**Skill or Will? Effects of Teacher Knowledge and Motivation on the Quality of
Technology-Enhanced Lesson Plans**

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Abstract

In an expertise study with 94 mathematics teachers varying in their teaching experience (i.e., pre-service, induction, in-service teachers), we examined effects of teachers' professional knowledge and motivational beliefs on their ability to effectively integrate educational technology into their lesson plans. We assessed teachers' professional knowledge (i.e., content knowledge, pedagogical content knowledge, technological knowledge), and their motivational beliefs (i.e., self-efficacy, utility-value). Additionally, teachers developed a worked-out lesson plan for introducing the Pythagorean theorem to secondary students. They were explicitly instructed to refer to the integration of technology in their lesson plans. Experienced teachers considered more cognitively activating tasks in their lesson plans and exploited the potential of technology more than inexperienced teachers. Mediation analyses revealed that this effect was explained by teachers' perceived utility-value of educational technology but not by their professional knowledge. These findings suggest that teachers' motivational beliefs play a decisive role for effectively integrating technology in mathematics instruction.

Keywords: educational technology, expertise research, professional knowledge, expectancy-value theory, mathematics teaching

1. Introduction

“Technology can amplify great teaching, but great technology cannot replace poor teaching” (OECD, 2015, p. 4). This quote nicely illustrates that educational technology can contribute to students’ achievement when it is adequately orchestrated in the classroom (e.g., Chauhan, 2017; Mayer, 2019; Puentedura, 2006; Zhu & Urhahne, 2018). Therefore, researchers often claim that teachers have to develop sophisticated professional competences comprising both cognitive factors (i.e., professional knowledge) and motivational beliefs (Kunter et al., 2013) to fully exploit the potential of technologies in a didactical manner and subsequently contribute to the effectiveness of technology-enhanced instruction. Whether and how teachers’ knowledge and motivational beliefs as distinct facets of their professional competences account for the effective integration of technology during teaching is still an open issue, predominantly because previous research mainly relied on self-reports (see also Akyuz, 2018; Voss, Kunter, & Baumert, 2011; Yeh, Hsu, Wu, & Chien, 2017, for related discussions).

Against this background, we conducted an expertise study with mathematics teachers ($N = 94$) differing in their expertise (i.e., years of teaching experience, level of teacher education qualification) to examine the effects of mathematics teachers’ professional knowledge and their motivational beliefs on their potential integration of technology. We used a scenario-based lesson planning approach, which allowed us to measure teachers’ technology integration in a situational manner.

1.1 Boundary Conditions for Technology Integration

Previous research has documented that in many educational systems teachers rarely use technology when teaching (e.g., Drossel, Eickelmann, & Gerick, 2017). For instance, Fraillon et al. (2014) examined teachers’ implementation of educational technology across 21 educational systems. The authors found that there were large discrepancies regarding the use

of technology across the different educational systems. For example, only one third of the participating German teachers reported regularly using technology for teaching – in contrast to 80% of the teachers from other countries like Australia. The question arises which boundary conditions account for the obtained discrepancies across the different educational systems. Against this background, Petko (2012) proposed the multidimensional will-skill-tool-framework describing three dimensions constraining teachers' integration of technology (see also Agyei & Voogt, 2011; Knezek & Christensen, 2016; Petko, Prasse, & Cantieni, 2018).

1.1.1 Tools: Availability of technological infrastructure. The availability of *tools* can be regarded as a fundamental boundary condition regarding the integration of technology for teaching (Gil-Flores, Rodríguez-Santero, & Torres-Gordillo, 2017; Petko, 2012). The dimension tools comprise the access to hardware (e.g., tablets, computers), software (e.g., applications, Web 2.0 tools), and infrastructure (e.g., internet-access, intranet-access). Regarding its effect on technology implementation, research showed that the mere availability of tools is a necessary but not sufficient pre-condition to integrate technology when teaching. For instance, Drossel et al. (2017) investigated the influence of infrastructure on teachers' technology use in a survey with a representative sample of in-service teachers ($N = 8920$). The authors found that teachers' technology use was only slightly (e.g., in Germany: $\beta = 0.09$) predicted by the availability of technology, indicating that other prevailing second-order factors than the mere availability of technology accounted for teachers' technology integration (see also Harris & Hofer, 2011; Krauskopf, Zahn, Hesse, & Pea, 2014, for related findings).

1.1.2 Skill: Teachers' professional knowledge. Teachers' professional knowledge and skills are regarded as two of those second-order determinants of effectively integrating technology. Teachers' professional knowledge needed for technology-enhanced teaching is subsumed under the term *technological pedagogical content knowledge* (i.e., TPACK, see

Chai, Koh, & Tsai, 2016; Mishra & Koehler, 2006; Willermark, 2018). TPACK is based on conceptualizations by Shulman (1986) and proposes distinct knowledge bases that are regarded as crucial for technology-enhanced teaching: Content knowledge (CK) refers to teachers' domain-specific subject-matter knowledge about instructional contents (e.g., mathematical knowledge about the Pythagorean theorem). Pedagogical content knowledge (PCK) comprises teachers' knowledge about domain-specific teaching representations (e.g., Pythagorean shearing proof) and students' (mis-)conceptions (e.g., " a^2 is equivalent to the length a "), which is necessary to make subject-matter knowledge comprehensible to students and adequately tailor their instruction (Baumert et al., 2010; Depaepe & König, 2018; Loewenberg Ball, Thames, & Phelps, 2008; Shulman, 1986). For teaching with technology, teachers additionally require technological knowledge (TK) about the use of technologies for teaching (e.g., how to use the app GeoGebra for visualizations in mathematics). Generally, it is suggested that ideally these knowledge components (CK, PCK, TK) should be well-connected to effectively integrate technology when teaching (Angeli & Valanides, 2009; Chai et al., 2016; Krauskopf et al., 2014; Mishra & Koehler, 2006; Olofson, Swallow, & Neumann, 2016), yielding an amalgam of knowledge (i.e., TPACK).

Research on (teacher) expertise demonstrated that acquiring such well-connected knowledge structures requires ample amounts of deliberate practice and, as with gaining teaching experience, novice teachers' isolated and basic knowledge gradually becomes integrated and organized (Berliner, 2004; Chi, Feltovich, & Glaser, 1981; Lachner & Nückles, 2016; McIntyre, Mainhard, & Klassen, 2017; Pauli & Reusser, 2003; Stürmer, Seidel, & Holzberger, 2016; Schmidt & Rikers, 2007), which enables experienced teachers to realize high-quality instruction (Kunter et al., 2013; Malmberg, Hagger, Burn, Mutton, & Colls, 2010; Meschede, Fiebranz, Möller, & Steffensky, 2017).

Previous research on technological pedagogical content knowledge predominantly focused on investigating the structure and connectedness of teachers' TPACK using self-report measures (e.g., Archambault & Barnett, 2010; Petko, 2012; Scherer, Siddiq, & Tondeur, 2019; Scherer, Tondeur, Siddiq, & Baran, 2018; Schmidt et al., 2009). For example, Lin, Tsai, Chai, and Lee (2013) investigated the relationships among the different TPACK components and their connectedness within Singaporean teachers ($N = 222$) by using self-reports. In line with Mishra and Koehler (2006), the authors obtained a seven-factor structure reflecting the different TPACK components. However, this factorial structure could rarely be replicated by other studies since then (see Archambault & Barnett, 2010; Koh, Woo, & Lim, 2013; Scherer et al., 2018). The mixed findings could be attributed to the use of self-report measures for assessing teachers' professional knowledge. Whereas for specific knowledge components, such as technological knowledge, self-reports have been demonstrated to be valid indicators of teacher knowledge, for complex and integrated knowledge structures (e.g., technological pedagogical knowledge), self-assessments become more error-prone, resulting in biased estimates of teacher knowledge (Akyuz, 2018; Hargittai, 2005; Kopcha, Ottenbreit-Leftwich, Jung, & Baser, 2014; Scherer et al., 2018).

1.1.3 Will: Teachers' motivation to use technology. The *will*-variable refers to teachers' motivational beliefs that impact the integration of technology. Commonly, motivational beliefs are conceptualized as an internal state which activates and guides (teaching) behavior (see Green, 2002; Lauermann, Eccles, & Pekrun, 2017). One central motivational construct which has been considered frequently in teacher education is the expectancy-value theory (e.g., Hwang, Hong, & Hao, 2018; Kale, 2018; Watt & Richardson, 2014). The theory assumes that (teaching) behavior is mostly constrained by self-efficacy beliefs (i.e., individual expectancy to successfully accomplish a task) and the general values which are associated with the task (e.g., utility-value of the task, see Eccles & Wigfield, 2002;

Gaspard, Häfner, Parrisius, Trautwein, & Nagengast, 2017). Regarding teachers' technology integration, specific models were developed and empirically tested which frame the integration of technology (cf. acceptance of technology) as a function of teachers' self-efficacy when using technology and their anticipated utility of technologies (e.g., Braak, Tondeur, & Valecke, 2004; Petko, 2012; Scherer et al., 2019). Scherer et al. (2019) conducted a meta-analytic structure-equation-modeling study comprising 114 empirical studies to investigate the potential effects of teachers' motivational beliefs (i.e., self-efficacy, utility-value) on the intention to use technology and their reported technology use. The authors found that teachers' motivational beliefs largely ($\beta = 0.334$) predicted teachers' intention to use technology when teaching. More pronounced intentions in using technologies subsequently resulted in higher levels of integrating technology ($\beta = 0.296$).

1.2 The Present Study: Examining Mathematics Teachers' Quality of Technology Integration

1.2.1 Study overview. Taken together, previous research has made valuable insights into teachers' cognitive and motivational boundary conditions of integrating technology. At the same time, it has tended to produce relatively mixed findings. The reasons for these mixed findings may be threefold. First, research predominantly relied on self-reports for assessing teachers' professional knowledge, which have been shown to be less reliable and less valid measures for assessing the complex and integrated knowledge structures which are required to integrate technology in the classroom (e.g., Akyuz, 2018). Second, research often focused on the effects of teachers' professional knowledge and motivational beliefs in an isolated manner (see Kunter, 2013 for a critical consideration). Thus, it is not clear whether and how cognitive and motivational factors may interact and differently contribute to integrating technology. Third, research often relied on simply assessing the mere frequency of technology use as a primary outcome. Although these findings provide evidence on the general use of technology

in the classrooms, these studies do not allow the investigation of the quality of technology integration (see Scherer et al., 2019; Voogt, Fisser, Roblin, Tondeur, & van Braak, 2013, for a critical consideration).

Based on the model by Petko (2012), we addressed these three drawbacks and investigated whether and how teachers' professional knowledge and motivational beliefs accounted for the quality of technology integration. To obtain sufficient variability in teachers' knowledge and their motivational beliefs, we followed a relative expertise approach (Ericsson, Hoffman, Kozbelt, & Williams, 2018), and compared mathematics teachers differing in their teaching experience, which was dependent on their status within the teacher education program (i.e., pre-service teachers, induction teachers, and in-service teachers). First, we assessed their motivational beliefs (i.e., self-efficacy beliefs and utility-value regarding technologies in school), and the basic components of professional knowledge for developing TPACK (i.e., content knowledge, pedagogical content knowledge, technological knowledge). Subsequently, we provided the teachers with a lesson-planning scenario to investigate their reasoning when designing technology-enhanced instruction. In this scenario, the teachers were asked to design a lesson plan to introduce the Pythagorean theorem to a secondary mathematics class. By means of content analysis, we rated the quality of the teachers' lesson plans regarding their instructional quality (Fauth, Decristan, Rieser, Klieme, & Büttner, 2014; Hugener et al., 2009; Kunter et al., 2013), and their potential level of technology exploitation (Hamilton, Rosenberg, & Akcaoglu, 2016; Puentedura, 2006).

1.2.2 Research Questions and Hypotheses

Teachers' professional knowledge. Following previous research on teacher expertise (e.g., Krauss et al., 2008; Kunter et al., 2013; Malmberg et al., 2010), we hypothesized that highly-experienced teachers (i.e., in-service teachers) would possess more content knowledge and pedagogical content knowledge than intermediately-experienced teachers (i.e., induction

teachers) and inexperienced teachers (i.e., pre-service teachers). Additionally, we explored expertise-related differences regarding the teachers' technological knowledge. We refrained from making clear predictions, as technological subject-matter is not an obligatory part of the curriculum in German teacher education programs and is currently mainly acquired from informal practice.

Teachers' motivational beliefs. We explored the teachers' motivational beliefs as an additional boundary condition of their technology integration (see also Scherer et al., 2019). Following the expectancy-value theory (Eccles & Wigfield, 2002), we explored potential expertise-related differences regarding teachers' self-efficacy beliefs in using technology (i.e., self-efficacy) and their general perceived utility of using technology for teaching (i.e., utility-value).

Quality of the lesson plans. Finally, we investigated the effects of teacher expertise on the quality of technology integration (as measured by the level of instructional quality and potential technology exploitation). We hypothesized that in-service teachers provide qualitatively better lesson plans than inexperienced teachers, whereas induction teachers lie in-between. Additionally, we analyzed whether teachers' professional knowledge (i.e., content knowledge, pedagogical content knowledge, technological knowledge) and/or teachers' motivational beliefs (i.e., self-efficacy, utility value) mediated the assumed effects of teaching experience on the quality of the lesson plans.

1. Method

2.1 Participants

Ninety-four German mathematics teachers (academic track) differing in their level of teaching experience and level of teacher education qualification (i.e., pre-service teachers, induction teachers, in-service teachers) participated in the study. We excluded one induction and one in-service teacher, as they did not complete the study. Thus, the final sample

comprised 92 mathematics teachers (63 female). The size of the recruited sample exceeded the required sample size as determined by a power analysis (GPower: Faul, Erdfelder, Buchner, & Lang, 2009). The required sample size was $N = 66$ when setting α -error to .05, power to .80, and the assumed effects to partial $\eta_p^2 = .13$, as recent studies showed large effects of teacher expertise on instructional quality (e.g., Baumert et al., 2010; Lachner & Nückles, 2016).

The pre-service teachers ($n = 28$) were undergraduate students with a major in mathematics teaching. They were in their fourth semester on average and had no teaching experience. The induction teachers ($n = 42$) were graduate students holding the first certificate of the teacher education program. They were enrolled in the specialized induction program for the German academic track (Gymnasium), and had on average half a year of teaching experience ($SD = 0.52$). The in-service teachers ($n = 22$) had successfully completed the teacher education program (i.e., university program, and the induction program), and possessed considerable teaching experience ($M = 14$ years, $SD = 11.2$).

2.2 Design

The study had a three-group one-factorial design, with the independent categorical variable *teaching experience* (i.e., pre-service teachers, induction teachers, in-service teachers), and the dependent variables *quality of technology integration* (i.e., instructional quality, technology exploitation). As mediating variables, we assessed teacher knowledge (i.e., content knowledge, pedagogical content knowledge, and technological knowledge), and their motivational beliefs (i.e., self-efficacy, utility-value).

2.3 Materials

2.3.1 Teachers' professional knowledge. We assessed teachers' professional knowledge with three different subtests.

Content knowledge. To assess teachers' in-depth content knowledge about the Pythagorean theorem (which was the topic of the provided scenario), two subject-matter experts holding a PhD degree in mathematics developed a content knowledge test. The test comprised 12 multiple-response items with four answer options (for examples, see the Appendix). The reliability of the content knowledge test was well-satisfied (Cronbach's $\alpha = .63$), given that we assessed different scientific aspects of the Pythagorean theorem.

Pedagogical content knowledge. To assess specific pedagogical content knowledge regarding the Pythagorean theorem, we administered two open questions which related to teachers' knowledge about students' problems and misconceptions (i.e., "Which difficulties do students generally encounter while learning the Pythagorean theorem?"; "Which misconceptions do students generally possess regarding the Pythagorean theorem?"). Answers were scored with a coding scheme (i.e., task-specific and general conceptual misconceptions, procedural difficulties, and pedagogical justification of the answer), yielding a possible maximum score of 8 (see also Krauss et al., 2008; Voss et al., 2011, for related approaches). Twenty percent of the answers were rated independently by two raters who were blind to the expertise conditions. Inter-rater reliability was very good, $ICC = .85$ (Wirtz & Caspar, 2002). Thus, only one rater coded the remaining answers.¹

Technological knowledge. We used a self-report measure for assessing technological knowledge, as recent empirical research documented the validity of self-report measures regarding specific technological knowledge (Akyuz, 2018; Hargittai, 2005). We administered the frequently used instrument by Hargittai (2005) and adapted it to mathematics instruction. The test comprised eight items (e.g., "I can install apps on tablets."; "I can design interactive

¹ Additionally, we recorded teachers' general pedagogical content knowledge by administering some sample items of the PCK-test by Krauss et al. (2008). The reliability of the selected sample items, however, was not satisfying. Therefore, we refrained from reporting these findings.

exercises for students with GeoGebra.”). Teachers answered the questions on a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). In a pre-study with 69 mathematics teachers, we demonstrated the consistency of the instrument, as we obtained the presumed one-factorial structure of the instrument, $\chi^2(28) = 189.60$, $p < .001$, KMO = .777, and high reliability, Cronbach’s $\alpha = .81$. The reliability of the questionnaire was replicated in the current sample, Cronbach’s $\alpha = .85$.

2.3.2 Motivational beliefs. Following the expectancy-value theory (Eccles & Wigfield, 2002; Gaspard et al., 2017), we measured teachers’ self-efficacy beliefs and their perceived utility-value regarding technology-enhanced teaching.

For the assessment of self-efficacy, we applied the questionnaire by Schmidt et al. (2009) comprising seven items (e.g., “I can teach lessons that appropriately combine mathematics, tablets, and teaching approaches”; “I can provide leadership in helping others to coordinate the use of content, tablets, and teaching approaches at my school”, see also Scherer et al., 2018; Yerdelen-Damar, Boz, & Aydın-Günbatar, 2017). The items were answered on a five-point Likert scale (1 = “strongly disagree” to 5 = “strongly agree”, Cronbach’s $\alpha = .90$).

Regarding perceived utility-value, we applied a scale by van Braak et al. (2004) comprising four items (e.g. “I believe that a progressive introduction of technology into education responds to our society’s changing needs”; “I highly value the introduction of technology in the classroom.”, see also Sang, Valcke, Braak, & Tondeur, 2010; Teo, Huang, & Hoi, 2018, Cronbach’s $\alpha = .83$). Again, the items were answered on a five-point Likert scale.

2.3.3 Lesson plan. To assess the quality of technology integration, we asked the teachers to provide a worked-out lesson plan for a tablet-based introduction lesson on the Pythagorean theorem in the 8th grade academic track at a German school. The teachers were given the

following scenario (see also, Ostermann, Leuders, & Nückles, 2015, for related scenarios in mathematics):

In your school, students and teachers were recently equipped with tablets. You are asked to regularly integrate tablets in your mathematics classes (8th grade). Your class comprises 30 students with different levels of mathematics achievement. The individual achievement levels are comparably distributed among the class (i.e., there are equally as many high-performing, medium-performing, and low-performing students). In the next lesson (45 minutes), you will introduce the Pythagorean theorem to your class. Please design a lesson plan for this lesson in the provided spreadsheet. You are free in selecting the instructional method. However, you are required to integrate tablets when teaching. The frequency and duration of the tablet use is left to you.

Additionally, the teachers were given a spreadsheet with three pre-defined columns (i.e., learning objectives, social form, and technology use) and a set of prompts to facilitate processing (e.g., “What are your learning objectives of the different lesson sequences?”, “How do you want to work on these objectives with your students in the different sequences?”, “How do you want to integrate tablets in the different sequences?” see Kramarski & Michalsky, 2010, for related approaches).

To analyze the level of technology integration, we applied a high-inference rating of instructional quality and technology exploitation (Hardy, Jonen, Möller, & Stern, 2006; Hugener et al., 2009; Puentedura, 2006). We rated the instructional quality of the generated lesson plans on the two dimensions of cognitive activation and instructional support. To improve the interrater reliability of the rating, the raters had 7 subcategories available to specify their judgments (i.e., provision of cognitive challenging activities, activation of prior knowledge, initiating of conceptual change, engaging students’ self-explanations, support of students’ self-discovery, provision of instructional structure, provision of prompts). For each

category, the teachers could receive 0 (i.e., subcategory not applied) to 3 points (i.e., completely applied), yielding a possible maximum score of 21. The sum scores were transformed to percentage scores. Two raters coded 20% of the lesson plans ($ICC = .84$).

For the analysis of technology exploitation, we used four dimensions (i.e., substitution, augmentation, modification, and redefinition, see Puentedura, 2006). As such, participants could receive 0 (i.e., no technology-use) to 4 (i.e., technology redefined teaching processes) points for the entire lesson plan. Interrater reliability was very good, $ICC = .90$.

2.4 Procedure

The entire study was tablet-based and lasted 90 minutes. The teachers were tested in small groups and were each seated in front of a tablet computer (Apple iPad 4) and a wireless keyboard. At the beginning, the experimenter informed the teachers about the main scope of the study and obtained written consent. In the introduction phase (15 minutes), the teachers answered the two motivation scales (i.e., self-efficacy, utility-value). In the knowledge assessment phase (30 minutes), the teachers completed the three knowledge tests (i.e., content knowledge test, pedagogical content knowledge test, technological knowledge test). In the planning phase (40 minutes), the teachers designed a lesson plan to assess their situational knowledge about integrating technology in mathematics instruction. At the end of the study, the teachers answered a short demographic questionnaire (e.g., gender, teaching experience, availability of tablets). After finishing the study, all teachers were debriefed.

3. Results

We applied an alpha level of .05 for all statistical analyses. We used partial η^2 (η_p^2) as an effect size measure, interpreting values $< .06$ as a small effect, values between .06 and .14 as a medium effect, and values $> .14$ as a large effect (see Cohen, 1988).

3.1 Preliminary Analyses

Several ANOVAs and χ^2 tests showed no significant differences between the expertise groups regarding gender $\chi^2(2) = 4.56, p = .102$; their possession of a private tablet, $\chi^2(2) = 3.90, p = .142$; and their instructional beliefs, $F(2, 89) = 0.62, p = .537, \eta_p^2 = .014$. Furthermore, the experienced teachers (i.e., induction and in-service teachers) were comparable regarding their amount of vocational training concerning the implementation of technology, $\chi^2(63) = 4.23, p = .238$ and regarding their average use of technology when teaching $\chi^2(63) = 0.34, p = .555$. Naturally, the three expertise groups differed regarding their teaching experience, $F(2, 89) = 54.93, p < .001, \eta_p^2 = .555$. For the descriptive statistics, see Table 1. Outlier analyses of the dependent variables indicated that our findings were not affected by extreme scores (see boxplot graphics in the Appendix).

Insert Table 1 about here

3.2 Analyses regarding Teachers' Professional Knowledge

First, we examined whether in-service teachers obtained higher scores in the content knowledge test and the pedagogical content knowledge test than the pre-service teachers, and whether induction teachers would perform in-between. As we had direct hypotheses, we conducted contrast analyses to test our hypotheses concerning teachers' professional knowledge (Furr & Rosenthal, 2003). We first tested whether experienced teachers (i.e., induction and in-service teachers) possessed more professional knowledge than inexperienced teachers (i.e., pre-service teachers), and therefore contrasted the experienced teachers against the inexperienced teachers (*between-expertise-contrast*: pre-service teachers: -2; induction teachers: 1; in-service teachers: 1). The second contrast tested for additional differences within the experienced teacher sample (*within-expertise-contrast*: pre-service teachers: 0; induction teachers: -1; in-service teachers: 1).

Regarding content knowledge, the between-expertise-contrast was significant, $F(1, 89) = 5.91, p = .017, \eta_p^2 = .062$ (medium effect). The within-expertise-contrast, however, was not significant, $F(1, 89) = 3.32, p = .721, \eta_p^2 = .001$ (small effect), indicating that experienced teachers possessed more content knowledge than inexperienced teachers. There were no significant differences within the experienced teachers (i.e., induction teachers, in-service teachers).

Regarding pedagogical content knowledge, a similar pattern emerged: The between-expertise-contrast was significant, $F(1, 89) = 33.97, p < .001, \eta_p^2 = .276$ (large effect). Again, the within-expertise-contrast was not significant, $F(1, 89) = 2.44, p = .122, \eta_p^2 = .027$ (small effect), indicating that experienced teachers outperformed inexperienced teachers without significant differences within the experienced teacher sample. Thus our hypotheses were partly confirmed, as experienced teachers outperformed inexperienced teachers on the content knowledge test and the pedagogical content knowledge test (see Table 1).

Furthermore, we explored potential differences regarding teachers' technological knowledge. As we had refrained from making directed hypotheses regarding this measure, we performed an ANOVA with technological knowledge as a dependent variable and the expertise groups as a between-subjects factor. The ANOVA was not significant, indicating that teachers possessed comparable technological knowledge independent of their expertise $F(1, 89) = 1.24, p = .292, \eta_p^2 = .027$ (small effect), see Table 1.

3.3 Analyses regarding Teachers' Motivational Beliefs

Similarly, we explored potential differences regarding motivational beliefs. We conducted a MANOVA with self-efficacy beliefs and perceived utility-value regarding technology as the dependent variables, and expertise groups as a between-subjects factor. The MANOVA was significant, $F(1, 89) = 6.51, p < .001, \text{Wilk's } \Lambda = 0.76, \eta_p^2 = .129$ (medium

effect; univariate ANOVAs: self-efficacy: $F(1, 89) = 6.93, p = .002, \eta_p^2 = .135$, utility-value: $F(1, 89) = 7.83, p < .001, \eta_p^2 = .150$).

Regarding the teachers' self-efficacy, the between-expertise-contrast was not significant $F(1, 89) = 0.08, p = .781, \eta_p^2 = .001$ (small effect), but the within-expertise-contrast showed significant differences between induction and in-service teachers, $F(1, 89) = 13.72, p < .001, \eta_p^2 = .134$ (medium effect), see Table 1. In-service and pre-service teachers had higher levels of self-efficacy beliefs than induction teachers.

Regarding teachers' perceived utility-value, in line with previous findings we found that experienced teachers reported higher levels of utility-value than inexperienced teachers, $F(1, 89) = 9.80, p = .002, \eta_p^2 = .099$ (medium effect). The differences between in-service teachers and induction teachers were also significant, $F(1, 89) = 8.67, p = .004, \eta_p^2 = .089$ (medium effect), see Table 1.

3.4 Analyses Regarding the Quality of Lesson Plans

Regarding the lesson plans, we hypothesized that experienced teachers should provide higher-quality lesson plans (i.e., instructional quality, technology exploitation) than inexperienced teachers, whereas induction teachers should perform in-between. As expected, our contrast analyses revealed significant effects for the between-expertise contrast, both for instructional quality, $F(1, 89) = 16.70, p < .001, \eta_p^2 = .158$ (large effect), and technology exploitation, $F(1, 89) = 6.84, p = .011, \eta_p^2 = .071$ (medium effect). The within-expertise contrast, however, was not significant, neither for instructional quality, $F(1, 89) = 0.68, p = .411, \eta_p^2 = .008$ (small effect) nor for technology exploitation, $F(1, 89) = .09, p = .769, \eta_p^2 = .001$ (small effect). Thus, the lesson-planning hypotheses were partly confirmed, as experienced teachers (induction and in-service teachers) outperformed inexperienced teachers (pre-service teachers).

3.5 Analyses regarding the mediating processes

Finally, we examined the underlying reasons for the effects of teaching expertise on the quality of lesson plans. Simple univariate correlations indicated that teachers' pedagogical content knowledge and perceived utility-value were linked to the instructional quality and technology exploitation, see Table 2.

Insert Table 2 about here

Given that we obtained significant differences between the expertise groups for teachers' pedagogical content knowledge and their perceived utility-value, and both variables significantly correlated with our quality indicators of the lesson plans (instructional quality, technology exploitation), in a next step we investigated whether the effect of teacher expertise on the quality of lesson plans was mediated by teachers' pedagogical content knowledge and/or their perceived utility-value. To test this hypothesis, we conducted mediation analyses with two simultaneous mediators (pedagogical content knowledge, utility value). Therefore, we contrast-coded teacher expertise with the between-expertise contrast as a predictor (pre-service teachers: -2; induction teachers: 1; in-service teachers: 1); either instructional quality or technology exploitation served as the dependent variables (see Figure 1). We applied the bootstrapping methodology by Hayes (2013) via the PROCESS macro for SPSS and ran 10,000 bootstrap samples to derive 95%-bias-corrected confidence intervals for the indirect effect. The mediation analyses revealed that the effect of expertise on instructional quality of the lesson plans was mediated by teachers' perceived utility-value, both for instructional quality, $a \times b = .019$, $SE = .011$, 95% CI [.002; .048], and technology exploitation, $a \times b = .061$, $SE = .032$, 95% CI [.012; .144], as zero was not included in the confidence intervals. Pedagogical content knowledge, however, did not serve as a significant mediator for either the instructional quality, $a \times b = -.002$, $SE = .018$, 95% CI [-.038; .033], or for technology exploitation, $a \times b = .024$, $SE = .032$, 95% CI [-.033; .095], as zero was included in the

confidence intervals. Apparently, only perceived utility accounted for the quality of teachers' technology integration but not their pedagogical content knowledge (see Figure 1).

Insert Figure 1 about here

4. Discussion

In the present study, we investigated whether teachers with different levels of teaching experience differently integrated educational technology while designing a mathematics lesson plan. In line with general findings on teacher expertise (Baumert et al., 2010; Berliner, 2004; McIntyre et al., 2017), we found that experienced teachers designed lesson plans with higher instructional quality and exploited the potential of technologies more than inexperienced teachers. Mediation analyses revealed that this effect of teaching experience was mediated by the perceived utility of technology for teaching. Thus, teachers' motivational beliefs played a crucial role for designing technology-enhanced mathematics instruction.

Our findings contribute to a better understanding of the cognitive and motivational boundary conditions that enable teachers to design and integrate technology into teaching (Petko, 2012). Although we found direct relations between teachers' professional knowledge (i.e., PCK) and the overall quality of the lesson plans, teachers' PCK did not explain the effect of teaching experience on the quality of the lesson plans. Instead, this effect was due to stronger perception regarding the perceived utility-value of integrating technology within the more experienced teachers. This finding is interesting, as central models of technology integration emphasize the substantial role of professional knowledge and skills for designing and implementing technology-enhanced instruction (Mishra & Koehler, 2006; Scherer et al., 2018). Therefore, our findings contribute to the otherwise scarce evidence that motivational beliefs play a crucial role in technology-enriched teaching. In line with the expectancy-value theory (Eccles & Wigfield, 2002; Gaspard et al., 2017), it seems that teachers' perceived utility-value increased their efforts to integrate technology in a didactical manner during the

lesson design, which subsequently increased the instructional quality and technology exploitation of the designed lesson plans. Therefore, following the will-skill-tool-framework (Petko, 2012), professional knowledge would act as a necessary pre-condition to design technology-enhanced instruction (as corroborated by the positive relation between PCK and the quality of lesson plans). Based on our findings, teachers' adequate motivational beliefs would constitute an indispensable additional factor which may positively intensify teachers' effort when planning and therefore improve the quality of technology integration. Process data by means of think-aloud protocols or interviews, however, are needed to further investigate the underlying planning processes (see McCarthy & Goldman, 2017, for recent applications).

From a methodological perspective, our study adds to potential advancements in measuring teachers' technological pedagogical content knowledge. Previous quantitative research primarily relied on self-report measures (Lin et al., 2013; Petko, 2012), which often suffer from reliability and validity issues. As a consequence, self-assessments of TPACK are often only weakly correlated with teachers' actual performance (Akyuz, 2018; Kopcha et al., 2014). In contrast, we followed a scenario approach in which teachers were required to plan a technology-enhanced lesson (see also Harris & Hofer, 2011; Kramarski & Michalsky, 2010). Additionally, we adapted frequently-used and feasible rating schemes from research on instructional quality to measure the quality of the lesson plans (e.g., Hugener et al., 2009; Kunter et al., 2013; Praetorius, Pauli, Reusser, Rakoczy, & Klieme, 2014). Using scenarios allows researchers to measure TPACK in a relatively controlled albeit highly contextualized manner, as teachers were asked to provide potential worked-out plans for a technology-enhanced mathematics lesson. This assumption is also corroborated by findings which documented that scenario approaches may trigger similar cognitive and motivational processes as authentic (teaching) practices (Bolzer, Strijbos, & Fischer, 2015; Robinson &

Clore, 2001). However, whether teachers who perform well in scenario-based assessments also implement high-quality technology-enhanced teaching in the classroom is yet an open issue.

Regarding educational practice, our findings further suggest that teachers' motivational beliefs should be more strongly considered in teacher education. Focusing on the motivational beliefs and their associated experiences may provide a beneficial approach to enhance teachers' professional development (Borko, 2004), for instance by integrating methods of systematic self-reflection in which teachers can monitor their motivational beliefs during technology-enhanced teaching.

4.1 Limitations and Future Research

One limitation refers to the causality of our findings, as we analyzed the quality of authentic lesson plans by different teacher groups that varied in the degree of their experience and consequently also in their level of professional knowledge. This approach contributed to the ecological validity of our findings. However, we did not experimentally manipulate the quality of teachers' professional knowledge (i.e., content knowledge, pedagogical content knowledge, technological knowledge) as well as their underlying motivational beliefs (i.e., self-efficacy, utility-value). Therefore, empirical conclusions regarding the causal role of teachers' motivational beliefs for the design of technology-enhanced lesson plans should be treated with caution (Hayes, 2013).

Another caveat is that we only used one single mathematical problem (i.e., the Pythagorean theorem) which possibly restricts the generalizability of our findings. The Pythagorean theorem can be regarded as a representative mathematical problem which is taught throughout secondary education and which requires both essential algebraic and geometric knowledge. Nevertheless, it would be worthwhile to replicate our findings with additional mathematical problems and in other domains, particularly in language learning or

the humanities, as they require different implementations of educational technology due to different core practices (Mishra & Koehler, 2006).

4.2 Conclusion

In conclusion, the present study contributes to a better understanding of teachers' cognitive and motivational conditions which enable them to implement technology in the mathematics classroom. Our findings show that motivational beliefs play a critical role in integrating technology into teaching. At the same time, the integration of technologies when teaching is essential for supporting students' digital literacy to use educational technology and digital tools in an effective and reflective manner (OECD, 2015). Thus, teachers can help students prepare for a digital future and support them in taking an active role in the society of that digital future.

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Table 1.
Means and Standard Deviations of the Dependent Measures as a Function of Teacher Expertise.

Variables	Pre-service teachers		Induction teachers		In-service teachers	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Professional knowledge ^a						
Content knowledge	75.52	7.70	79.97	9.87	81.75	6.11
Pedagogical content knowledge	34.23	10.23	57.32	23.44	65.08	22.92
Technological knowledge	42.85	12.98	46.11	13.32	42.99	15.87
Motivational beliefs ^b						
Utility-value	2.71	0.91	2.98	.73	3.63	0.89
Self-efficacy beliefs	3.08	1.02	2.69	.84	3.58	0.87
Quality of lesson plan ^a						
Instructional quality	50.83	14.81	61.58	12.12	64.39	11.74
Technology exploitation	50.89	24.98	63.09	19.31	64.77	21.35

^a Values represent percentage scores. ^b Teacher ratings ranged from 1 = “strongly disagree” to 5 = “strongly agree”.

Table 2. *Bivariate Correlations among the Dependent Measures.*

	1	2	3	4	5	6
1 Instructional quality	1					
2 Technology exploitation	.577**	1				
3 Content knowledge	.094	.079	1			
4 Pedagogical content knowledge	.209*	.223*	.284**	1		
5 Technological knowledge	-.117	.077	.056	.140	1	
6 Utility-value	.327**	.422**	.134	.218*	.293**	1
7 Self-efficacy beliefs	.131	.235*	.006	.079	.704**	.543**

Note. * $p < .05$. ** $p < .001$.

1A **1B**

Figure 1. Findings of the parallel mediation analyses for instructional quality (Figure 1A) and technology exploitation (Figure 1B) with teaching experience coded between-expertise-contrast (pre-service teachers = -2, induction teachers = 1, in-service teachers = 1) as independent variable. Pedagogical knowledge, instructional quality, and technology potential were measured by percentage scores. Numbers represent unstandardized path coefficients for direct and total effects (in parentheses). $*p < .05$. $**p < .01$.

Appendix

Example items of the content knowledge test (translated from German)

Cosine theorem

Mark the right answer(s) about the cosine theorem.

- ☐ The cosine theorem is a special case of the Pythagorean theorem.
- ☒ The theorems about the congruence of triangles indicate that a triangle is fully determined by the components side – angle – side or side – side – side. With the cosine theorem, the fourth component can be calculated, either a side (if side – angle – side is given) or an angle (if side – side – side is given).
- ☒ You can use the Pythagorean theorem to prove the cosine theorem.
- ☐ One of the formulations of the cosine theorem is: The sum of the inner angles of a triangle is 180° .

Trigonometric Pythagorean theorem

Mark the right answer(s) about the trigonometric Pythagorean theorem.

- ☒ One of the formulations of the trigonometric version of the Pythagorean theorem is: For every angle α and every real number c the following applies: $(\sin^2 \alpha + \cos^2 \alpha) * c^2 = c^2$.
- ☐ Another formulation of the trigonometric version of the Pythagorean theorem is: For every angle α and every real number c the following applies: $(\sin^2 \alpha - \cos^2 \alpha) * c^2 = c^2$.
- ☒ The validity of the trigonometric Pythagorean theorem can be shown with the Pythagorean theorem based on the unit circle.
- ☐ The unit circle disc has the surface area 1.

Plane and normal

Suppose E is a plane in a three-dimensional, Euclidian vector space V , N is the normal of E and π is the projection of V on E along N .

Mark the right answer(s) about planes and normals.

- ☒ If G is a circular arc located in a plane which is parallel to E , $\pi(G)$ is a circular arc as well.
- ☒ If G is a straight line which is parallel to N , $\pi(G)$ is a dot.
- ☐ If H is a section of a straight line G in V , $\pi(H)$ is longer than H .
- ☐ If G is a straight line parallel to E and if H is a section of G , H is longer than $\pi(H)$.

Outlier analysis with boxplot graphics

To test whether our results were not due to outliers or extreme scores, we reanalysed our data without the two identified outliers in the subsequent boxplot graphics of the dependent variables. As removing these two participants from the sample would not change our findings we decided to not exclude them in the reported analysis.