Eliciting teachers' technological pedagogical knowledge

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This paper starts from the understanding that teachers' knowledge is situated, grounded in knowledge derived from formal training and from experiences in practice. Based on this understanding we examine teachers' reasoning in relation to the pedagogical choices teachers make while using ICT in practice. We argue that teachers' reasoning about pedagogy elicits their technological pedagogical knowledge (TPK). Data from 29 video cases show how elementary teachers used ICT to facilitate specific pedagogical strategies (e.g., activating learning, classroom management, dealing with diversity, fostering learning strategies). Findings indicate that teachers used ICT mostly to promote activation of learning. Many teachers reasoned about using ICT for adapting their teaching to student needs, but this was seldom observed in practice. The few teachers who showed behaviour supporting adaptive teaching and fostering learning strategies almost always used ICT to facilitate these pedagogical strategies. We argue that for effective teaching with ICT it is important that teachers learn to reason explicitly about how ICT can support specific pedagogical strategies. The results from this study provide suggestions for what is needed in teacher education programs and professional development initiatives to support teachers in acquiring TPK.

Introduction

Although researchers acknowledge the power of technology for teaching and learning with information and communication technology (ICT), the evidence shows only small effects on student achievement (e.g., Cheung & Slavin, 2012; Rakes, Valentine, McGatha & Ronau, 2010; Salvin, Lake & Groff, 2009; Tamim, Bernard, Borokhovski, Abrami & Schmid, 2011), while effective teachers influence about 30% of student achievement differences through the way they teach (Hattie, 2012; Van de Grift, Van der Wal & Torenbeek, 2011). Thus, effective teaching with ICT depends on *how* teachers use ICT when teaching students with different interests and capabilities (European Commission, 2013; Heitink, Voogt, Verplanken, van Braak & Fisser, 2016; Mishra & Koehler, 2006; Webb & Cox, 2004).

How teachers use ICT in practice is determined by their knowledge of the affordances of ICT for education and by their educational beliefs. Teachers' knowledge is situated knowledge, influenced by formal training, experiences in day-to-day practice and teachers' personal pedagogical beliefs (Brown, 2009; Calderhead, 1996; Voogt, Fisser, Tondeur & van Braak, 2016). This form of knowledge is highly personal and often implicit. To develop insights into teachers' knowledge about teaching and learning with ICT, it is necessary to elicit teachers' professional reasoning that is focused on using ICT in practice (Heitink et al., 2016; Voogt et al., 2016). Technological pedagogical content knowledge (TPACK) is a framework which describes knowledge teachers need to use ICT effectively in teaching students with different interests and capabilities. According to this framework, technological knowledge should be integrated into pedagogical content knowledge (Mishra & Koehler, 2006).

Although effective teaching depends on how teachers use ICT in their teaching, no study has focused on teachers' technological pedagogical knowledge (TPK) in particular. TPK is an especially important knowledge domain for teachers working in elementary education, because these teachers are expected to teach a large variety of subjects and therefore often do not have deep content knowledge of each subject.

To understand why and how elementary school teachers use ICT to facilitate their use of diverse pedagogical strategies in the classroom, such as differentiation, classroom management, and teaching students how to regulate their learning, we need to elicit teachers' technological pedagogical knowledge (TPK). The purpose of this study is to understand how and why teachers use ICT to facilitate the enactment of specific pedagogical strategies that are associated with effective teaching.

The question is how we can make TPK, a form of situated knowledge, explicit. Much research about TPACK makes use of instruments that measure teachers' self-perception of ICT use in education. Such indirect measures tend to have validity problems, as these measures depend on teachers' self-confidence and their ability to judge their own competences. Moreover, we argue that TPK is shown not only in the way teachers act in practice but also in their professional reasoning. Teachers use professional reasoning to make choices about the pedagogical strategies they enact in practice. Therefore, an observational instrument that captures teachers' professional reasoning in conjunction with the enactment of pedagogical strategies is a better alternative. Teachers' professional reasoning about their ICT use in practice has not been studied much, and results are still very general (Heitink et al., 2016). This research will go into more detail regarding teachers' professional reasoning in relation to the pedagogical choices teachers make while using ICT in practice. Not only do the results from this study provide insight into the professional reasoning teachers rely on when using ICT in practice, the study also provides a basis for suggestions about what is needed in pre-service teacher education programs and in-service teacher professional development initiatives to support pre-service and practicing teachers in acquiring TPK. Eliciting teachers' technological pedagogical knowledge can give insight into whether teachers' ICT use is effective and identify knowledge gaps and misconceptions.

Theoretical underpinnings

Several studies have shown that teachers support their pedagogical strategies by integrating ICT into their teaching, for example, to increase student interaction, to help explain complex concepts, to maintain students' attention, to adapt their teaching to individual student needs and to make their teaching process more efficient (Jang & Tsai, 2012). However, research by Yeh, Hsu, and Chien (2017) showed that just using ICT in practice (gaining experience) is not enough to attain higher order TPACK. One of the best indicators for promoting TPACK development was having teachers evaluate their instructional performance on ICT uses (Yeh et al., 2017). This means teachers used their professional reasoning ability to inform their ICT use in practice as a way to develop their TPACK. Moreover, a study by Hakkarainen et al. (2001) suggested that how teachers use ICT in practice depends on their pedagogical thinking. This implies that in order to use ICT for supporting pedagogical strategies, teachers need to make use of their TPK in their professional reasoning to make choices about the pedagogical strategies they use in practice. The practical knowledge that underlies teachers' teaching choices (and hence teachers' professional reasoning) is based on formal knowledge gained through professional education and informal knowledge gained from day-to-day experiences in specific contexts (Calderhead, 1996; Koh, Chai, & Tay, 2014; Meijer, Verloop, & Beijaard, 1999; Voogt et al., 2016). This means TPK is tacit, situated knowledge that can be defined as the whole of the knowledge and insights that underlie teachers' use of pedagogical strategies in conjunction with ICT in their specific educational practice.

How the enactment of TPK occurs in practice is based on the pedagogical strategies teachers prefer to apply. Hence, teachers' pedagogical strategies for teaching and learning are what lead their ICT use, not the ICT devices themselves (Tondeur, van Braak, Ertmer, & Ottenbreit-Leftwich, 2016). This means that teachers need to be able to make a connection between the pedagogical strategies they use and the ICT they want to apply (Hew & Brush, 2007). This connection is made through teachers' professional reasoning. Teachers' teaching practice and professional reasoning need to match in order to be effective in realising specific learning goals (Heitink et al., 2016; Hicks, 2006; Koehler & Mishra, 2008; Koehler, Mishra, & Yahya, 2007). The pedagogical strategies teachers decide to enact depend on local contextual factors (Phillips, 2016). Contextual factors that influence the way teachers use ICT are, for example, ICT infrastructure, time, curriculum requirements and students' social-economic backgrounds (Aesaert, van Braak, van Nijlen, & Vanderlinde, 2015).

The pedagogical strategies that teachers use in practice reflect their teaching choices made through professional reasoning. A detailed and specific classification of the concrete pedagogical strategies teachers enact in practice is the *teaching acts* identified by Van de Grift (2007). Van de Grift (2013)

provided an extensive literature review in which specific pedagogical strategies that are associated with effective teaching are identified. Based on the identified pedagogical strategies, Van de Grift developed an observation instrument to measure these pedagogical strategies in practice. The identified pedagogical strategies are focused on creating a safe, stimulating learning climate, efficient classroom management, clear instruction, providing lessons that activate student learning, adaptive teaching and teaching learning strategies (Van de Grift, 2007, 2013; Van de Grift, Helms-Lorenz, & Maukana. 2014, Van de Grift, Van der Wal, & van Veen, 2011):

- A safe and stimulating learning climate includes the influence of school climate factors on student learning. A climate in which self-confidence, mutual respect and a positive atmosphere are stimulated results in higher student achievement than a negative climate that includes disrespect, disruptive competition and stress.
- Efficient classroom management concerns efficient use of allocated lesson time. Effective teachers spend their time on instructional activities that lead to orderly lessons and organised classrooms with few behaviour problems with students.
- Clear instruction is about structured lessons in which the teacher uses specific instructional strategies to help students learn subject matter with different interests and capabilities. Setting clear objectives, providing targeted feedback and monitoring students' understanding are important aspects.
- Activating learning includes interactive teaching methods that involve students in their own learning. By involving students and providing active lessons, effective teachers aim to stimulate students' self-confidence, critical thinking and problem-solving skills. The teacher asks questions that trigger students' thinking and stimulates them to think out loud.
- Adaptive teaching is focused on tailored instruction. The teacher adapts instruction, learning goals and lesson materials to individual students or student groups.
- Teaching learning strategies is based on cognitive strategies that can be used to help perform higher-level operations. The teacher teaches students how simplify complex tasks and how to check solutions to problems. Critical thinking and thinking and problem-solving strategies are also important in this category.

Research has shown that these pedagogical strategies can be ordered from very basic (providing a safe learning climate and classroom management) to more complex (adaptive teaching and teaching learning strategies) (Van de Grift et al., 2014; Van de Grift et al., 2011; Van der Lans, van de Grift, van Veen, 2015). Furthermore, these pedagogical strategies are significantly related to student involvement and positively related to students' learning outcomes (Denham & Lieberman, 1980). Van de Grift (2007) therefore argued that student involvement is a necessary condition for effective teaching. Student involvement regards the students' interest and active involvement in their learning. In this study, we are seeking to identify the contribution of ICT to teachers' pedagogical strategies, including student involvement in their learning as a necessary condition for effective teaching.

Research questions

In this study, we argue that using ICT to support pedagogical strategies in teaching is based on teachers' technological pedagogical knowledge about teaching and learning with ICT. To develop insights into teachers' technological pedagogical knowledge, it is necessary to elicit teachers' professional reasoning that is focused on using ICT for pedagogical strategies in conjunction with the enactment of these pedagogical strategies. Therefore, this study focused on the following research question: How and why do teachers use ICT to facilitate their enactment of pedagogical strategies in practice? In particular: (a) How do teachers use ICT to facilitate the enactment of pedagogical strategies? (b) How do teachers reason about using ICT to facilitate the enactment of pedagogical strategies?

Materials and methods

Procedure

The data for this study were collected through video cases. In a national open call, teachers were invited to participate in the study. Teachers were asked to shoot a 10 to 15 minute video clip about their use of

ICT and their reasons for using ICT in that particular practice. They could decide for themselves what they wanted to present. In addition to the video clip, teachers completed a brief questionnaire about their perceived level of technological expertise, the perceived added value of ICT and the need to professionalise their use of ICT. The answers to these questions were compared with a national benchmark. Analysis showed that the teachers in our sample scored significantly higher on these items than the teachers in the national benchmark sample (see Voogt et al., 2014). Thus, the teachers in our sample are more positive and confident regarding the use of technology in education and see more need for professionalisation in the use of ICT than the average Dutch teacher.

Teachers received a protocol for structuring the video clip. Teachers had to use about half of the time to show a particular practice and half of the time to comment on the practice by addressing specific questions. The protocol was tested with six video cases to make sure that the procedure was consistent and the data obtained could be used. The original database was made up of a total of 157 video cases, from which we selected 29 video clips for this study. Selection was based on the results of a prior study in which all 157 videos were analysed (Heitink et al., 2016). The following selection criteria were applied: (1) the video shows the integration of ICT with subject matter and/or pedagogical strategies, (2) the video shows a match between teachers' professional reasoning and the technology-rich practices showed, and (3) the video concerns elementary education teachers. Because of the match between professional reasoning and practice, the 29 videos that resulted from this selection were considered examples of adequate technology-rich practices in primary education.

Instruments

The observation instrument used to identify the contribution of ICT to teachers' pedagogical strategies was based on the instrument for assessing teaching acts (Van de Grift et al., 2011). Figure 1 shows a part of the instrument. Items that reflect teachers' pedagogical strategies were formulated for each of the six categories: (1) safe learning climate (4 items), (2) efficient classroom management (4 items), (3) clear instruction (7 items), (4) activating learning (6 items), (5) adaptive teaching (4 items) and (6) teaching learning strategies (6 items). Student involvement (3 items) was rated separately and included items about their engagement, interest and focus on learning. All scales were internally consistent ($\alpha > 0.77$). For each item, a rater could indicate (yes/no) whether the teacher showed this pedagogical strategy in practice (P), whether ICT was used for this pedagogical strategy (ICT) and whether the teacher reasoned about the use of ICT for this specific pedagogical strategy (R).

Indicator	The teacher…	Observed?		
Safe learning climate	..shows respect for students in behavior and language	P	ICT	R
	..creates a relaxed atmosphere	P	ICT	R
	..supports student self-confidence	P	ICT	R
	..ensures mutual respect	P	ICT	R
Efficient classroom management	..ensures that the lesson runs smoothly	P	ICT	R
	..checks during processing whether students are carrying out tasks properly	P	ICT	R
	..ensures effective class management	P	ICT	R
	..uses learning time efficiently	P	ICT	R
Clear instruction	..explains the subject matter clearly	P	ICT	R
	..gives feedback to students	P	ICT	R
	..Involves all students in the lesson	P	ICT	R

Figure 1. Part of the observation instrument. P indicates the teacher showed this pedagogical strategy in practice, ICT indicates ICT was used for this pedagogical strategy and R indicates whether the teacher reasoned about the use of ICT in this pedagogical strategy.

Data analysis

The data collected through the observation instrument were analysed using summative content analysis (Hsieh & Shannon, 2005). First, data were quantified using descriptive statistics (counts and mean number of clips) for teachers' professional reasoning (R), pedagogical practice (P) and the use of ICT to support the pedagogical practice (ICT). Second, a latent content analysis was done to achieve a more in-depth view and interpretation of teachers' reasoning and practice for each of the seven categories (safe learning climate, efficient classroom management, clear instruction, activating learning, adaptive teaching, teaching learning strategies, and student involvement). All videos were transcribed and coded using Atlas-ti©. Themes were inductively derived and clustered into the pedagogical strategies described by Van de Grift (2007). For example, a teacher who reasoned about why she used ICT to teach two grades simultaneously was labeled as *reasoning - efficient classroom management – uses learning time efficiently*. A teacher reasoning about why she used Google apps to provide feedback on the work students were doing at that moment was labeled as *reasoning - clear instruction – gives feedback to students*. To foster the reliability of the data extraction process, 10 videos were double-coded by two researchers, after which differences were discussed. After this, both researchers coded the remaining 19 videos. This process resulted in a Cohen's kappa of 0.77, which is substantial (Landis & Koch, 1977).

Sample characteristics

All 29 cases originated from primary education. There were 10 male and 19 female teachers among the cases. Most hardware used in these cases were personal computers or laptops (24 times) and interactive whiteboards (21 times). Some teachers used mobile phones (2 times), tablets (4 times) or cameras (3 times). Most software used was presentation software (25 times). A few cases used processing software (e.g., Microsoft Word; 8 times) and the Internet (7 times). Communication software (3 times), drill and practice software (3 times), multimedia editing software (3 times), evaluation software (2 times) and simulation software (1 time) were used in a minority of the cases. The use of ICT was often presented in different subject domains (Table 1). However, in a number of the video cases learning about ICT was the dominant focus of the lesson. Therefore, we also distinguished ICT as a separate subject domain. For example, one video showed how students produced a stop-motion video about a made-up story. The type of story students made up, or how they would make up that story was not that important; the teacher focused on the technical part of how a stop-motion video can be made. We therefore decided to position ICT as a separate subject domain.

Table 1
Overview of subject domains presented in the video cases

Subject domain	% of total video cases
Math	21
Language	52
Social studies	31
Arts	3
ICT	17

Results

General Results

Figure 2 shows the means for frequency of teachers' use of the pedagogical strategies and for student involvement in their learning. The figure also shows the extent to which teachers used ICT in those pedagogical strategies or to promote student involvement and the extent to which teachers reasoned professionally about their ICT use in this specific practice. These results show that teachers mostly focused their teaching (P) on involving students, followed by creating a safe learning environment, efficient classroom management and activating learning. The use of ICT to support their teaching was shown in diverse ways. ICT was mainly used to support the pedagogical strategies of activating learning, clear instruction, adaptive teaching and efficient classroom management. Remarkably, most professional reasoning about the use of ICT was focused on supporting adaptive teaching, followed by efficient classroom management. In the subsequent sections we further elaborate on these general findings.

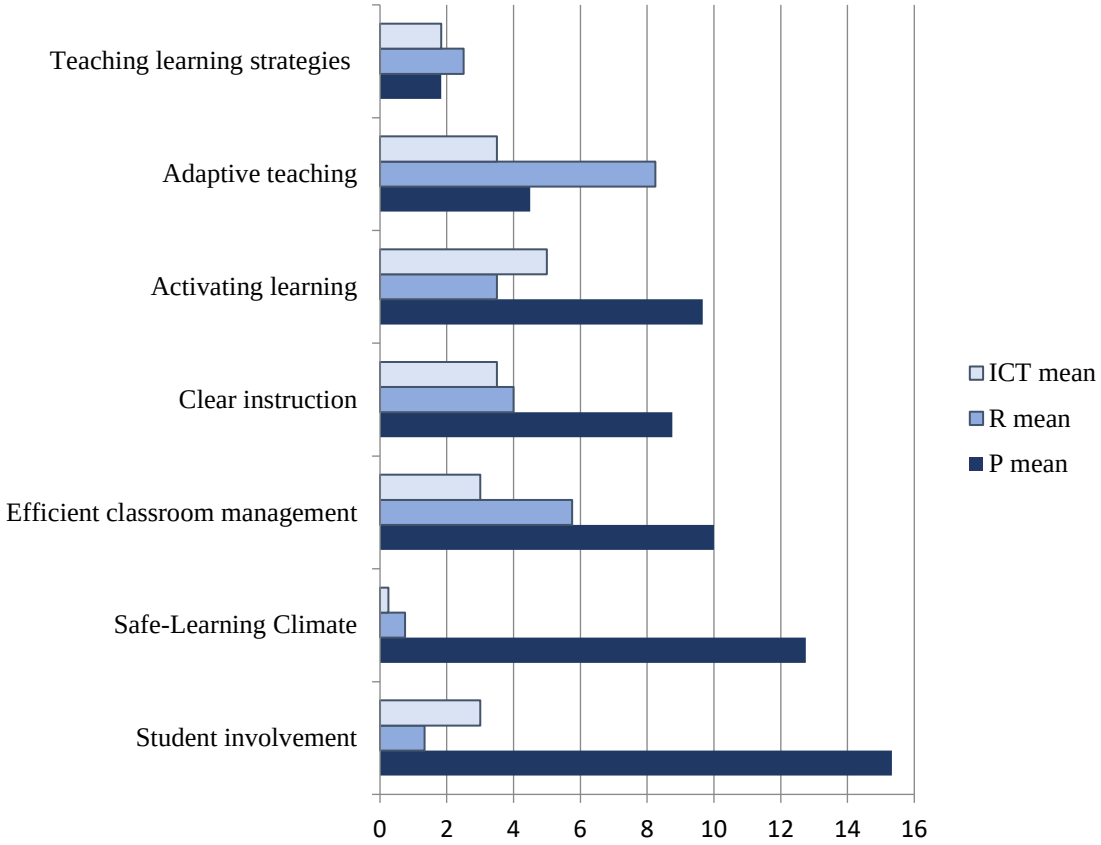

Figure 2. Mean number of video clips rated as including indicators for pedagogical strategies (P), the use of ICT to support these pedagogical strategies (ICT) and the extent to which teachers reasoned professionally about their ICT use (R) (n = 29).

Student involvement

Student involvement in learning is considered a necessary condition for effective teaching. In this study we found that the students showed in the video clips were relatively often involved in their learning (average number of clips = 15.33); in particularly, student engagement was shown in about two-thirds of the video clips. The results are presented in Table 2. ICT was used to foster student involvement in relatively few video clips. Teachers also rarely reasoned about the use of ICT for this purpose. An illustration of the use of ICT to foster student involvement is a teacher who provided classroom instruction about spelling rules. The teacher explained the spelling rule and asked the students to think about the spelling rules for a word in pairs. She asked every pair about that word, after which the other pairs had to discuss the corresponding spelling rule and write the word correctly on their tablet. The words that were written by the students appeared on the interactive white board. The teacher asked one pair to explain the spelling rule that goes with that word. The teacher explained why she uses ICT in this way:

> When I used this same method with pen and paper I noticed that not everyone wrote the words down. Now they have to write something and discuss the spelling rules with each other and at least hear from another student why they have to write word that way and which spelling rule applies to that. This makes students more engaged with the lesson and I also notice that they are more enthusiastic.

Table 2
Student involvement. Number of video clips that showed students were involved in their learning (P), the use of ICT to foster student involvement (ICT) and teachers' reasoning about ICT use to foster student involvement (R)

Student involvement indicators	P	ICT	R
Students are engaged	19	5	2
Students are focused on learning	11	2	0
Students show interest	16	2	2

Safe learning climate
Table 3 presents the results on the pedagogical strategy of providing a safe learning climate. As can be seen, teachers frequently showed teaching behaviour that contributes to a safe learning climate (average number of clips = 12.75), however, they did not tend to use ICT for this pedagogical strategy, and rarely reasoned about the use of ICT to support for this practice. Only one video showed how the teacher created a relaxed atmosphere in a discussion about the impact of social media. Students in grade 6 had to make news items for the social media page of their school. The teacher evaluated these news items by discussing whether the images used in the news items were representative for the school, whether the language was appropriate and whether the news items were accessible for everyone in the school, including the younger students (e.g., 5-year-olds). The teacher said the following about this specific use of ICT in her lesson:

> We want to teach students to use social media appropriately and safely. These lessons focus on making students aware of using social media; what kind of pictures are you putting out there and why or why not, what do you write to a friend and why would face-to-face talks be more appropriate for other subjects.

Table 3
Safe learning climate. Number of video clips that showed this specific teacher behaviour in their practice (P), their use of ICT in this practice (ICT) and their reasoning about ICT use in this practice (R)

Safe learning climate indicators	P	ICT	R
Creates a relaxed atmosphere	12	1	1
Shows respect for students in behaviour and language	14	0	0
Supports student self-confidence	13	0	0
Ensures mutual respect	12	0	1

Classroom management
The results for the pedagogical strategy of classroom management are given in Table 4. The results show that teachers displayed a lot of teaching behaviour to manage their classroom (average number of clips = 10). They did not often use ICT for promoting classroom management. An exception is the behavior: *uses learning time efficiently*. Several teachers showed how they incorporate ICT to use learning time in an efficient way, and even more teachers reasoned about using ICT for this purpose, but did not show it in their practice. Teachers' reasoning about the potential of ICT for time management occurred quite often, but was not always demonstrated in the practice that was presented in the video clip. An illustration of the use of ICT for time management was presented in a video clip in which one teacher taught language arts to grades 4 and 5 (10- and 11-year-old students) simultaneously. The students in grade 4 used a tablet with headset and went through the instructional videos the teacher had prepared for this lesson. At the same time, the teacher taught the grade 5 students face-to-face. After the instructional period, both grades used their workbooks to work on assignments and could ask questions of the teacher. The teacher provided the following reasoning about the use of ICT in this practice:

> Since this class consists of two grades, they both need different instruction. By using ICT this way, both grades receive instruction at the same time, one face-to-face and one through the instruction I created with EduCreations. This way everybody can work on the assignments in their workbooks at the same time, which gives me the opportunity to give feedback and answer questions for all the students.

Table 4
Classroom management. Number of video clips that showed this specific teacher behaviour in their practice (P), their use of ICT in this practice (ICT) and their reasoning about ICT use in this practice (R)

Classroom management indicators	P	ICT	R
Uses learning time efficiently	5	4	10
Checks during processing whether students are carrying out tasks properly	18	5	6
Ensures effective class management	4	1	4
Ensures that the lesson runs smoothly	13	2	4

Clear instruction
An overview of the number of clips concerning the pedagogical strategy of clear instruction is presented in Table 5. Teachers in our sample used teaching behaviour to provide clear instruction relatively often (average number of clips = 8.75). They tended to use ICT relatively often for involving students in their lessons and for providing feedback to students, but not much for the other aspects of teaching behaviour that contribute to providing clear instruction. Teachers reasoned more about the use of ICT for providing feedback than they showed it in their practice. A teacher who used ICT for providing feedback is provided in the following example: Students (grades 5 and 6) were working on an essay using Google apps. While students were working in their documents, a feedback comment from the teacher popped up selecting a specific part of the text. Students revised that part right away and wrote something back to the teacher. The teacher explained why she uses ICT this way:

> Because the students' work is shared with me, I can give live feedback during the students' learning process. This gives me the opportunity to influence and improve both the quality of the process and the final product.

Table 5
Clear instruction. Number of video clips that showed this specific teacher behaviour in their practice (P), their use of ICT in this practice (ICT) and their reasoning about ICT use in this practice (R)

Clear instruction indicators	P	ICT	R
Involves all students in the lesson	10	7	7
Gives feedback to students	9	5	8
Encourages students to do their best	4	2	5
Checks during instruction whether students have understood the subject matter	10	4	2
Clearly explains teaching tools and tasks	10	4	2
Explains the subject matter clearly	13	5	2
Gives well-structured lessons	8	1	3
Explains the lesson objectives at the start of the lesson	6	0	3

Activating learning
An overview of the number of clips on the pedagogical strategy of activating learning is presented in Table 6. Teaching behaviour that fosters this pedagogical strategy was observed relatively often (average number of clips = 9.67), in particular the use of teaching methods (20 times), having students think out loud (13 times) and providing interactive instruction (12 times). ICT was used to support activation of student learning and in providing interactive instruction. Teachers also reasoned about the value of using ICT in supporting these practices, although less than would be expected. An example of such uses of ICT was a teacher who showed a movie about the Dutch royal house to students in the 6th grade as part of social studies. After the movie the teacher used the interactive white board to present a quiz with questions about the Dutch Royal House. Students used their own device (e.g., smartphone, laptop, tablet) to answer the questions and an overview of the answers appeared on the interactive whiteboard. The teacher discussed the answers after every question. When asked why the teacher used ICT in this practice the teacher said:

> I made an interactive presentation with questions. The students can use their own devices to vote for the right answer and are actively involved with the lesson this way. Additionally,

> this way students' prior knowledge is activated and I get an idea of what students already know, so I can build on that knowledge in the following lessons.

Table 6
Activating learning. Number of video clips that showed specific teacher behaviour in their practice (P), their use of ICT in this practice (ICT) and their reasoning about ICT use in this practice (R)

Activating learning indicators	P	ICT	R
Encourages students to reflect on solutions	1	1	1
Provides interactive instruction	12	11	6
Uses teaching methods that activate students' learning	20	14	10
Boosts the self-confidence of weak students	3	2	3
Asks questions that encourage students to think	9	1	1
Has students think out loud	13	1	0

Adaptive teaching
The number of clips on the pedagogical strategy adaptive teaching are shown in Table 7. We observed teaching behaviour that contributed to adaptive teaching in relatively few video clips (average number of clips = 4.50). However, when a teacher showed this behaviour in the specific practice presented in the video clip, they almost always used ICT. But, we also observed that a number of teachers reasoned about the use of ICT in the video clips for adapting teaching to different student needs, without really showing this use of ICT in this specific practice. The following example presents a teacher who used ICT for realising adaptive teaching. He used ICT for supporting dyslexic students with their reading problems. The students used a tablet with software that helps them by enlarging texts, highlighting texts and speaking texts out loud. The students made pictures with the tablet of instructional schemes and used this to zoom in on certain parts of that instruction. The teacher explains why she used ICT in this way:

> I showed that a student with heavy dyslexia could use ICT to support his reading and writing issues. Texts are adapted to his needs because the software gives him the opportunity to enlarge text and read text out loud. By using ICT this way, dyslexic students can follow the lesson in the same pace as the rest of the students and they are working with textual content that fits their thinking level instead of a text that is intended for a much lower grade level. And because it's all digital, the weak motor skills in writing these students often have is not an issue either.

Table 7
Adaptive teaching. Number of video clips that showed this specific teacher behaviour in their practice (P), their use of ICT in this practice (ICT) and their reasoning about ICT use in this practice (R)

Adaptive teaching indicators	P	ICT	R
Offers weak students additional learning and instruction time	4	4	7
Adapts instruction to relevant students differences	4	4	6
Adapts processing of subject matter to student differences	6	4	8
Checks whether the lesson objectives have been achieved	4	2	12

Teaching learning strategies
Table 8 presents the number of clips on the pedagogical strategy of teaching learning strategies (average number of clips = 2.00). As can be seen, the teaching behaviour underlying this pedagogical strategy was observed even less than adaptive teaching. Teaching students to check solutions and encouraging students to use control activities were not seen at all. Relatively often, teachers were seen in the video clips to be encouraging students to apply what they have learned (6 times). However, although the pedagogical strategy of teaching learning strategies was not seen often, teachers almost always used ICT to support specific teaching behaviours. An example from a kindergarten teacher illustrates how ICT was being used in a project where students were making a digital picture book about Red Riding Hood. The teacher brought the class of five-year-old students together and let them think of a story. When the story had been thought out, the students worked in pairs on parts of the story, making drawings that would fit with that specific part. In this way, the teacher helped the students to simplify the creation of a story and picture book. Then the teacher brought the group together while projecting the draft picture-story on the smart

board. In a group discussion, the teacher evaluated this intermediate product together with the students, encouraging them to think critically by asking constructive questions. The students came to the conclusion that, among other things, the story text was missing. Afterwards, students revised based on that evaluation and added a voice over with the story text that went with their part of the story to their drawing. The teacher said about the ICT use in this practice:

> This way the students learn to cut the whole story into short scenes and think about what pictures they would need to take to make sure the reader understands what is happening. ICT also makes it easier for the students to look at their intermediate products and think about how they can improve the story.

Table 8
Teaching learning strategies. Number of video clips that showed this specific teacher behaviour in their practice (P), their use of ICT in this practice (ICT) and their reasoning about ICT use in this practice (R)

Teaching learning strategies indicators	*P*	*ICT*	*R*
Encourages students to use control activities	0	0	1
Teaches students to check solutions	0	0	1
Encourages students to think critically	3	3	4
Teaches students how to simplify complex problems	1	1	1
Encourages students to apply what they have learned	6	5	6
Asks students to reflect on strategies for finding solutions	2	1	2

Conclusion and discussion

The underlying rationale for this study was that effective teachers influence about 30% of student achievement differences through the way they teach (Hattie, 2012; Van de Grift et al., 2011). For this reason, we wanted to know about the extent to which teachers use ICT to foster effective teaching, which we operationalised as pedagogical strategies that have been found to contribute to effective teaching (Van de Grift et al., 2011). We were interested in whether and why teachers use ICT to support effective teaching. We argued that eliciting teachers' reasoning about their use of ICT to realise effective teaching in a specific practice shows teachers' TPK. In the Netherlands (and in many other countries around the world), elementary school teachers are in charge of their own classroom and must teach many different subjects. They are not subject-matter specialists. For this reason, we argued that it is useful to focus on TPK in the context of elementary education. Through capturing professional reasoning in conjunction with the enactment of pedagogical strategies, this study is the first to provide detailed insights into teachers' (elicited) TPK. Eliciting teachers' technological pedagogical knowledge can for example give insight into whether teachers' ICT use is effective and identify knowledge gaps and misconceptions about their use of ICT. These insights enable targeted interventions focused on preparing teachers for integrating ICT in their educational practice.

The findings from this study indicate that the teachers in our study showed the use of pedagogical strategies that fostered student involvement, a safe learning climate, classroom management, activation of students' learning and clear instruction. Much less often did we observe pedagogical strategies to promote adaptive teaching and teaching learning strategies. Fewer videos showed examples of what Van de Grift et al. (2011) indicated as the 'higher levels' of pedagogical strategies. An explanation for this can be that the higher levels of pedagogical strategies are more complex and therefore harder to perform for teachers (Van der Lans et al., 2015). These findings corroborate the findings from other studies on teachers' pedagogical strategies, not related to teachers' uses of ICT (e.g., Berliner, 2001; Nilsson, 2008). Apparently teachers need more practice in performing the more complex tasks. The teachers in our sample provided examples of ICT use supporting all of the pedagogical strategies, as well as student involvement, but by far the highest level of ICT use was shown in supporting pedagogical strategies to promote *activation of student learning*. In addition, although few teachers were observed enacting pedagogical strategies supporting adaptive teaching and teaching learning strategies, they almost always used ICT to facilitate these pedagogical strategies. Furthermore, we need to realise that some pedagogical strategies might not be as suitable for ICT use as others. Aspects of a safe and stimulating learning climate, for example, are highly focused on teacher-student and student-student communication. In the context of classroom teaching where teachers and students are both present, which was the case in our

study, the use of ICT for this purpose seems less obvious. This might be completely different in the case of online teaching. We also investigated how teachers reason about the way they use ICT to facilitate specific pedagogical strategies. Remarkably, while teachers' practices (P) were mainly focused on the lower levels of pedagogical strategies, teachers' professional reasoning seemed more focused on the higher levels of pedagogical strategies. For example, teachers reasoned considerably more about using ICT to adapt their teaching to individual students or student groups than was actually observed in the practices they showed. Similar findings were found in a study by So and Kim (2009) about student teachers. It might be that the teachers in our study see the potential of ICT for fostering these pedagogical strategies, but do not yet feel comfortable in using ICT for these purposes. The latter is a concern, as the teachers in our study are more positive and confident about using ICT in education than the average Dutch teacher.

In this study we used video clips to observe teachers' practice. A trade-off is that only a limited view of classroom reality is presented in these video clips, and that we were not able to ask additional questions when a teacher did not reason about a particular action. However, these videos showed practices that teachers deliberately chose to show and we asked them to reason about the specific practice that was shown. We therefore think that the data provided through the video clips are informative for this exploratory study. Moreover, using video clips allows teachers to demonstrate their professional reasoning used at a specific moment of practice (Alonzo & Kim, 2016) and offer a rich resource for reflecting upon their actions in practice (Rosenstein, 2008). In addition, we have no indications that teachers felt hindered in presenting their practice by the length of the video clip.

Implications for teacher education programs

The findings from our study show that for effective teaching with ICT, teacher education should focus on teaching teachers to reason explicitly about their ICT use and should foster their ability to share, experience and reflect on uses of ICT in ways that support the development of their TPK. In other words, teacher education initiatives need to focus on ICT use that fosters knowledge-based teaching behaviour that contributes to effective teaching with technology.

Based on a literature review, Tondeur et al. (2012) presented a model for effective preparation of pre-service teachers for ICT integration. In this model, critical factors that needed to be considered in the constructive and iterative process of teaching teachers to use ICT in their teaching were role models, reflection, collaboration, feedback, authentic experiences and design. We argue that this model is also appropriate in any kind of teacher professional learning. Authentic and practical examples of teaching with ICT, which we used in this study, can support teachers in learning how to operationalise TPACK in their practice (Ertmer & Ottenbreit-Leftwich, 2010; Hofer & Harris, 2015; Tondeur et al., 2012). Video clips offer rich situational information based on teachers' actual experiences (Rosaen, Lundeberg, Cooper, Fritzen, & Terpstra, 2008). The video clips used in this study show teachers explaining to others how they used ICT for specific pedagogical strategies and why. The video clips present teachers' concerns about a specific problem, and the teachers explain how ICT helps them to solve this problem. Based on the findings from this study, we argue that examples of teaching with ICT should present a variety of uses of ICT for specific pedagogical strategies that address pedagogical problems teachers experience in their day-to-day practice. Such examples can be used for sharing experiences and reflecting about how to use ICT in the classroom, which is a rich source for (pre-service) teachers to learn from (Alonzo & Kim, 2016) and strengthens their professional learning. Video clips about teachers' use of ICT can be a source of inspiration for (pre-service) teachers and offer ample opportunities to learn from, because the clips can provide authentic experiences with ICT in a safe, open-ended learning environment. This suggests that teachers can be each other's role models when they present their pedagogical practice and are explicit about the reasons for their enacted pedagogical strategies. In addition, teachers can design and implement their own uses of ICT for supporting themselves in specific pedagogical strategies, and they can prepare a video clip in which they show their practice and reflect upon their experiences, preferably with their colleagues. Such video clips can be a powerful tool in (pre-service) teacher education interventions that aim to prepare teachers for their use of ICT, and develop their TPK.

Based on this study, we argue that underlying teachers' practice is a professional reasoning process. Teachers need to be aware of this reasoning to be able to tailor practical examples from other teachers to their own context. Therefore, practical examples alone are not enough. To improve effective teaching

with ICT, teachers' reasoning about how the use of ICT contributes to teaching and learning needs to be further developed. Teachers' reasoning can be informed by research, including research carried out in teachers' own context. The instrument used for this study focused on ICT use to support effective teaching behaviour related to specific pedagogical strategies. This instrument can also be used to critically examine (pre-service) teachers' own practice and can be used for this purpose in teacher education interventions. Initial teacher education programs and professional development initiatives need to realise that the development of TPK starts where teachers are. For this reason it is important to create open-ended learning environments in which (pre-service) teachers can articulate their reasoning about their teaching experiences and how they think ICT can support them. Only then can next steps be taken. Video clips such as the ones analysed for this study serve as a powerful tool to further develop teachers' TPK.

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References

Aesaert, K., van Braak, J., van Nijlen, D., & Vanderlinde, R. (2015). Primary school pupils' ICT competences: Extensive model and scale development. *Computers & Education, 81*, 326–344. https://doi.org/10.1016/j.compedu.2014.10.021

Alonzo, A. C., & Kim, J. (2016). Declarative and dynamic pedagogical content knowledge as elicited through two video-based interview methods. *Journal of Research in Science Teaching, 53*(8), 1259–1286. https://doi.org/10.1002/tea.21271

Berliner, D. C. (2001). Learning about learning from expert teachers. *International Journal of Educational Research, 35*(5), 463–483. https://doi.org/10.1016/S0883-0355(02)00004-6

Brown, M. (2009). The teacher-tool relationship: Theorizing the design and use of curriculum materials. In J. T. Remillard, B. Herbel-Eisenman & G. Lloyd (Eds.), *Mathematics teachers at work: Connecting curriculum materials and classroom instruction* (pp. 17–36). New York, NY: Routledge.

Calderhead, J. (1996). Teachers: Beliefs and knowledge. In D. Berliner, & R. Calfee (Eds.), *Handbook of educational psychology* (pp. 709–725). New York, NY: MacMillan.

Cheung, A. C. K., & Slavin, R. E. (2013). How features of educational technology applications affect student reading outcomes: A meta-analysis. *Educational Research Review, 7*(3), 198–215. https://doi.org/10.1016/j.edurev.2012.05.002

Denham, C., & Lieberman, A. (1980). *Time to learn: A review of the Beginning Teacher Evaluation Study*. Washington, DC: National Institute of Education, U.S. Dept. of Education.

Ertmer, P. A., & Ottenbreit-Leftwich, A. T (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education, 42*(3). 255–284. https://doi.org/10.1080/15391523.2010.10782551

European Commission (2013). *The international computer and information literacy study (ICILS). Main findings and implications for education policies in Europe*. Luxembourg: Office for Official Publications of the European Communities.

Hakkarainen, K., Muukonen, H., Lipponeni, L., Ilomaki, L., Rahikainen, M. & Lehtinen, E. (2001). Teachers' information and communication technology (ICT) skills and practices of using ICT. *Journal of Technology and Teacher Education, 9*(2), 181–197. Retrieved from http://www.editlib.org/p/8427

Hattie, J. (2012). *Visible learning. A synthesis of over 800 meta-analyses relating to achievement*. New York, NY: Routledge.

Heitink, M., Voogt, J., Verplanken, L., van Braak, J., & Fisser, P. (2016) Teachers' professional reasoning about their pedagogical use of technology. *Computers & Education 101*, 70–83. https://doi.org/10.1016/j.compedu.2016.05.009

Hew, K. F., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research and Development, 55*(3), 223–252. https://doi.org/10.1007/s11423-006-9022-5

Hicks, T. (2006). Expanding the conversation: A commentary toward revision of Swenson, Rozema, Young, McGrail, and Whitin. *Contemporary Issues in Technology and Teacher Education, 6*(1), 46–

55. Retrieved from http://www.citejournal.org/volume-6/issue-1-06/english-language-arts/expanding-the-conversation-a-commentary-toward-revision-of-swenson-rozema-young-mcgrail-and-whitin

Hofer, M., & Harris, J. (2015). Developing TPACK with learning activity types. In M. Hofer, L. Bell, & G. Bull (Eds.), *Practitioner's guide to technology, pedagogy, and content knowledge (TPACK): Rich media cases of teacher knowledge* (pp. 7-1–7-14). Waynesboro, NC: AACE.

Hsieh, H, & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research, 15*(9), 1277–1288. https://doi.org/10.1177/1049732305276687

Jang, S. & Tsai, M. (2012). Reasons for using or not using interactive whiteboards: Perspectives of Taiwanese elementary mathematics and science teachers. *Australasian Journal of Educational Technology, 28*(8), 1451–1465. https://doi.org/10.14742/ajet.781

Koehler, M., & Mishra, P. (2008). Introducing TPCK. In AACTE Committee on Innovation and Technology (Eds.), *Handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 3–29). New York, NY: Routledge.

Koehler, M., Mishra, P., & Yahya, K. (2007). Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy and technology. *Computers & Education, 49*(3), 740–762. https://doi.org/10.1016/j.compedu.2005.11.012

Koh, J. H. L., Chai, C. S., & Tay, L. Y. (2014). TPACK-in-Action: Unpacking the contextual influences of teachers' construction of technological pedagogical content knowledge (TPACK). *Computers & Education, 78*, 20–29. https://doi.org/10.1016/j.compedu.2014.04.022

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics, 33*(1), 159–174. https://doi.org/10.2307/2529310

Meijer, P. C., Verloop, N., & Beijaard, D. (1999). Exploring language teachers' practical knowledge about teaching reading comprehension. *Teaching and Teacher Education, 15*(1), 59–84. https://doi.org/10.1016/S0742-051X(98)00045-6

Mishra, P. & Koehler, J.M. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054. Retrieved from https://www.tcrecord.org/content.asp?contentid=12516

Nilsson, P. (2008) Teaching for understanding: The complex nature of pedagogical content knowledge in pre-service education. *International Journal of Science Education, 30*(10), 1281–1299. https://doi.org/10.1080/09500690802186993

Phillips, M. (2016). Processes of practice and identity shaping teachers' TPACK enactment in a community of practice. *Education and Information Technologies, 22*(4), 1–26. https://doi.org/10.1007/s10639-016-9512-y

Rakes, C. R., Valentine, J. C., McGatha, M. B., & Ronau, R. N. (2010). Methods of instructional improvement in Algebra: A systematic review and meta-analysis. *Review of Educational Research, 80*(3), 372–400. https://doi.org/10.3102/0034654310374880

Rosaen, C. L., Lundeberg, M., Cooper, M., Fritzen, A., & Terpstra, M. (2008). Noticing noticing: How does investigation of video records change how teachers reflect on their experiences? *Journal of Teacher Education, 59*(4), 347–360. https://doi.org/10.1177/0022487108322128

Rosenstein, B. (2008). Video use in social science research and program evaluation. *International Journal of Qualitative Methods, 1*(3), 22–43. https://doi.org/10.1177/160940690200100302

Salvin, R. E., Lake, C., & Groff, C. (2009). Effective programs in middle and high school mathematics: A best-evidence synthesis. *Review of Educational Research, 79*(2), 839–911. https://doi.org/10.3102/0034654308330968

So, H. J. & Kim, B. (2009) Learning about problem based learning: Student teachers integrating technology, pedagogy and content knowledge. *Australasian Journal of Educational Technology, 25*(1), 101–116. https://doi.org/10.14742/ajet.1183

Tamim, R. M., Bernard, R. M., Borokhovski, E., Abrami, P. C., & Schmid, R. F. (2011). What forty years of research says about the impact of technology on learning: A second-order meta-analysis and validation study. *Review of Educational Research, 81*(1), 4–28. https://doi.org/10.3102/0034654310393361

Tondeur J., van Braak, J., Ertmer, P. A., & Ottenbreit-Leftwich, A. (2016). Understanding the relationship between teachers' pedagogical beliefs and technology use in education: a systematic review of qualitative evidence. *Educational Technology Research and Development, 65*(3), 1–21. https://doi.org/10.1007/s11423-016-9481-2

Tondeur, J., van Braak, J., Sang, G., Voogt, J., Fisser, P., & Ottenbreit-Leftwich, A. (2012). Preparing pre-service teachers to integrate technology in education: A synthesis of qualitative evidence *Computers & Education, 59*, 134–144. https://doi.org/10.1016/j.compedu.2011.10.009

Van de Grift, W. (2007). Quality of teaching in four European countries: a review of the literature and application of an assessment instrument. *Educational Research, 49*(2), 127–152. https://doi.org/10.1080/00131880701369651

Van de Grift, W. (2013). Measuring teaching quality in several European countries. *School Effectiveness and School Improvement, 25*(3), 295–311. https://doi.org/10.1080/09243453.2013.794845

Van de Grift, W., Helms-Lorenz, M., & Maulana, R. (2014). Teaching skills of student teachers: Calibration of an evaluation instrument and its value in predicting student academic engagement. *Studies in Educational Evaluation, 43*, 150–159. https://doi.org/10.1016/j.stueduc.2014.09.003

Van de Grift, W., Van der Wal, M., & Torenbeek, M. (2011). Ontwikkeling in de pedagogisch didactische vaardigheid van leraren in het basisonderwijs [Development of primary school teachers' pedagogical content knowledge]. *Pedagogische Studiën, 88*, 416–432. Retrieved from http://pedagogischestudien.nl/download?type=document&identifier=616687

Van der Lans, R. M., van de Grift, W., & van Veen, K. (2015). Developing a teacher evaluation instrument to provide formative feedback using student ratings of teaching acts. *Educational Measurement: Issues and Practice, 34*(3), 18–27. https://doi.org/10.1111/emip.12078

Voogt, J., Fisser, P., Tondeur, J. & van Braak, J. (2016). Using theoretical perspectives in developing an understanding of TPACK. In M. Herring, M.J. Koehler & P.Mishra (Eds.). *Handbook of technological pedagogical content knowledge (TPACK) for educators* (2nd ed.) (pp. 33–51). New York, NY: Routledge.

Voogt, J., van Braak, J., Heitink, M., Verplanken, L., Fisser, P., & Walraven, A. (2014). *Didactische ICT-bekwaamheid van docenten [Pedagogical ICT competences of teachers]*. Zoetermeer: Kennisnet.

Webb, M., & Cox, M. (2004). A review of pedagogy related to information and communications technology. *Technology, Pedagogy and Education, 13*(3), 235–285. https://doi.org/10.1080/14759390400200183

Yeh, Y., Hsu, Y. & Chien, S. (2017). Exploring the structure of TPACK with video-embedded and discipline-focused assessments. *Computers & Education, 104*, 49–64. https://doi.org/10.1016/j.compedu.2016.10.006

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