"
Information repository	"…, because you can **find a lot of information**, for example about political events on YouTube" "… as a **source** of ideas …"

Table A.1 (continued)

Lesson start	"You could **start a lesson** with a YouTube clip …" "**Introduction** to the topic …" "… to use YouTube as **introduction** to a lesson series …"
Motivation	"**Combining content and entertainment to make it easier to remember the content**."
Productive use (students)	"... having **students create** a video (e.g. about a play) and **upload** it there." "You could **upload** the videos that are supposed to be published there and **embed** them on a website …"
Students' media literacy	"Learning goal: Development of the **competence to the goal-oriented creation of videos**."
Teacher presentation	"… uncommented **presentation** …" "… **presenting** scientific phenomena and approaches to describe them, for example the 'the lemon battery'" "… to **demonstrate** the flow of movements during shot-put."
Vividness	"In physics, there are well done contributions on experiments and **visualizations** of scientific **phenomena** (e.g. Schrödinger's cat)" "…ideal to **explain** everyday chemical **phenomena**"

Table A.2

Items tapping pedagogical knowledge, from ETS Praxis II example items, http://www.ets.org/praxis/prepare/materials/test_prep.

Item		Item English original, correct answer in **bold**	Applied in Study
1		A student in the process of solving a fabrication problem in the manufacturing laboratory asks the teacher what assembly procedures should be used. The teacher's best response would be to	1, 3
	a	give an opinion as to the best assembly procedure for the particular problem	
	b	suggest two or three possible assembly procedures and have the student select one	
	c	place the responsibility completely on the student for making the judgment	
	d	**use leading questions to help the student review and analyze the relative merits of several assembly procedures**	
	e	refer the student to a reference on assembly procedures	
2		The most important consideration in designing successful messages to be transmitted through graphic communications is knowledge and understanding of	1, 2, 3
	a	current technologies	
	b	the capabilities of the designer	
	c	the estimated cost of the project	
	d	the limitations of the printer	
	e	**the nature of the audience**	
3		The students in a third-grade class are going to perform an experiment in which they will measure the amount of time it takes for one, two, and eight ice cubes to melt in a given quantity of water at a particular temperature. They will then predict the melting times for four and for sixteen ice cubes in water of the same temperature. Of the following, a skill that is prerequisite to making successful predictions for this experiment is the ability to	1, 3
	a	**make accurate observations**	
	b	read a chart showing the data	
	c	use a metric scale	
	d	identify likenesses and differences	

Table A.2 (continued)

Item		Item English original, correct answer in **bold**	Applied in Study
4		Which of the following would be the best indication to a teacher that students are beginning to think critically about science?	1, 3
	a	They talk about earthquakes, space probes, and science-related information in the news.	
	b	They begin to read more books and articles about science on their own.	
	c	**They successfully plan and carry out simple experiments to test questions raised in classroom discussions.**	
	d	They correctly answer the teacher's questions about the procedures used after observing science experiments being done.	
5		In a successful discovery learning session, the teacher should most likely serve in which of the following roles?	1, 2, 3
	a	The teacher will serve primarily as an audience for the students' finished products.	
	b	The teacher will serve primarily as stage director, assigning to each student a role that is critical to achieving the class goal.	
	c	The teacher will serve primarily as referee, resolving disagreements and keeping students on task.	
	d	**The teacher will serve primarily as a resource, available if needed but otherwise unobtrusive.**	
6		During a visit to a second-grade classroom, a student teacher observed a child spending the time allotted for a worksheet either looking out of the window or doodling on his paper. When the student teacher asked the child if he needed help on the assignment, he said no. When asked why he wasn't doing it, he pointed to another student and said, "She does all her work fast and when she's done, she gets more work." The boy's reaction suggests which of the following about his classroom?	1, 3
	a	A routine has been established for students who are having trouble finishing an assignment to ask the teacher for assistance.	
	b	**A routine for rewarding students who finish work promptly is not in place.**	
	c	Students must work alone on seatwork, without consulting other students.	
	d	Students who finish work before the whole class is finished must not interrupt the students who are still working?	

Table A.3

Items tapping pedagogical knowledge, German original items from Schulte et al., 2008.

Item		*Item translated from German original, correct answer in **bold***	Applied in Study
7		*What should students with a high need to avoid failure learn?*	1
	a	*To increase their effort to increase success and avoid failure.*	
	b	*To interpret failure as something internal and stable, to increase motivation.*	
	c	***To set realistic goals in order to understand the relation between their own effort and outcomes more easily.***	
	d	*To work cooperatively in order to support social comparison.*	
8		*Referring to which reference standard can have a positive influence on the motivation of students?*	1, 2, 3
	a	*The social reference standard.*	
	b	*The criterial reference standard.*	
	c	***The individual reference standard.***	
	d	*The supportive reference standard.*	
9		*Which of the following alternatives describes a controllable attribution of a student after a bad test result?*	1, 3
	a	*"I simply don't have any sense of numbers."*	
	b	*"With this teacher nobody succeeds, she just demands too much."*	
	c	***"I am too lazy to learn."***	
	d	*"Sometimes you're lucky and prepare exactly the right topic, sometimes you're not."*	
10		*Typical symptoms of teacher under a lot of stress or with Burnout syndrome are*	1, 3
	a	*Dizziness, labored breathing, depression, reading difficulties.*	
	b	***Gastro-intestinal diseases, headache, muscle tension, allergies, loss of efficiency.***	
	c	*Headache, muscle tension, but no loss of efficiency.*	
	d	*Distancing from the students, but no physical symptoms.*	

Table A.3 (continued)

Item		*Item translated from German original, correct answer in **bold***	Applied in Study
11		*According to its current definition, dyslexia is characterized by*	1, 3
	a	*slow reading or spelling errors regardless of general intelligence.*	
	b	***normal to high general intelligence and slow reading or spelling errors.***	
	c	*slow reading or spelling errors and low general intelligence.*	
	d	*average reading from grade 2 and spelling errors regardless of intelligence.*	
12		*If you compare the test score of a student with the class' average score, this indicator is referred to as*	1, 2, 3
	a	*the individual reference standard.*	
	b	*the criterial reference standard.*	
	c	***the social reference standard.***	
	d	*no special reference standard.*	
13		*Brophy (1981) distinguished between effective and ineffective ways for teachers to praise students. Which of the following alternatives describes effective praise?*	1, 2, 3
	a	***Rewarding the achievement of performance criteria that were specified in advance.***	
	b	*Global positive feedback on a student's performance.*	
	c	*Guiding a student to compare him- or herself with others and to foster competition.*	
	d	*Praising the participation in a task, regardless of the student's performance.*	
14		*To de-escalate conflicts and to avoid violence, it is recommended*	1
	a	*not to cover violent topics and to avoid too much activity in class.*	
	b	*to design schools to be comfortable and to leave the topic of violence to the parents.*	
	c	*to raise students liberally and to avoid putting them under the pressure of group norms that damn violence.*	
	d	***To avoid frustration and boredom in class and to explain the consequences of violence from the victim's perspective.***	

Table A.3 (continued)

Item		*Item translated from German original, correct answer in **bold***	Applied in Study
15		*Which components of collaborative learning are being considered mandatory by Slavin (1994) and other researchers?*	1, 3
	a	*A transparent point- and appraisal system, individual feedback for all team members, and individual conversations with troublesome members.*	
	b	***Team related incentives, individual responsibilities, and equal chances of success for all team members.***	
	c	*Consequent abdication of grades, individual reference standards for appraisal, and everyday relevance of topics.*	
	d	*Strict prevention of social comparison, application of new media, and abandonment of the common pattern of lessons (45-min-work cycle).*	
16		*Which are the four levels of communication following Schulz von Thun?*	1
	a	***Factual level, relationship level, self-revelation level, appeal level.***	
	b	*Content level, communication level, conflict level, instructional level.*	
	c	*Micro level, macro level, meta level, sub level.*	
	d	*Achievement level, emotional level, sensory level, cognitive level.*	
17		*Why is meta-cognition not always effective?*	1, 2, 3
	a	***It prolongs the learning time; however for easy tasks automatic processes are more effective.***	
	b	*Because it increases the probability that the thoughts of students are being further distracted*	
	c	*Because the cognitive processes of the students are not apparent to the teacher.*	
	d	*Because obviously, collaborative learning is being supported, although in some cases competition between students increases.*	
18		*What is meta-cognition?*	1, 2, 3
	a	*Assessment of the student's cognitive processes during learning by the teacher.*	
	b	*Training modules to foster collaborative learning in culturally diverse classrooms.*	
	c	***Collective term for phenomena, activities, and experiences that are related to knowledge about and regulation of one's own cognitive processes.***	
	d	*Strategies for focusing on a topic, to avoid distracting thoughts.*	

Table A.3 (continued)

Item		*Item translated from German original, correct answer in **bold***	Applied in Study
19		*Intellectual giftedness is on the cognitive level characterized by an IQ of*	1
	a	*> 120.*	
	b	*< 100.*	
	c	*> 100.*	
	d	***> 130.***	
20		***Which are the two central processes proposed by Piaget?***	1, 3
	a	*Tolerance and identity.*	
	b	*Diffusion and extinction.*	
	c	***Accommodation and assimilation.***	
	d	*Self-determination and self-regulation.*	
21		*When does a person, according to Lazarus's stress model, perceive a situation as stressful?*	1, 3
	a	***When a person experiences a situation as threatening and cannot cope with it relying on own resources.***	
	b	*When a person experiences a situation as extremely threatening.*	
	c	*When primary and secondary appraisal seem personally relevant.*	
	d	*When a person experiences a situation as threatening, even though being able to cope with it relying on own resources.*	
22		*According to Skinner's theory of operant conditioning, what does negative reinforcement refer to?*	1, 3
	a	*The presentation of a appetitive stimulus.*	
	b	***The taking away of an aversive stimulus.***	
	c	*Not reinforcing a behavior.*	
	d	*The punishment of a behavior.*	

Appendix B: Coding Schemes, and Regression Tables Study 2.

Table B.1.

Example lesson plan vignette used in the TPCK evaluation task.

In cooperation with experts on the didactics of history and language arts we developed a task for implementing the news reel video you just watched in combination with WebDIVER in class. We will describe this task to you briefly and then ask you to rate it with regard to several criteria. The lesson plan for the task was as follows:

During two subsequent lessons of 45 minutes each students of class 10 or 11 (*Gymnasium* and *Realschule*[a]) started by individually reading short introductory texts on

- the historical context of the Berlin Blockade and the Air Lift in post-war Germany in 1948,
- the use of newsreels shown in cinemas as a means of propaganda, and
- the main stylistic devices of film production, such as camera angles.

Then, students, still individually, familiarized themselves with the WebDIVER software with the help of a written instruction. After a short break students were joined in dyads and were asked to use WebDIVER to work on the following task:

> ‘Your task is to design a concept how to prepare the video of the original newsreel from 1948 so that other students from class 10 or 11 without prior knowledge can learn from it. Evidently, this is not a contemporary film, but it was produced in a different phase of German history. In order to better understand this material an dto learn from it, your concept should help a learner to understand which context information to consider and which purpose this film hat in its day. There are three important aspects students should learn about:
>
> - Events of German’s post-war history
> - The use of stylistic devices in film production in general
> - The newsreel as a historic example for using film as a means of propaganda.’

Subsequently, student dyads began to work with WebDIVER selecting screenshots, sequences, and details in the film and annotating in titles or comments what to notice there and which additional information to consider. All common WebDIVER functions could be used during this phase. In a closing sequence, students indicated how satisfied they were with their collaboration and the concept they had developed for preparing the newsreel.

Table B.2

Coding scheme for lesson plans for the newsreel video and WebDIVER, TPCK design task.

Category	Example answers, keywords in bold
Content elaboration	“The students should – depending on their **prior knowledge**, of course – **set** [the film] **in** the historical **context**” “[Students should] **put themselves into the position** of the population at that time” “**Independent thinking**, **activate** own **knowledge**” “[...] watch the end of the film first and have students **reflect** on what it is about”
Detail perception	“Add comments to persons and elaborate (possibly on **style of clothing**, **facial expression**, etc.) “Role of WebDIVER: **Focusing** on single utterances and sequences” “[...] should emphasize **single pieces of information** ([foster] the competence to **focus** Lernziel).”
Empathy	“**Empathy**” “Students **perceive the tense atmosphere** in Germany at that time.”
Exchange	“Finally, the whole video will be presented and **discussed**.” “[...] and have them discuss about it.” “Separating the sequences and working on them **in groups**.” “Learning goal: **division of work** as an aspect of the scientific method.”
Historic comparison	“[...] in order to draw a **comparison** between how we define good rhetoric **today** in contrast to how it was done **at that time**.” “Bring **current** TV news along for **comparison**” “**Compare** features of the speech in the video **with political speeches of today**.”

Table B.2 (continued)

Category	Example answers, keywords in bold
Lesson start	“[...] WebDIVER as **introduction** to a lesson series” “New way/ **approach to classroom** practice” “By a shortened sequence they could get a **first impression** of the situation.” “Choose it as an **entry to a lesson**”
Material preparation (teacher)	“**I would cut out** selected sequences of the newsreel and emphasize others” “**You could add annotations** to images, for example of the destroyed and unused train tracks **and ask** [students] that way what this is about.” “WebDiver would be used by the teacher to **prepare the material**.”
Motivation	“Create variety – arouse **interest**” “Arouse students’ **curiosity**”
Shortening movies	“The video is too short to further **clip it**.” “I would not use WebDIVER in this case at all: The film is **too short**.”
Students' media literacy	“Students should learn how to **critically deal with media**” “Analyze the change of media: Films in the past and now; **understand and analyze** content of **different media**, juxtapose with texts.” “(**Internet-) research competence**”
Students’ productive use	“**Use for editing** the film and cutting out scenes” “[...] to be **used by students to create** a completely new message from the audio material.” “**Students should add** the inner feelings of the people as comments.”
Teacher presentation	“I would **show** the whole film” “**show** the video sequence” “I can imagine **presenting** the short speech as a sequence”
Vividness	“Getting to know the **stylistic devices of the film**” “Cut out parts of the video that **illustrate** well **how the news reels looked** at that time.” “Getting an **impression of** the situation and develop a personal relation to the people in the film, which **is easier to create with video + audio** than with text or pictures alone.”

Table B.3.1
Summary of hierarchical regression analysis for variables predicting the elaborateness of proposed ideal uses of WebDIVER in class (N = 24).

	Model 1			Model 2		
Step and predictor	*B*	*SE B*	β	*B*	*SE B*	β
PK	0.02	0.39	.01	0.25	0.32	.14
TK	3.48	2.07	.36	0.33	1.84	.03
Mm cognitive[a]				9.82	2.71	.63
Mm socio-cognitive[a]				2.80	2.48	.19
R^2		.13			.52	
F for change in R^2		0.38			7.50**	

Note: PK = pedagogical knowledge, TK = technological knowledge, mm = mental model.
[a]Binary coding, -1 = aspect not contained in mental model, 1 = aspect contained in mental model.
*$p < .05$. **$p < .01$.

Table B.3.2
Summary of hierarchical regression analysis for variables predicting the overall quality of proposed ideal uses of WebDIVER in class (N = 24).

	Model 1			Model 2		
Step and predictor	*B*	*SE B*	β	*B*	*SE B*	β
PK	0.01	0.04	.05	0.03	0.04	.15
TK	0.25	0.22	.26	0.00	0.23	.00
Mm cognitive[a]				0.82	0.33	**.51***
Mm socio-cognitive[a]				0.20	0.30	.14
R^2		.08			.32	
F for change in R^2		0.90			3.36^{+}	

Note: PK = pedagogical knowledge, TK = technological knowledge, mm = mental model.
[a]Binary coding, -1 = aspect not contained in mental model, 1 = aspect contained in mental model.
$^{+}p = .06$*$p < .05$. **$p < .01$.

Table B.3.3

Summary of hierarchical regression analysis for variables predicting cognitive aspects of proposed ideal uses of WebDIVER in class (N = 24).

	Model 1			Model 2		
Step and predictor	*B*	*SE B*	β	*B*	*SE B*	β
PK	0.00	0.02	-.01	0.01	0.02	.06
TK	0.10	0.12	.19	-0.03	0.12	-.06
Mm cognitive[a]				0.54	0.18	**.62****
Mm socio-cognitive[a]				-0.04	0.16	-.05
R^2		.03			.35	
F for change in R^2		0.37			**4.70***	

Note: PK = pedagogical knowledge, TK = technological knowledge, mm = mental model.
[a]Binary coding, -1 = aspect not contained in mental model, 1 = aspect contained in mental model.
*$p < .05$. **$p < .01$.

Table B.3.4

Summary of hierarchical regression analysis for variables predicting socio-cognitive aspects of proposed ideal uses of WebDIVER in class (N = 24).

	Model 1			Model 2		
Step and predictor	*B*	*SE B*	β	*B*	*SE B*	β
PK	0.01	0.02	.08	0.02	0.02	.18
TK	0.02	0.12	.04	-0.10	0.13	-.19
Mm cognitive[a]				0.29	0.20	.34
Mm socio-cognitive[a]				0.20	0.18	.25
R^2		.01			.17	
F for change in R^2		0.10			1.86	

Note: PK = pedagogical knowledge, TK = technological knowledge, mm = mental model.
[a]Binary coding, -1 = aspect not contained in mental model, 1 = aspect contained in mental model.
*$p < .05$. **$p < .01$.

Table B.3.5

Summary of hierarchical regression analysis for variables predicting specificity of affordances described in proposed ideal uses of WebDIVER in class (N = 24).

	Model 1			Model 2		
Step and predictor	*B*	*SE B*	β	*B*	*SE B*	β
PK	0.01	0.03	.06	0.02	0.03	.17
TK	0.10	0.17	.13	-0.11	0.17	-.14
Mm cognitive[a]				0.59	0.26	**.49***
Mm socio-cognitive[a]				0.22	0.24	.19
R^2		.03			.27	
F for change in R^2		0.28			3.26[+]	

Note: PK = pedagogical knowledge, TK = technological knowledge, mm = mental model.
[a]Binary coding, -1 = aspect not contained in mental model, 1 = aspect contained in mental model.
[+]p = .06, *p < .05. **p < .01.

Table B.3.6

Summary of hierarchical regression analysis for variables predicting the likelihood of implementing the example lesson plan of the TPCK evaluation task (n = 21).

	Model 1			Model 2		
Step and predictor	*B*	*SE B*	β	*B*	*SE B*	β
PK	0.02	0.04	.13	0.02	0.04	.15
TK	-0.06	0.18	-.09	0.08	0.19	.11
Mm cognitive[a]				-0.28	0.29	-.24
Mm socio-cognitive[a]				-0.43	0.25	-.41
R^2		.02			.20	
F for change in R^2		0.17			1.85	

Note: PK = pedagogical knowledge, TK = technological knowledge, mm = mental model.
[a]Binary coding, -1 = aspect not contained in mental model, 1 = aspect contained in mental model.
**p* < .05. ***p* < .01.

Table B.3.7

Summary of hierarchical regression analysis for variables predicting cognitive goals of the TPCK evaluation task (n = 21).

	Model 1			Model 2		
Step and predictor	*B*	*SE B*	β	*B*	*SE B*	β
PK	0.05	0.02	**.50***	0.06	0.02	**.57***
TK	0.11	0.10	.21	0.19	0.10	.36
Mm cognitive[a]				-0.36	0.16	**-.44***
Mm socio-cognitive[a]				0.03	0.14	.04
R^2		0.35			0.51	
F for change in R^2		**4.83***			2.64	

Note: PK = pedagogical knowledge, TK = technological knowledge, mm = mental model.
[a]Binary coding, -1 = aspect not contained in mental model, 1 = aspect contained in mental model.
**p* < .05. ***p* < .01.

Table B.3.8

Summary of hierarchical regression analysis for variables predicting socio-cognitive goals of the TPCK evaluation task (n = 21).

	Model 1			Model 2		
Step and predictor	*B*	*SE B*	β	*B*	*SE B*	β
PK	0.02	0.03	.16	0.04	0.03	.28
TK	-0.02	0.16	-.03	0.08	0.14	.12
Mm cognitive[a]				-0.69	0.22	**-.63***
Mm socio-cognitive[a]				0.30	0.19	.30
R^2		0.03			0.47	
F for change in R^2		0.23			**6.68***	

Note: PK = pedagogical knowledge, TK = technological knowledge, mm = mental model.
[a]Binary coding, -1 = aspect not contained in mental model, 1 = aspect contained in mental model.
*p < .05. **p < .01.

Table B.3.9
Summary of hierarchical regression analysis for variables predicting the elaborateness of participants' lesson plans (TPCK design task) (N = 24).

	Model 1			Model 2		
Step and predictor	*B*	*SE B*	β	*B*	*SE B*	β
PK	1.81	0.85	**.39***	2.12	0.88	**.46***
TK	8.19	4.51	.34	4.92	5.10	.20
Mm cognitive[a]				7.41	7.53	.19
Mm socio-cognitive[a]				6.29	6.89	.17
R^2		.36			.42	
F for change in R^2		**5.90***			0.97	

Note: PK = pedagogical knowledge, TK = technological knowledge, mm = mental model.
[a]Binary coding, -1 = aspect not contained in mental model, 1 = aspect contained in mental model.
*$p < .05$. **$p < .01$.

Table B.3.10
Summary of hierarchical regression analysis for variables predicting the overall quality of participants' lesson plans (TPCK design task) (N = 24).

	Model 1			Model 2		
Step and predictor	*B*	*SE B*	β	*B*	*SE B*	β
PK	0.07	0.05	.31	0.07	0.05	.32
TK	0.25	0.24	.21	0.31	0.28	.27
Mm cognitive[a]				-0.44	0.41	-.23
Mm socio-cognitive[a]				0.24	0.38	.13
R^2		0.19			0.24	
F for change in R^2		2.39			0.73	

Note: PK = pedagogical knowledge, TK = technological knowledge, mm = mental model.
[a]Binary coding, -1 = aspect not contained in mental model, 1 = aspect contained in mental model.
*$p < .05$. **$p < .01$.

Table B.3.11

Summary of hierarchical regression analysis for variables predicting the cognitive goals in participants' lesson plans (TPCK design task) (N = 24).

	Model 1			Model 2		
Step and predictor	*B*	*SE B*	β	*B*	*SE B*	β
PK	0.05	0.04	.23	0.06	0.05	.26
TK	0.40	0.23	.35	0.37	0.28	.32
Mm cognitive[a]				-0.04	0.41	-.02
Mm socio-cognitive[a]				0.19	0.37	.11
R^2		.23			0.24	
F for change in R^2		3.17^+			0.13	

Note: PK = pedagogical knowledge, TK = technological knowledge, mm = mental model.
[a]Binary coding, -1 = aspect not contained in mental model, 1 = aspect contained in mental model.
$^+p = .06$. $*p < .05$. $**p < .01$.

Table B.3.12

Summary of hierarchical regression analysis for variables predicting the socio-cognitive goals in participants' lesson plans (TPCK design task) (N = 24).

	Model 1			Model 2		
Step and predictor	*B*	*SE B*	β	*B*	*SE B*	β
PK	0.02	0.02	.25	0.03	0.02	.25
TK	-0.01	0.12	-.02	-0.07	0.13	-.13
Mm cognitive[a]				0.33	0.19	.39
Mm socio-cognitive[a]				-0.14	0.18	-.17
R^2		.06			.21	
F for change in R^2		0.67			1.75	

Note: PK = pedagogical knowledge, TK = technological knowledge, mm = mental model.
[a]Binary coding, -1 = aspect not contained in mental model, 1 = aspect contained in mental model.
$^+p = .06$. $*p < .05$. $**p < .01$.

Table B.3.13

Summary of hierarchical regression analysis for variables predicting specificity of affordances described in participants' lesson plans (TPCK design task) (N = 24).

	Model 1			Model 2		
Step and predictor	*B*	*SE B*	β	*B*	*SE B*	β
PK	0.01	0.02	.14	0.02	0.02	.25
TK	-0.06	0.11	-.12	-0.11	0.11	-.24
Mm cognitive[a]				-0.05	0.17	-.07
Mm socio-cognitive[a]				0.33	0.15	**.46***
R^2		.02			.21	
F for change in R^2		0.24			2.27	

Note: PK = pedagogical knowledge, TK = technological knowledge, mm = mental model.
[a]Binary coding, -1 = aspect not contained in mental model, 1 = aspect contained in mental model.
$^{+}p = .06$. $*p < .05$. $**p < .01$.

Appendix C: Screenshots, Coding Schemes and MS Excel Syntax Study 3.

Figure C.0.1. Screenshot 1 of WebDIVER introduction for control group (TK only) and experimental condition 1 (TK+PK).

Figure C.2. Screenshot 2 of WebDIVER introduction for control group (TK only) and experimental condition 1 (TK+PK).

Aufbau von DIVER

Unter dem Video befinden sich die ***Play-***, ***Mark-*** und die ***Record***-Funktionen mit denen man Ausschnitte bilden kann (siehe Abbildung). Mit diesen Elementen legt man also Panels an. Im Videobild befindet sich ein rechteckiger gelber Rahmen. Diesen kann man zum Zoomen verwenden. Das heißt, nur der Teil des Videos wird ausgeschnitten, der von dem Rahmen umschlossen ist.

(A) Play
Um das Video abzuspielen klickt man auf die Play- Funktion. Erneutes Klicken pausiert das Video.

(B) Mark
Um ein **Standbild**, bzw. ein Detail daraus (s. nächste Seite) auszuschneiden, klickt man auf ***Mark***. Dazu klickt man einmal mit der linken Maustaste auf Mark. Das Standbild das gerade sichtbar ist, wird als Panel zum Arbeitsbereich hinzugefügt. Es öffnet sich ein Textfeld in das eine Überschrift eingegeben werden kann.

(C) Record
Um eine **Video-Sequenz** auszuschneiden, klickt man auf ***Record***, um die Aufnahme zu beginnen. Der Button beginnt zu blinken und ist nun mit Stopp beschriftet. Um die Aufnahme zu beenden, klickt man diesen Button erneut. Der Zeitstempel des Panels beinhaltet Anfangs- und Endzeit der Sequenz. Zum Verändern der Länge einer Sequenz, klickt man auf ***Trim*** oben rechts im Panel und passt Beginn und Ende der Sequenz entsprechend an.

Figure C.3. Screenshot 3 of WebDIVER introduction for control group (TK only) and experimental condition 1 (TK+PK).

Zoomen

Der ***gelbe Rahmen*** im Video dient zum Zoomen (siehe Abbildung). Innerhalb des Videos können kleinere Bereiche im Videobild mit seiner Hilfe ausgewählt und aufgenommen werden. Bei der Aufnahme von Standbildern oder Sequenzen wird nur der Bereich innerhalb dieses Rahmens aufgenommen. Man kann die Größe und die Position des Rahmens verändern und ihn wie die Linse einer virtuellen Kamera durch das Video bewegen.

Die **Größe verändert** man, indem man mit der Maus in eine Ecke des gelben Rahmens klickt und die Taste gedrückt hält. Durch das Bewegen des Mauspfeils zum Zentrum, bzw. zum Rand des Rahmens, lässt sich der Rahmen auf die gewünschte Größe ziehen. Um den Rahmen wieder auf die maximale Größe zu bringen, positioniert man ihn in der Mitte des Videobilds und vergrößert ihn wie beschrieben. Um den Rahmen **als Ganzes zu verschieben**, klickt man ins Zentrum, hält die linke Maustaste gedrückt und bewegt den Rahmen mit der Maus.

Figure C.4. Screenshot 4 of WebDIVER introduction for control group (TK only) and experimental condition 1 (TK+PK).

Textanmerkungen

Haben Sie ein DIVER-Panel angelegt, können Sie im ***Überschriften-Feld (A)*** und ***Kommentar-Feldern (B)*** Text hinzufügen (siehe Abbildung).

(A) Überschriften
Wurde ein DIVER-Panel über den Mark- oder Record-Button erstellt, kann man sofort einen Titel im **Überschriften-Feld** einfügen. Möchte man die Eingabe später ändern, klickt man zunächst auf ***edit*** (oben rechts). Der Text kann dann bearbeitet werden. Die Eingabe lässt sich mit ***Submit*** speichern. ACHTUNG, ***nicht*** auf die ***Delete*-Funktion eines Panels** (oben rechts) klicken, um die Eingabe in das Überschriften-Feld zu ändern. Denn dies löscht das gesamte Panel, nicht nur den Text. Die Eingabe im Titelfeld ändert man, indem man erneut auf edit klickt und die Änderungen mit Submit speichert.

(B) Kommentare
Angemeldete Nutzer können Kommentare zu den einzelnen Panels hinzufügen. Der Nutzername der Verfasser erscheint für das Panel und jeden der Kommentare separat. Die Anzahl der Kommentare zu einem Panel ist unbeschränkt. Um einen Kommentar hinzuzufügen klickt man auf ***add comment***. Es öffnet sich das grau hinterlegte **Kommentar-Feld**. Eingaben werden mit ***Submit*** gespeichert. Mit ***edit*** können Eingaben bearbeitet werden. Hier dient die ***delete*-Funktion eines Kommentars** (siehe Abbildung unten rechts) dazu, nur den jeweiligen Kommentar zu löschen. Kommentare können durch Klicken auf den kleinen Pfeil neben add comment ein- und ausgeblendet werden. Die Anzahl der Kommentare wird in Klammern angezeigt.

Figure C.5. Screenshot 5 of WebDIVER introduction for control group (TK only) and experimental condition 1 (TK+PK).

Panels kopieren und einfügen

Bereits erstellte Panels können kopiert und an einer gewünschten Stelle einfügt werden.
Um ein Panel zu kopieren, klickt man auf ***copy*** **(A)**, in der oberen rechten Leiste des gewünschten Panels. Um es anschließend einzufügen klickt man ***paste*** **(B)** in der Leiste des Bildschirms (siehe Abbildung).
Ist ein bestimmtes Panel angewählt (=Panel ist Türkis hinterlegt), wird das kopierte Panel nach diesem eingefügt. Ist kein Panel angewählt, wird das kopierte Element am Ende des Arbeitsbereichs eingefügt.

Verschieben von Panels (Drag & Drop)

Die Reihenfolge der Panels kann mit der ***Drag and Drop***-Funktion durch verschieben verändert werden. Man wählt das zu verschiebende Panel durch einen Klick auf das Miniaturbild aus. Dann klickt man mit der linken Maustaste in den türkisfarbenen Streifen am oberen Rand und die Taste gedrückt halten. Der Mauspfeil wird zu einem **Navigationskreuz (A)** (siehe Abbildung links), mit dem man das Panel an die gewünschte Stelle ziehen kann **(B)** (siehe Abbildung rechts). Um es dort zu platzieren, lässt man die Maustaste los.

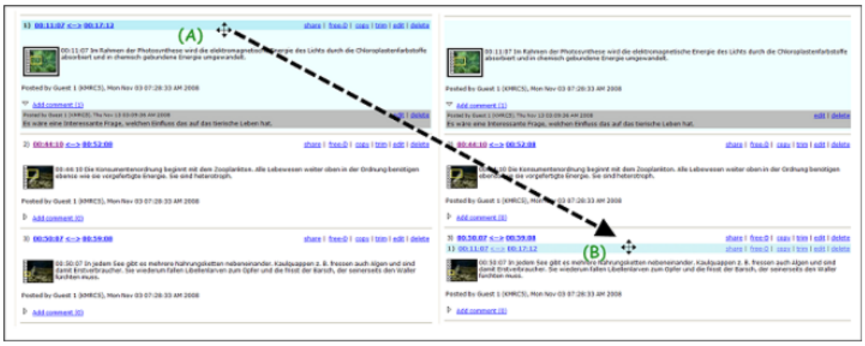
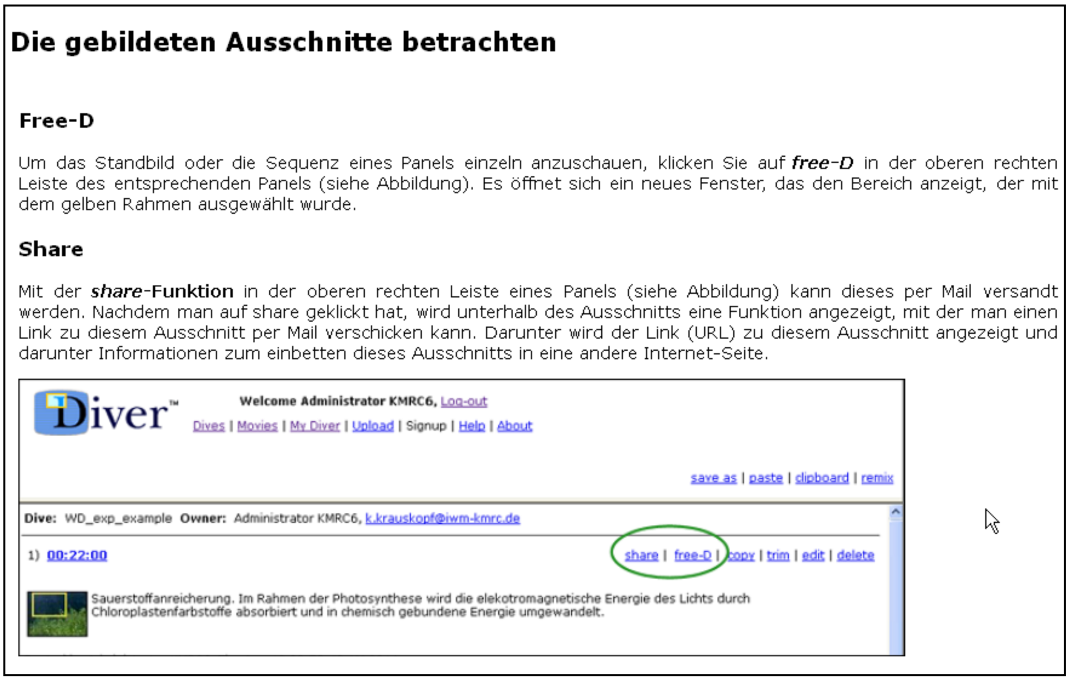


Figure C.6. Screenshot 6 of WebDIVER introduction for control group (TK only) and experimental condition 1 (TK+PK).



Die gebildeten Ausschnitte betrachten

Free-D

Um das Standbild oder die Sequenz eines Panels einzeln anzuschauen, klicken Sie auf ***free-D*** in der oberen rechten Leiste des entsprechenden Panels (siehe Abbildung). Es öffnet sich ein neues Fenster, das den Bereich anzeigt, der mit dem gelben Rahmen ausgewählt wurde.

Share

Mit der ***share*-Funktion** in der oberen rechten Leiste eines Panels (siehe Abbildung) kann dieses per Mail versandt werden. Nachdem man auf share geklickt hat, wird unterhalb des Ausschnitts eine Funktion angezeigt, mit der man einen Link zu diesem Ausschnitt per Mail verschicken kann. Darunter wird der Link (URL) zu diesem Ausschnitt angezeigt und darunter Informationen zum einbetten dieses Ausschnitts in eine andere Internet-Seite.

Figure C.7. Screenshot 7 of WebDIVER introduction for control group (TK only) and experimental condition 1 (TK+PK).

Figure C.8. Screenshot 8 of WebDIVER introduction for control group (TK only) and experimental condition 1 (TK+PK).

Lern-Funktionen digitaler Video-„Werkzeuge"

Im Internet sind digitale Video-Werkzeuge (Tools) frei verfügbar. Mit ihnen können Nutzer Videos selbst gestalten. Diese technischen Werkzeuge sind dabei auch **Denk-Werkzeuge, denn sie unterstützen individuelles und kooperatives Lernen durch spezielle Funktionen**. Im Vergleich zu Wiedergabeprogrammen (z.B. Windows MediaPlayer) ermöglichen Video-Tools den Nutzerinnen die aktive Gestaltung bestehender Videos. Man kann Teile auswählen, markieren, bearbeiten oder in neue Reihenfolgen bringen. Weil diese Tools im Internet verfügbar sind, ist es auch leicht, die eigenen Bearbeitungen mit anderen zu teilen und zu diskutieren.

Video-Tools besitzen ausgewählte Funktionen, die beeinflussen, wie Nutzer mit einem Video umgehen. Sie unterstützen zum Beispiel die Analyse, den Vergleich oder das Interpretieren von Videos. Dabei können Nutzer viele unterschiedliche Perspektiven auf ein Video einnehmen und dies dann direkt am Video verdeutlichen. Sie können dadurch tiefer in das Video „eintauchen".

Figure C.9. Screenshot 1 of pedagogical information in experimental condition 1 (TK+PK).

Lern-Funktionen digitaler Video-„Werkzeuge"

Nutzerinnen können zum Beispiel Ausschnitte eines Videos auswählen und neu ordnen. Dadurch vertiefen sie ihr Verständnis des Inhalts. Denn diese Umgestaltung lenkt die Aufmerksamkeit und dadurch die kritische Diskussion auf bestimmte Themen und Aspekte. Das Umgestalten eines Videos regt auch den Vergleich verschiedener Darstellungen der gleichen Information an.

Auch für das gemeinsame Lernen bieten solche Video-Tools verschiedene Möglichkeiten. Je nach Funktion beeinflussen sie wie mehrere Nutzer mit Videoinhalten umgehen. Das hat eine Auswirkung darauf wie sie das Video gemeinsam verstehen und interpretieren. Zum Beispiel können Funktionen für die Auswahl von Video-Sequenzen Vergleiche anregen und Diskussionen darüber einleiten. Lernende werden angeregt, sich zu einigen, bevor sie ihre Gedanken in der konkreten Bearbeitung eines Videos festhalten.

Das Auswählen bestimmter Videoteile lenkt dabei die Entwicklung eines gemeinsamen Verständnisses. Zum Beispiel kann die technische Funktion des Zoomens den Lernenden dabei helfen, im Video genau auf relevante Stellen zu „zeigen". Sie können dann ihre gemeinsame Aufmerksamkeit leichter auf dieselben Aspekte richten. Das erleichtert es ihnen Ausgangspunkte für die gemeinsame Arbeit zu bestimmen. Wichtig dabei ist, dass verschiedene technische Funktionen die Aufmerksamkeit unterschiedlich lenken: Das Zoomen auf Details bewirkt die Fokussierung von Wahrnehmung und Aufmerksamkeit. Das Gegenüberstellen verschiedener Segmente regt zum Vergleich an.

Durch die Arbeit am Videomaterial können die Ideen der Lernenden direkt an den relevanten Stellen in Bild und Wort festgehalten werden. Dadurch stehen diese Ideen später zur Verfügung und gehen seltener verloren.

Figure C.10. Screenshot 2 of pedagogical information in experimental condition 1 (TK+PK).

Aufbau von DIVER

In WebDIVER können Filme eigener Wahl hochgeladen und bearbeitet werden. Es werden persönliche Kopien der Filme erstellt, die dann im ***DIVER-Arbeitsbereich*** zur Verfügung stehen (siehe Abbildung). Diese konkreten Handlungen am Video unterstützen die Denkprozesse bei der Analyse, dem Vergleich oder beim Diskutieren und Interpretieren der Videoinhalte.

Auf der linken Seite der Oberfläche befindet sich das Video mit den Abspiel- und Auswahlfunktionen (siehe Abbildung). Rechts befindet sich der DIVER-Arbeitsbereich. Hier erscheinen die gewählten Standbilder und Sequenzen als einzelne ***DIVER-Panels*** **untereinander**, nachdem Sie angelegt wurden. Der Arbeitsbereich unterstützt die Arbeit am Video insgesamt wie ein externes Gedächtnis. Überlegungen zum Video gehen so seltener verloren und können mit anderen geteilt werden.

Panels sind jeweils durch ein **Miniaturbild**und den **Zeitstempel** des ausgewählten Videosegments gekennzeichnet (siehe Abbildung). Hierdurch bleibt die Reihenfolge der Szenen im Originalvideo nachvollziehbar, auch wenn man die Panels später neu ordnet. Durch das Klicken auf das Miniaturbild kann man ein Panel anwählen, das sich dann Türkis färbt. Panels beinhalten außerdem Bereiche für Texteingaben. Sie befinden sich neben den Miniaturbildern. Angemeldete Nutzer können dort ***Überschriften*** und ***Kommentare*** zu jedem Ausschnitt hinzufügen. Auf diese Weise werden Überlegungen während der Analyse direkt an den relevanten Stellen in Bild und Wort festgehalten. Sie stehen dann für die weitere Arbeit zur Verfügung und können den Verlauf der weiteren Diskussion über das Video beeinflussen.

Figure C.11. Screenshot 1 of WebDIVER introduction for experimental condition 2 (TPK).

Aufbau von DIVER

Unter dem Video befinden sich die ***Play-***, ***Mark-*** und die ***Record***-Funktionen mit denen man Ausschnitte bilden kann (siehe Abbildung). Der rechteckige gelbe Rahmen im Videobild dient zum Zoomen auf Details. Durch das Ausschneiden von Stellen im Video, bzw. Details innerhalb des gelben Rahmens wird die individuelle und gemeinsame Aufmerksamkeit gelenkt. Die Panels dokumentieren dabei die Ergebnisse dieser Prozesse.

(A) Play
Um das Video abzuspielen klickt man auf die Play- Funktion. Erneutes Klicken pausiert das Video.

(B) Mark
Um ein **Standbild**, bzw. ein Detail daraus (s. nächste Seite) auszuschneiden, klickt man auf ***Mark***. Das Standbild das gerade sichtbar ist, wird als Panel zum Arbeitsbereich hinzugefügt. Es öffnet sich ein Textfeld in das eine Überschrift eingegeben werden kann. Hierdurch ist es möglich digital genau auf die Stellen zu „zeigen", die man relevant findet und diese auch für andere zu verdeutlichen.

(C) Record
Um eine **Video-Sequenz** auszuschneiden, klickt man auf ***Record***, um die Aufnahme zu beginnen. Um die Aufnahme zu beenden, klickt man diesen Button erneut. So kann z.B. die Besonderheit einer Kamerafahrt hervorgehoben werden und als Ausgangspunkt für eine Analyse dienen. Zum Verändern der Länge einer Sequenz, klickt man auf ***Trim*** oben rechts im Panel und passt Beginn und Ende der Sequenz entsprechend an.

Figure C.12. Screenshot 2 of WebDIVER introduction for experimental condition 2 (TPK).

Zoomen

Innerhalb des Videos können mit dem ***gelben Rahmen*** (siehe Abbildung) relevante Bereiche ausgewählt werden, um auf Details des Videos zu fokussieren und sie hervorzuheben. Bei der Aufnahme von Standbildern oder Sequenzen wird nur der Bereich innerhalb dieses Rahmens aufgenommen. Man kann die Größe und die Position des Rahmens verändern und ihn wie die Linse einer virtuellen Kamera nutzen, um auch bewegte Objekte genauer zu betrachten. So können z.B. auch Veränderungen und andere Prozesse in die Analyse und die Interpretation des Videos einbezogen werden.

Die **Größe verändert** man, indem man mit der Maus in eine Ecke des gelben Rahmens klickt und die Taste gedrückt hält. Durch das Bewegen des Mauspfeils zum Zentrum, bzw. zum Rand des Rahmens, lässt sich der Rahmen auf die gewünschte Größe ziehen. Um den Rahmen wieder auf die maximale Größe zu bringen, positioniert man ihn in der Mitte des Videobilds und vergrößert ihn wie beschrieben. Um den Rahmen **als Ganzes zu verschieben**, klickt man ins Zentrum, hält die linke Maustaste gedrückt und bewegt den Rahmen mit der Maus.

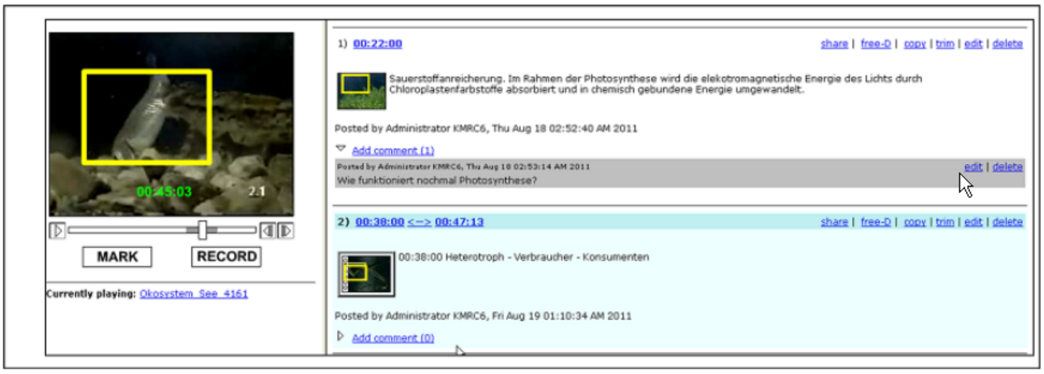


Figure C.13. Screenshot 3 of WebDIVER introduction for experimental condition 2 (TPK).

Textanmerkungen

Haben Sie ein DIVER-Panel angelegt, können Sie im ***Überschriften-Feld (A)*** und ***Kommentar-Feldern (B)*** Text hinzufügen (siehe Abbildung).

(A) Überschriften
Wurde ein DIVER-Panel über den Mark- oder Record-Button erstellt, kann man sofort einen Titel im **Überschriften-Feld** einfügen. In der Gruppenarbeit regt das Verfassen einer gemeinsamen Überschrift die Nutzer dazu an, sich über Ihre Sichtweisen auszutauschen und sich zu einigen, bevor sie den Text eingeben. Um die Eingabe zu ändern, klickt man auf ***edit*** (oben rechts) und speichert Änderungen mit ***Submit***. ACHTUNG, ***nicht*** auf die ***Delete*-Funktion eines Panels** (oben rechts) klicken, um die Eingabe in das Überschriften-Feld zu ändern. Denn dies löscht das gesamte Panel. Die Eingabe im Titelfeld ändert man, indem man erneut auf edit klickt und die Änderungen mit Submit speichert.

(B) Kommentare
Angemeldete Nutzer können Kommentare zu den einzelnen Panels hinzufügen. Der Nutzername der Verfasser erscheint für das Panel und jeden der Kommentare separat, damit man sich in Diskussionen leichter aufeinander beziehen kann. So können direkt an den relevanten Ausschnitten verschiedene Interpretationen einer Information diskutiert werden. Um einen Kommentar hinzuzufügen klickt man auf ***add comment***. Es öffnet sich das grau hinterlegte **Kommentar-Feld**. Eingaben werden mit ***Submit*** gespeichert und mit ***edit*** bearbeitet. Hier dient die ***delete*-Funktion eines Kommentars** (siehe Abbildung unten rechts) dazu, nur den jeweiligen Kommentar zu löschen. Kommentare können durch Klicken auf den kleinen Pfeil neben add comment ein- und ausgeblendet werden. Die Anzahl der Kommentare wird in Klammern angezeigt.

Figure C.11. Screenshot 4 of WebDIVER introduction for experimental condition 2 (TPK).

Panels kopieren und einfügen

Panels können kopiert werden, um dieselbe Information in unterschiedliche Zusammenhänge zu stellen.
Um ein Panel zu kopieren, klickt man auf ***copy*** **(A)**(siehe Abbildung), in der oberen rechten Leiste des gewünschten Panels. Um es anschließend einzufügen klickt man ***paste*** **(B)**(siehe Abbildung) in der Leiste des Bildschirms.
Ist ein bestimmtes Panel angewählt (=Panel ist Türkis hinterlegt), wird das kopierte Panel nach diesem eingefügt. Ist kein Panel angewählt, wird es am Ende des Arbeitsbereichs eingefügt.

Verschieben von Panels (Drag & Drop)

Bereits erstellte Panels können in eine neue Reihenfolge gebracht werden, um eigene Perspektiven auf das Video zu erarbeiten und zu dokumentieren. Die Panels können mit der ***Drag and Drop***-Funktion neu, z.B. thematisch, angeordnet werden. Dies unterstützt durch die aktive Verarbeitung des Videos die Entwicklung eines besseren Verständnisses seiner Inhalte. Dazu wählt man das zu verschiebende Panel durch einen Klick auf das Miniaturbild aus. Dann klickt man in den türkisfarbenen Streifen am oberen Rand und hält die Taste gedrückt. Der Mauspfeil wird zu einem **Navigationskreuz (A)** (siehe Abbildung links), mit dem man das Panel an die gewünschte Stelle ziehen kann **(B)** (siehe Abbildung rechts). Um es dort zu platzieren, lässt man die Maustaste los.

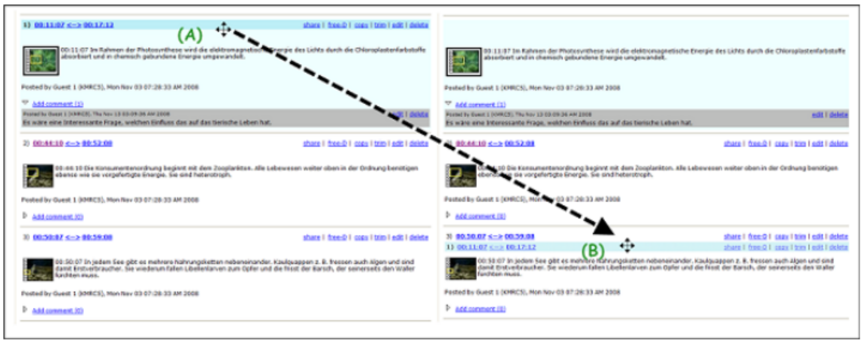


Figure C.15. Screenshot 5 of WebDIVER introduction for experimental condition 2 (TPK).

Figure C.16. Screenshot 6 of WebDIVER introduction for experimental condition 2 (TPK).

Figure C.17. Screenshot 7 of WebDIVER introduction for experimental condition 2 (TPK).

Figure C.18. Screenshot 8 of WebDIVER introduction for experimental condition 2 (TPK).

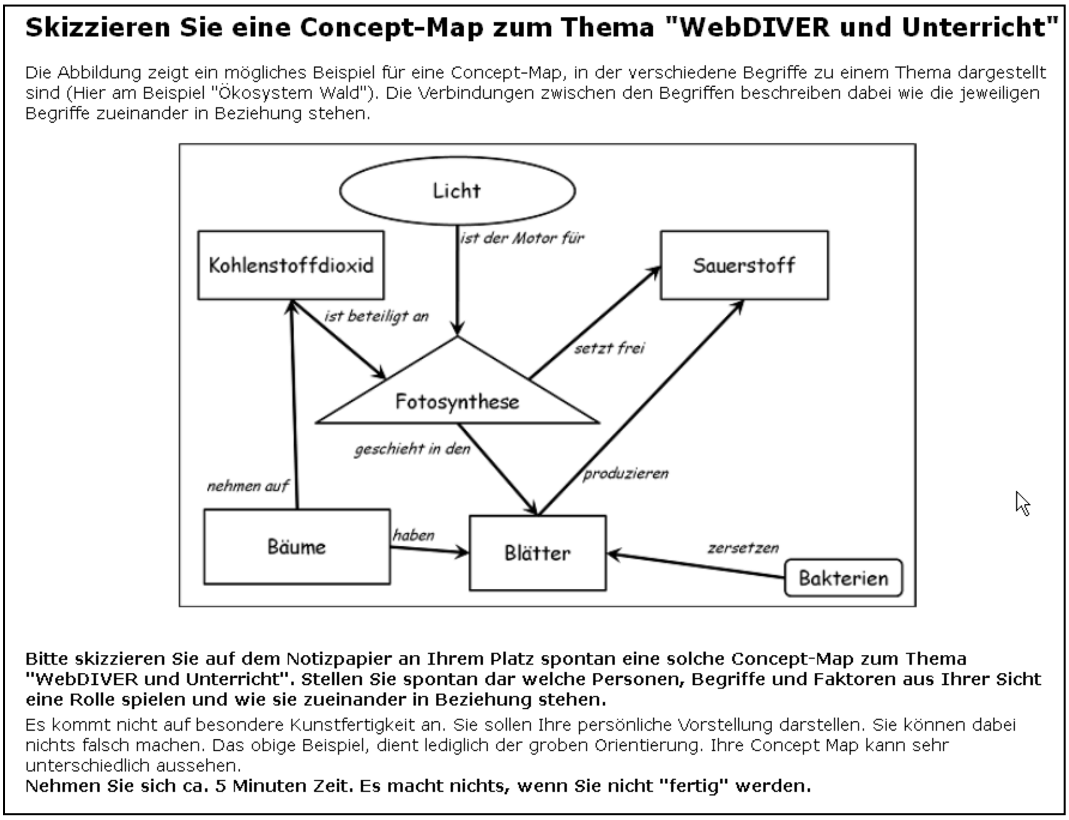


Figure C.19. Screenshot of concept mapping task instruction.

Table C.1

Categories, keywords and MS Excel syntax for coding the recall of WebDIVER functions.

WebDIVER function	Keywords (English translation)	EXCEL formula for German keywords (counts were dichotomized later)
Play	Play, watch, free-d	=(ZÄHLENWENN($D3:$M3;"*abspielen*") +ZÄHLENWENN($D3:$M3;"*anseh*") +ZÄHLENWENN($D3:$M3;"anschauen") +ZÄHLENWENN($D3:$M3;"free-d"))
Still images	Image, mark	=(ZÄHLENWENN($D3:$M3;"*bild*") +ZÄHLENWENN($D3:$M3;"*mark*"))
Sequences	Sequence, video segment video element scene	=(ZÄHLENWENN($D3:$M3;"*sequenz*") +ZÄHLENWENN($D3:$M3;"*videosegment*") +ZÄHLENWENN($D3:$M3;"*videoelement*") +ZÄHLENWENN($D3:$M3;"*szene*"))
Zooming	Zoom, focus, enlarge	=(ZÄHLENWENN($D3:$M3;"*zoom*") +ZÄHLENWENN($D3:$M3;"*fokus*") +ZÄHLENWENN($D3:$M3;"*zomm*") +ZÄHLENWENN($D3:$M3;"*vergrö*"))
Titles	Title	=(ZÄHLENWENN($D3:$M3;"*überschrift*") +ZÄHLENWENN($D3:$M3;"*titel*") +ZÄHLENWENN($D3:$M3;"*ueberschrift*"))
Commenting	Comment	=ZÄHLENWENN($D3:$M3;"*komment*")
Copying & pasting	copy	=(ZÄHLENWENN($D3:$M3;"*kopier*") +ZÄHLENWENN($D3:$M3;"*copy*"))

Table C.1 (continued)

WebDIVER function	Keywords (English translation)	EXCEL formula for German keywords (counts were dichotomized later)
Reordering	Order, drag, move, sort, remix	=(ZÄHLENWENN($D3:$M3;"*ordn*") +ZÄHLENWENN($D3:$M3;"*drag*") +ZÄHLENWENN($D3:$M3;"*verschieb*") +ZÄHLENWENN($D3:$M3;"*sortier*") +ZÄHLENWENN($D3:$M3;"*reihenfolg*") +ZÄHLENWENN($D3:$M3;"*abfolg*") +ZÄHLENWENN($D3:$M3;"*remix*"))
Sharing	Mail, send, recommend, share	=(ZÄHLENWENN($D3:$M3;"*mail*") +ZÄHLENWENN($D3:$M3;"*verschick*") +ZÄHLENWENN($D3:$M3;"*versend*") +ZÄHLENWENN($D3:$M3;"*weiterempf*") +ZÄHLENWENN($D3:$M3;"*share*") +ZÄHLENWENN($D3:$M3;"*geteilt*") +ZÄHLENWENN($D3:$M3;"*teilen*"))
Embedding	Website, embed, homepage	=(ZÄHLENWENN($D3:$M3;"*website*") +ZÄHLENWENN($D3:$M3;"*einbett*") +ZÄHLENWENN($D3:$M3;"*hompage*") +ZÄHLENWENN($D3:$M3;"*verlink*") +ZÄHLENWENN($D3:$M3;"Netz"))

Table C.2

Categories, keywords and MS Excel syntax for coding the teaching approaches in participants' lesson plans, TPCK design task.

Teaching approach	Sub categories	Keywords (English translation)	EXCEL formula for German keywords
Teacher-Centered	Material Preparation (teacher)	Prepare[a], to trim[a], provide[a], lesson preparation	=ZÄHLENWENN($H3;"*vorbereit*") +ZÄHLENWENN($H3;"*zurecht*") +ZÄHLENWENN($H3;"*bereitstell*") +ZÄHLENWENN($D3:$I3;"*unterrichts-vorbereitung*")
	Shortening Movies	Shorten, too long	=ZÄHLENWENN($D3:$I3;"*kürz*") +ZÄHLENWENN($D3:$I3;"*zu lang*")
	Teacher Presentation	absorb, transmit[a], present[a], show[a], rewind[a], fast forward[b]	=ZÄHLENWENN($D3:$I3;"*rezip*") +ZÄHLENWENN($H3;"*vermittl*") +ZÄHLENWENN($H3;"*vorführ*") +ZÄHLENWENN($H3;"*präsenti*") +ZÄHLENWENN($H3:$I3;"*spul*")
Student-Centered	Student Motivation	Interest, motivation, boring, exciting, variation	=ZÄHLENWENN($D3:$I3;"*interess*") +ZÄHLENWENN($D3:$I3;"*motiva*") +ZÄHLENWENN($D3:$I3;"*motivi*") +ZÄHLENWENN($D3:$I3;"*langweil*") +ZÄHLENWENN($D3:$I3;"*langeweil*") +ZÄHLENWENN($D3:$I3;"*spannend*") +ZÄHLENWENN($D3:$I3;"*abwechsl*")
	Student Media Literacy	Media, stylistic device, camera position, sensitize	=ZÄHLENWENN($D3:$I3;"*medi*") +ZÄHLENWENN($D3:$I3;"*stilmittel*") +ZÄHLENWENN($D3:$I3;"*kameraf*") +ZÄHLENWENN($D3:$I3;"*sensibi*")
	Student Active Use	Active, autonomous, not passive, create [imperative][a], use [imperative][a]	=ZÄHLENWENN($D3:$I3;"*aktiv*") +ZÄHLENWENN($D3:$I3;"*selbständ*") +ZÄHLENWENN($D3:$I3;"*eigenständ*") +ZÄHLENWENN($D3:$I3;"*nicht passi*") +ZÄHLENWENN($D3:$I3;"*selbstständig*") +ZÄHLENWENN($D3:$I3;"*erstell*") +ZÄHLENWENN($D3:$I3;"*selbst*") +ZÄHLENWENN($F3;"*stellt*") +ZÄHLENWENN($F3;"*benutzt*")

Table C.2 (continued)

Teaching approach	Sub categories	Keywords (English translation)	EXCEL formula for German keywords
Attention Guidance Focus	Detail Perception	Detail, focus(ing), look closer	=ZÄHLENWENN($D3:$I3;"*detail*") +ZÄHLENWENN($D3:$I3;"*einzelh*") +ZÄHLENWENN($D3:$I3;"*fokus*") +ZÄHLENWENN($D3:$I3;"*genauer hinsehen*")
	Focusing Attention	Crucial, attention, concentrate	=ZÄHLENWENN($D3:$I3;"*wesentl*") +ZÄHLENWENN($D3:$I3;"*aufmerk*") +ZÄHLENWENN($D3:$I3;"*konzentr*")
Comprehension Focus	Empathy	Feel, emotion, empathy, put oneself in one's position	=ZÄHLENWENN($D3:$I3;"*gefühl*") +ZÄHLENWENN($D3:$I3;"*emotion*") +ZÄHLENWENN($D3:$I3;"*mitfühl*") +ZÄHLENWENN($D3:$I3;"*empat*") +ZÄHLENWENN($D3:$I3;"*hineinver*")
	Comparison	Compare, opposite to, on the other hand	=ZÄHLENWENN($D3:$I3;"*vergleich*") +ZÄHLENWENN($D3:$I3;"*gegenüber*") +ZÄHLENWENN($D3:$I3;"*andererseits*")
Collaboration Focus		Group, discuss, exchange, partner work, in pairs	=ZÄHLENWENN($D3:$I3;"*gruppe*") +ZÄHLENWENN($D3:$I3;"*diskuss*") +ZÄHLENWENN($D3:$I3;"*austausch*") +ZÄHLENWENN($D3:$I3;"*diskut*") +ZÄHLENWENN($D3:$I3;"*partnerarbeit*") +ZÄHLENWENN($D3:$I3;"*zu zweit*")

Note. Excel columns: D = lesson plan content, E = learning goal/process, F = task instruction, G = procedure, H = teacher role, I = technology added-value.

[a]keyword only considered in descriptions specific aspects, see column specification.

Table C.3

Categories, keywords and MS Excel syntax for coding the recall of VideoANT functions.

VideoANT function	Keywords (English translation)	EXCEL formula for German keywords (counts were dichotomized later)
Play	Play, watch, start, rewind / fast forward	=(ZÄHLENWENN($D2:$K2;"*abspielen*") +ZÄHLENWENN($D2:$K2;"*ansehen*") +ZÄHLENWENN($D2:$K2;"*anschauen*") +ZÄHLENWENN($D2:$K2;"*start*") +ZÄHLENWENN($D2:$K2;"*betrach*") +ZÄHLENWENN($D2:$K2;"*spul*"))
Markers	Mark, pin	=(ZÄHLENWENN($D2:$K2;"*mark*") +ZÄHLENWENN($D2:$K2;"*nadel*"))
Annotating	Create, insert, comment, annotate	=ZÄHLENWENN($D2:$K2;"*erstell*") +ZÄHLENWENN($D2:$K2;"*füg*") +(((ZÄHLENWENN($D2:$K2;"*komment*") +ZÄHLENWENN($D2:$K2;"*anmerk*") +ZÄHLENWENN($D2:$K2;"*bemerk*")) /(ZÄHLENWENN($D2:$K2;"*komment*")+ZÄHLENWENN($D2:$K2;"*anmerk*")+ZÄHLENWENN($D2:$K2;"*bemerk*"))))
Editing	Edit, refine	=(ZÄHLENWENN($D2:$K2;"*bearbe*") +ZÄHLENWENN($D2:$K2;"*aufberei*") +ZÄHLENWENN($D2:$K2;"*edit*"))
Reordering	Order, move	=(ZÄHLENWENN($D2:$K2;"*ordn*") +ZÄHLENWENN($D2:$K2;"*verschie*") +ZÄHLENWENN($D2:$K2;"*folge*"))
Timeline	Timeline	=(ZÄHLENWENN($D3:$K3;"*zeitleist*") +ZÄHLENWENN($D3:$K3;"*timeline*"))
Sharing	Share, send, mail, access, link, embedd	=(ZÄHLENWENN($D2:$K2;"*teil*") +ZÄHLENWENN($D2:$K2;"*send*") +ZÄHLENWENN($D2:$K2;"*mail*") +ZÄHLENWENN($D2:$K2;"*verfüg*") +ZÄHLENWENN($D2:$K2;"*link*") +ZÄHLENWENN($D2:$K2;"*schick*") +ZÄHLENWENN($D2:$K2;"*einbett*"))
Cutting out[a]	Cut	=(ZÄHLENWENN($D2:$K2;"*schneid*"))

Note. [a]function applying to WebDIVER, considered to assess incorrect transfer.

Summary

Teaching is a complex and ill-defined task that requires teachers to be knowledgeable in several domains, namely, content, pedagogy, and their specific connections. Moreover, today's teachers must be acquainted with a number of technologies that can effectively support students' learning in their subjects. With this, the task of teaching has become even more complex due to the rapid development of emerging digital technologies that offer a wide range of possibilities for individual and collaborative learning. Thus, teachers do not simply need to know "where to click" to operate technological functions, but they need to grasp how these functions impact individual and collaborative learning. A conceptual framework that tries to account for this perspective on technology while considering the mentioned sub-domains of teachers' professional knowledge is the Technological Pedagogical Content Knowledge framework (TPCK, Koehler & Mishra, 2008; Mishra & Koehler, 2006). Its central claim is that teachers need to consider technological aspects of their knowledge (TK) as an integrated part of other relevant sub-domains of teacher knowledge, namely, content knowledge (CK) and pedagogical knowledge (PK). However, above and beyond characterizing the content of the proposed knowledge sub-domains, researchers invested in the TPCK approach have neglected to provide a theoretical basis for more concrete and confutable assumptions (Graham, 2011; Voogt et al., 2012) and add a process-oriented perspective to the current structure oriented-perspective. There is a lack of clear definitions of how knowledge in the proclaimed sub-domains is mentally represented and how the different sub-domains presumably interrelate. Furthermore, it also remains an open issue whether TPCK as a construct defines a unique knowledge representation or a combination automatically arising from knowledge in the sub-domains (cf. *transformative* versus *integrative* view of TPCK, Angeli & Valanides, 2009). The present dissertation addresses these issues in two parts.

First, based on these considerations, the present dissertation proposes theoretical specifications of the TPCK framework in order to derive assumptions about the proposed knowledge representations of the sub-domains, their interrelations, and TPCK as a construct. The claim is formulated that teachers have to mentally represent how the technological affordances and how they interact with pedagogy and content. In order to specify this notion of perceived affordances, these are defined as knowledge about the

impact of technological functions on relevant dimensions of teaching and learning, namely, their functions in supporting cognitive, socio-cognitive, meta-cognitive and motivational learning goals. More concretely, it is assumed that in order to pedagogically leverage the potential of emerging technology, at a first level of cognitive integration teachers need to construct mental models that represent the technology's functions in the light of the complexity of the task of teaching and the teacher's prior professional knowledge. Furthermore, I propose a second level of cognitive integration that defines TPCK as a teacher's meta-conceptual awareness of the demands of the teaching task, the teachers' own professional knowledge in the other sub-domains, and the contextual constraints. Overall, TPCK as a scientific normative framework has to assume a coherent structure of basic underlying assumptions (cf. framework theories, Vosniadou, 1994) that constrain the construction of mental models in concrete situations. In sum, these considerations offer a more concrete specification of the notion of TPCK as a unique body of knowledge (cf. the *transformative* view of Angeli & Valanides, 2009).

Second, in the context of the TPCK there are no systematic empirical studies trying to assess the influence of teachers' prior knowledge on their understanding of technology and ultimately their intentions of using technology in their teaching. Empirically, the challenge to construct appropriate mental models of the learning-relevant functions of a technology becomes particularly evident for more traditional technologies, such as film and video. On the one hand, these are "revolutionized" by the new technological developments. On the other hand, the everyday use of video in the classroom does not offer pedagogies that make the integration of this potential easily possible (Hobbs, 2006). Therefore, digital video technology is chosen as an exemplar for emerging technologies in the empirical part of this dissertation. Three studies investigated the assumption that mental models of technology functions impact on teachers' lesson planning for utilizing sample emerging technology and how prior PK influences these relationships. In all studies, pre-service teachers' PK and TK, as well as their pedagogical beliefs were assessed as potential presuppositions for participants' mental models of learning-relevant functions. Mapped onto the sub-domains of the TPCK framework these mental models were considered an indicator for the participants' Technological Pedagogical Knowledge (TPK), that is, the content-general potential of the respective technology. As a dependent variable lesson plans are considered indicators for the participants' performance in tasks requiring Technological Pedagogical Content

Knowledge (TPCK). Finally, an experimental paradigm was introduced to contrast different hypotheses about the development of TPCK (*integrative* versus *transformative*).

Study 1 investigated whether pre-service teachers' prior PK can predict the complexity of their mental models of the learning-relevant functions of a known digital video technology (YouTube); and, in turn, whether that complexity predicted two aspects of planning the use of YouTube with students in class: The intended use and an ideal use. The results were in line with the expectation that the mental models participants possessed of the functions of YouTube had a distinct influence on their lesson planning. In detail, higher prior PK positively predicted the quality of participants' lesson planning for YouTube. However, this influence was mediated by the complexity of their mental models of YouTube for the proposed ideal instructional applications of YouTube, and showed a marginal indirect effect for its intended use. Overall, the statistical effects were of moderate to small size. In their lesson plan ideas for instructional use of YouTube, participating pre-service displayed rather conservative applications of YouTube, focusing on YouTube as an audio-visual medium, and as a searchable database with some additional Web 2.0 features.

Based on the findings from Study 1, the aim of Study 2 was to investigate how pre-service teachers' mental models of the learning-relevant functions of a newly encountered video technology (WebDIVER^{TM}) impact their lesson planning for this technology. Furthermore, the subjects of participating pre-service teachers were constrained to history and language arts. With regard to lesson planning, the concrete topic of propaganda in post-war Germany was provided as a sample topic. In addition to designing an own lesson plan for this sample content a sample lesson plan was provided that was evaluated by participants. Qualitative results show that participants represented the specific socio-cognitive functions of the tool in their mental models. In contrast to this, in their designed lesson plans, specific tool functions were only partly reflected and participants relied upon tool-unspecific uses. Quantitative analyses showed that participants' mental models of the functions of WebDIVER predicted their proposed ideal uses of the video tool and their ratings of an example lesson plan. Of more interest, representing cognitive or socio-cognitive functions of a technology differentially predicted the evaluation and design of lesson plans. Furthermore, both were distinct from the influence of prior PK and pedagogical beliefs (constructivist orientation).

Overall, results of Study 3 showed that that in comparison to a control group (only technological information), more general characteristics of participants' mental models of WebDIVER could be supported by both experimental manipulations, that is, presenting pedagogical information and technological information regardless of is form (providing pedagogical information separately versus modeling its cognitive integration) supported more complex mental models of WebDIVER with regard to its pedagogical impact. The same was true for the TPCK evaluation, comprehension and design task. However, only the explicit modeling of how to integrate information about technological functions and their pedagogical impact lead to a more complete mental models, and more central representation of pedagogical agents (students and teachers). In line with this, pre-service teachers in this condition created more student-centered and less teacher-centered lesson plans for WebDIVER. An important finding was that for many indicators the effects were only present for participants with higher prior PK. Especially with regard to transfer task performance a good week later: only participants with higher prior PK in the condition that modeled the cognitive integration of pedagogical and technological information showed a deeper pedagogical understanding comparing WebDIVER to another tool (VideoANT).

In conclusion, by elaborating on the representational form of the knowledge sub-domains proposed by the TPCK framework it was possible in the present dissertation to lay ground for deducing more concrete hypotheses about their interrelations. Thus, a first step was taken to formulate a process-oriented elaboration of the TPCK framework. In line with this, the present empirical findings could provide initial evidence that indeed abstract pedagogical knowledge, and mental models of tool functions as TPK indicator showed distinct influences on the lesson planning for pre-service teachers using the sample of digital video technology. The two studies, however, in which the construction of more complex mental models of the sample technology was not supported showed that participating pre-service teachers did not focus on leveraging the specific potential of the respective video technology, but instead reverted to common patterns of using video for instruction. In contrast, the third, experimental study, provided evidence that modeling the integration of pedagogical and technological information fosters a more complex understanding of tool affordances and more student-centered use of digital video technology. In sum, the results of this dissertation contribute to the understanding of how (pre-service) teachers develop media-related competence. Simultaneously this dissertation creates a foundation for more specific operationalizations of assumptions underlying the TPCK framework that can now be tested in future experimental research.

Zusammenfassung

Unterrichten ist eine komplexe Aufgabe, die von Lehrkräften umfassendes Wissen in mehreren Inhaltsbereichen verlangt. Dabei gelten Fachwissen und pädagogisch-psychologisches Wissen, als auch deren Zusammenspiel im fachdidaktischen Wissen (Pedagogical Content Knowledge, vgl. Shulman, 1986; 1987), als besonders bedeutsam. Heutzutage ist es darüber hinaus von Bedeutung, dass Lehrkräfte mit einer Reihe von Technologien vertraut sind, die Schülerinnen und Schüler beim Lernen eine Bandbreite von Möglichkeiten bieten. Die rapide und stetige Weiterentwicklung sogenannter *emergenter* digitaler Technologien erhöht hierbei jedoch Komplexität einer entsprechenden Unterrichtsplanung in besonderem Maße. Für die sinnvolle Einbindung solcher digitaler Technologien in den Fachunterricht ist es also nicht ausreichend, wenn Lehrkräfte wissen, wo sie klicken müssen; sie müssen vielmehr erfassen, wie diese technischen Funktionen individuelles und kooperatives Lernen beeinflussen. Erst hierdurch wird die Anpassung von allgemeinen Potentialen emergenter Technologien (repurposing) für die spezifische Unterstützung in der Unterrichtsgestaltung möglich.

Ein konzeptueller Rahmen, der diese Auffassung von Technologie aufgreift und sie im Zusammenspiel mit den genannten Bereichen des professionellen Wissens von Lehrkräften betrachtet, ist das Technological Pedagogical Content Knowledge, kurz TPCK, Rahmenmodell (Koehler & Mishra, 2008; Mishra & Koehler, 2006). Die zentrale Annahme dieses Ansatzes ist, dass Lehrkräfte technologisches Wissen (Technological Knowledge, TK) mit ihrem Fachwissen (Content Knowledge, CK) und pädagogischen Wissen (Pedagogical Knowledge, PK) integriert repräsentieren müssen, um effektiv mit Technologie zu unterrichten. In der entsprechenden Forschungsliteratur haben sich die Autorinnen und Autoren bisher jedoch weitestgehend darauf beschränkt, die verschiedenen Unter-Inhaltsbereiche, die sich aus den Überschneidungen dieser drei Basis-Bereiche ergeben, inhaltlich zu umreißen. Dabei wurde versäumt, theoretische Ansätze bereitzustellen, die es ermöglichen konkretere und falsifizierbare Annahmen aus dem TPCK Rahmenmodell abzuleiten (Graham, 2011; Voogt et al., 2012). Zum einen mangelt es daher an klaren Definitionen der Art und Weise, wie das Wissen in den beschriebenen Unterbereichen mental repräsentiert ist und in welcher Beziehung diese zueinander stehen. Zum anderen fehlt eine Definition dessen, was die Besonderheit des Technological Pedagogical Content Knowledge – des zentralen Konstrukts – im Hinblick

auf seine mentale Repräsentation auszeichnet (vgl. die *transformative* und *integrative* Sichtweise auf dieses Konstrukt diskutiert von Angeli & Valanides, 2009). Die vorliegende Dissertation geht auf diese offenen Fragen in zwei Teilen ein.

Zuerst wird durch theoretische Überlegungen über die mentalen Repräsentationen der propagierten Wissensbereiche versucht das TPCK Rahmenmodell genauer zu spezifizieren. Daraus werden dann Annahmen darüber abgeleitet, wie diese bei der Entwicklung des übergreifenden technologischen Wissens (TPCK als Konstrukt) zusammenwirken und wie dieses Konstrukt genauer gefasst werden kann. Ich gehe davon aus, dass es für Lehrkräfte notwendig ist den Aufforderungscharakter einer Technologie, sogenannte Affordanzen, und wie er mit Fachinhalt und pädagogischen Prinzipien in Wechselwirkung steht, mental zu repräsentieren. Dabei wird eine genauere Definition dieser Affordanzen vorgeschlagen, und zwar als Einfluss technologischer Funktionen auf die Erreichung kognitiver, sozio-kognitiver, meta-kognitiver und motivationaler Lernziele seitens der Schülerinnen und Schüler. Darauf aufbauend wird davon ausgegangen, dass Lehrkräfte auf einer ersten Ebene der kognitiven Integration mentale Modelle dieser lernrelevanten Funktionen konstruieren müssen, um das Potential einer Technologie auszuschöpfen. Dabei ist es für die Lehrkraft notwendig, die Komplexität der an sie gestellten Aufgabe sowie ihr eigenes professionelles (Vor-)Wissen zu berücksichtigen. Daher wird weiter davon ausgegangen, dass auf einer zweiten Ebene der kognitiven Integration TPCK als meta-konzeptuelles Verständnis (meta-conceptual awareness) der Lehrkraft zu definieren ist, d.h. als eine Bewusstheit für die Anforderungen der Lehr-Aufgabe, für das eigene professionelle Wissen in den spezifizierten Unterbereichen und für die Einschränkungen durch den jeweiligen Kontext. Insgesamt ergibt sich daraus für TPCK als normatives theoretisches Rahmenmodell eine Konzeptionalisierung als kohärente Struktur basaler Annahmen (vgl. framework theories, Vosniadou, 1994), welche die Bandbreite der möglichen mentalen Modelle in einer jeweiligen konkreten Situation einschränken. Zusammengefasst ergeben diese theoretischen Erörterungen eine konkrete Ausformulierung der bisher groben Annahme, TPCK stelle einen eigenständigen Wissenskorpus dar (vgl. die *transformative* Sichtweise bei Angeli & Valanides, 2009).

Im Anschluss daran geht die vorliegende Dissertation im zweiten Teil darauf ein, dass im Zusammenhang mit dem TPCK Rahmenmodell keine systematische empirische Forschung existiert, welche die Einflüsse professionellen Vorwissens von Lehrkräften auf ihr Verstehen emergenter Technologien und letztlich ihre diesbezügliche

Unterrichtsplanung untersucht. Für die entsprechenden empirischen Studien dieser Dissertation wurden dabei digitale Videotechnologien genutzt, sogenannte Video-Werkzeuge (hier YouTube und WebDIVER^{TM}), als Beispieltechnologie. Das Medium Video wird zum einen durch die beständige Entwicklung vor allem Web-basierter Anwendungen „revolutioniert“. Zum anderen jedoch existiert für Video eine längere Tradition für seine Nutzung im Unterricht, die zudem dadurch gekennzeichnet ist, dass der Einsatz von Videos zumeist nicht mit eigentlichen Lernzielen verbunden wird (vgl. Hobbs, 2006). Vor dem Hintergrund dieses Spannungsfeldes scheinen digitale Videowerkzeuge besonders geeignet, da Lehrkräfte hierbei besonders herausgefordert sind, die konkreten Potentiale der jeweiligen Technologie zu erkennen und gegen traditionelle Verwendungen von Videos abzugrenzen, um einen Zusatznutzen der Technologie für Lehr-Lernprozesse zu kreieren.

Unter Verwendung dieser Beispieltechnologie wurde in drei Studien die Annahme geprüft, ob die mentalen Modelle, welche die Teilnehmenden von den Funktionen einer Technologie konstruieren, den Einflüsse von Vorwissen (PK) und gezielter Unterstützung eines komplexeren Technologieverständnisses auf die Unterrichtsplanung mediieren. In allen Studien wurden das pädagogische und technologische Vorwissen sowie die lehr-lerntheoretischen Überzeugungen von Lehramtsstudierenden (constructivist orientation) als mögliche Vorbedingungen für deren mentale Modelle lernrelevanter Technologiefunktionen erhoben. Vor dem Hintergrund des TPCK Rahmenmodells werden diese mentalen Modelle als Indikatoren für den Unterbereich des inhaltsunspezifischen Technological Pedagogical Knowledge (TPK) verstanden und die Skizzen für Unterrichtspläne als Indikatoren für die Fähigkeit der Teilnehmenden Aufgaben zu lösen, die alle Aspekte von TPCK ansprechen. In Studie 1 wurde untersucht, ob das pädagogische Vorwissen von Lehramtsstudierenden verschiedener Fächer die Komplexität ihrer mentalen Modelle lernrelevanter Funktionen eines bekannten Video-Werkzeugs (YouTube) vorhersagen kann. Anschließend wurde geprüft, ob die mentalen Modelle ihrerseits verschiedene Aspekte der Unterrichtsplanung (ideale und geplante Verwendung) für diese Technologie vorhersagen können. Die Ergebnisse zeigten im Einklang mit den vorhergehenden Annahmen, dass höheres pädagogisches Vorwissen ein signifikanter Prädiktor für die Qualität der Unterrichtspläne war. Darüber hinaus wurde für den Aspekt der idealen Verwendung von YouTube im Unterricht dieser Zusammenhang durch die Komplexität der mentalen Modelle mediiert. Für die geplante

Verwendung zeigte sich ein marginaler indirekter Effekt. Insgesamt waren die Effekte klein bis moderat. Eine inhaltliche Betrachtung der Unterrichtspläne ergab, dass die teilnehmenden Lehramtsstudierenden im Hinblick auf eine ideale Verwendung von YouTube im Unterricht relativ konservative Vorschläge beschrieben und dabei auf allgemeine audio-visuelle Eigenschaften, z.B. Anschaulichkeit, fokussierten. Andere zentrale Aspekte in den Plänen bezogen sich auf YouTube als durchsuchbare Datenbank mit einigen interaktiven Web 2.0-Funktionen.

In einer zweiten Studie wurde dann geprüft, ob diese Zusammenhänge auch im Falle eines neu kennen gelernten Video-Werkzeuges mit vorwiegend kollaborativen Funktionen (WebDIVER™) gezeigt werden können. In dieser Studie wurde zudem der Inhaltsbereich auf die Fächer Deutsch und Geschichte beschränkt und ein spezifisches Thema für die Unterrichtsplanung vorgegeben, und zwar die Wochenschau als Propagandamittel in Nachkriegsdeutschland inklusive einer konkreten Wochenschau zur Berlin Blockade und Luftbrücke. Die Unterrichtsplanung als abhängige Variable wurde um eine Beurteilungsaufgabe erweitert, in der die teilnehmenden Lehramtsstudierenden ein Beispiel für den Einsatz der präsentierten Wochenschau zusammen mit WebDIVER (vgl. Zahn, Pea, et al., 2010) auf verschiedenen Dimensionen einschätzen sollten. Qualitative Analysen zeigten, dass die Teilnehmenden die spezifischen sozio-kognitiven Funktionen des Video-Werkzeugs in ihren mentalen Modellen durchaus repräsentierten, in ihren Unterrichtsplänen hingegen auf unspezifische Verwendungen der Technologie zurückgriffen. Quantitative Analysen zeigten, dass die mentalen Modelle der Funktionen von WebDIVER, welche die Teilnehmenden hatten, je nach Repräsentation kognitiver oder sozio-kognitiven Funktionen unterschiedlich mit eigenen Plänen für die Verwendung dieser Technologie im Unterricht und der Beurteilung eines Beispiel-Unterrichtsplans zusammenhingen: kognitive Funktionen zeigten einen positiven Zusammenhang mit idealen Verwendungsmöglichkeiten aber einen negativen mit der Beurteilung der Potentiale des Beispiels; sozio-kognitive Funktionen waren positive mit der Technologiebeschreibung in konkreten Unterrichtsideen verbunden. Insgesamt zeigte sich, dass die Indikatoren für die mentalen Modelle der Teilnehmenden wie in Studie 1 vom pädagogischen Vorwissen (PK) und auch pädagogischen Überzeugungen empirisch unterschieden werden konnten.

Die Ergebnisse der dritten Studie zeigten, dass im Vergleich zu einer Kontrollgruppe (nur technische Informationen) allgemeinere Eigenschaften der mentalen

Modelle der teilnehmenden Lehramtsstudierenden durch beide experimentellen Interventionen (separate Gabe pädagogischer Informationen versus Modellierung der kognitive Integration dieser Informationen) gleichermaßen zu komplexeren mentalen Modellen von WebDIVER im Hinblick auf Konsequenzen fürs Unterrichten führten. Dies galt in ähnlicher Weise für die Ausführung der TPCK-Aufgaben der Beurteilung, des Verständnisses und der Erstellung von Unterrichtsplänen. Im Hinblick auf vollständigere mentale Modelle und eine zentralere Repräsentation der Lernenden zeigte sich jedoch, dass nur die explizite Modellierung der kognitiven Integration von Informationen über technische Funktionen und Informationen über ihre möglichen pädagogischen Auswirkungen einen begünstigenden Einfluss hatte. Dies galt auch für die erstellten Unterrichtspläne, die in dieser Bedingung stärker schüler- und weniger lehrerzentriert waren. Für viele Indikatoren der abhängigen Variablen zeigte sich darüber hinaus, dass die Effekte nur für Lehramtsstudierende mit relativ höherem pädagogischem Vorwissen (PK) auftraten. Dies galt insbesondere für die Transferaufgabe, in der die Teilnehmenden WebDIVER mit einem weiteren zuvor unbekannten Video-Tool (VideoANT) nach gut einer Woche vergleichen sollten.

In den theoretischen Erörterungen dieser Dissertation wurde insgesamt betrachtet eine Spezifikation der mentalen Repräsentation der vom TPCK Rahmenmodell propagierten Inhaltsbereiche des Professionswissens von Lehrkräften vorgenommen. Diese stellte wiederum eine Grundlage dar für die kohärentere Beschreibung des Rahmenmodells und die Ableitung spezifischer Annahmen über das Zusammenwirken der verschiedenen Unterbereiche. Vor diesem Hintergrund konnten schließlich in zwei korrelativen Studien mit Lehramtsstudierenden die spezifischen Einflüsse von pädagogischem Vorwissen und den mentalen Modellen lernrelevanter Funktionen von Video-Werkzeugen in Abgrenzung von lehr-lerntheoretischen Überzeugungen gezeigt werden. Beide Studien zeigten aber auch, dass die geplante Verwendung digitaler Video-Werkzeuge als Beispiel für emergente Technologien sich oft nicht auf die spezifischen Potentiale der jeweiligen Technologie zu Nutze macht. Das Verständnis der Technologie-Funktionen schien z.T. durch bekannte Muster der Verwendung von Video im Unterricht eingeschränkt. Im Gegensatz dazu konnte in einer experimentellen Studie gezeigt werden, dass das explizite Modellieren der kognitiven Integration pädagogischer und technischer Information die Konstruktion komplexerer mentaler Modelle der Lernfunktionen eines Video-Tools unterstützen kann und dies auch auf die Unterrichtsplanung durchschlägt.

Insgesamt tragen die Ergebnisse dieser Dissertation zum weiteren Verständnis der Entwicklung und Förderung technologischer Kompetenzen von (zukünftigen) Lehrkräften bei und bilden gleichzeitig eine neue Grundlage für die Überprüfung spezifischer Hypothesen in zukünftigen experimentellen Studien.

Acknowledgements

http://www.youtube.com/watch?v=QNR_jMdVBpE