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Teachers' professional reasoning about their pedagogical use of technology

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ABSTRACT

This study focused on teachers' reasoning about the use of technology in practice. Both teachers' professional reasoning and their technology use were investigated. Through video cases, 157 teachers demonstrated their technology use in practice and commented on the reasoning behind their actions. Results show that most technology use was intended to strengthen both pedagogy and subject matter, or else pedagogy alone. Reasons addressed making learning attractive for students, realizing educational goals and facilitating the learning process. The majority of teachers' technology use in practice shows aspects of the knowledge transfer model of teaching. Most technology tools were used to support a learning activity; the use of technology was essential in only a few video cases. About half of the video cases showed alignment between reasoning and practice. The results contribute to better understanding of how teachers reason professionally about their technology use.

1. Introduction

Given the vast development of technological applications, education cannot ignore the use of technology for teaching and learning. However, using technology in education is not easy for most teachers, as it often implies organizational changes (e.g., time- and place-independent learning, tailored instruction, etc.) and changes in the way educational content is offered to students (Voogt, 2008). These changes require teachers to implement new teaching and learning practices (Mishra & Koehler, 2006; Voogt & Pareja Roblin, 2012; Webb & Cox, 2004).

The way teachers cope with new teaching and learning practices depends on how they reason about their professional work (Brown, 2009). Therefore insight into teachers' reasoning is needed in order to understand their teaching practices (Meijer, Zanting, & Verloop, 2002). Teachers' reasoning is based on their knowledge, beliefs and experiences (Sang, Valcke, Van Braak, & Tondeur, 2010; Van Driel, Verloop, & De Vos, 1998). Although ample research has studied the impact of teachers' knowledge (e.g., Kafyulilo, Fisser, Pieters, & Voogt, 2015) and educational beliefs (e.g., Ertmer, 2005; Prestridge, 2012) on their use of technology in teaching and learning, little is known about the professional reasoning teachers rely

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on regarding their use of technology within their pedagogical practices. Therefore, the purpose of this study was to understand teachers' reasoning about the way they use technology within their pedagogical practice.

1.1. Theoretical underpinnings

1.1.1. Teachers' professional reasoning about technology

Teachers' reasoning about the use of technology in their practice stems from their professional knowledge (Webb & Cox, 2004). Teachers' professional knowledge, also referred to as practical knowledge (Meijer, Verloop, & Beijaard, 1999), is defined as 'the knowledge and beliefs that underlie his or her [teacher] actions' (p. 60). Professional/practical knowledge is related to context and content, based on formal knowledge and beliefs about technology and education, and develops through (reflections on) day-to-day experiences in the field (Van Driel et al., 1998; Voogt, Fisser, Tondeur, & Van Braak, 2016).

Meijer (1999) identified eight categories of practical knowledge on which teacher decisions and the professional reasoning supporting those decisions are based. These categories cover teachers' knowledge about (1) the subject/domain, (2) student characteristics, (3) learning processes and conceptualizations, (4) educational goals, (5) the curriculum, (6) instructional techniques and (7) interaction. Studies in the field of technology have identified similar categories of professional reasoning and knowledge. For example, Niess (2011) mentioned knowledge about instructional techniques and representations for teaching and learning a certain subject. Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, and Sendurur (2012) found that the reasons teachers gave for using technology were related to the desire to enrich or supplement the existing curriculum and to provide a different pedagogical approach. Furthermore, Akgun (2013) emphasized that effectiveness, efficiency and attractiveness are key components in fostering student learning goals, student achievement and the appeal of the learning process. Teachers' professional reasoning should incorporate at least one of these components to accomplish successful technology use in practice.

Mishra and Koehler (2006) introduced Technological Pedagogical Content Knowledge (TPACK) as an important element of teachers' professional knowledge when they intend to incorporate technology within their educational practice. TPACK assumes that technological knowledge should be an integrated part of pedagogical content knowledge. This means that teachers need more than basic technological skills to be able to use technology to strengthen their pedagogical approach when providing subject-matter instruction to students with different interests and capabilities. Having TPACK helps teachers to select appropriate technologies that fit with the pedagogy and content in a specific context. Irrelevant use of technology and use of technology that has a poor fit with the pedagogy and subject matter can lead to negative learning effects (Webb & Cox, 2004).

1.1.2. Teachers' technology use in educational practice

In line with the underlying ideas of TPACK, teachers who use technology successfully in their teaching need to be able to 'fit' pedagogy, content and technology. Britten and Cassady (2005) argued that an important aspect of this 'fit' also relates to the necessity of using specific technologies to realize specific learning goals. They proposed a continuum representing the extent to which teaching practice depends on the technology application. In this continuum, 'non-essential use of technology' refers to learning activities that do not depend on the selected technology. 'Supportive use of technology' means that the technology application supports the implementation of the learning activity, but is not essential for achieving the intended learning goals. The use of technology is called 'essential' when the learning activity cannot be carried out without the technology application. An important aspect of teachers' professional knowledge regarding technology use is to know whether and how the technology applications they select are essential or at least supportive for realizing the goals in a particular learning activity.

This fit is demonstrated in the (technology-rich) learning activities that teachers develop. Based on their professional knowledge, teachers develop learning activities that are oriented more toward either transfer or construction of knowledge (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur, Hermans, Van Braak, & Valcke, 2008; Niederhauser & Stoddart, 2001). Research shows that it is not the isolated learning activity that affects learning, but the way the teacher structures learning activities in a learning environment (Lai, 2008; Voogt, 2008). Learning environments that incorporate technology can be characterized by: the role of technology, curriculum characteristics, class organization, teacher and student roles, control of the learning activity, and organization of assessment and feedback (Ertmer et al., 2012; Kozma, 2003; Lai, 2008; Voogt, 2008).

1.2. Research questions

In this study we argue that the educational use of technology concerns not only teachers' actual use of technology in the classroom but also the underlying professional reasoning. This study addresses the following research question and subquestions: *How do teachers reason about the use of technology in their pedagogical practice?*

1. *How do teachers reason professionally about their use of technology?*
2. *How do teachers use technology in their pedagogical practice?*
3. *To what extent is teachers' professional reasoning aligned with their use of technology?*

2. Materials and methods

2.1. Procedures

To collect data from a reasonably large sample that allowed for observation of teachers' professional reasoning and technology use in their pedagogical practice, it was decided to use video cases. Through a national open call, teachers were invited to participate in this study. To participate teachers were asked to record a 10–15 min video clip and complete a questionnaire. The video should include an example from their actual (technology-rich) teaching activities with students, and a commentary about the reasoning behind their actions. Teachers received a protocol for the structure of this video case but decided themselves which technology-rich practice they wanted to show in the video clip. In this way teachers were required to focus on the practice they showed and their reasoning about this practice. In most video clips about half of the time was devoted to show teacher's practice and half of the time was used to comment on this practice (we acknowledge the trade-off of this approach and discuss this matter in "limitations"). Fig. 1 presents a simplified overview of the protocol. The protocol was tested with six video cases to reach consistency in the procedures and ensure the collection of appropriate data. In the questionnaire teachers were asked about their educational beliefs, their level of technological expertise and their TPACK. A

VIDEO PROTOCOL

Show your technology use in practice including a commentary in which you explain why you use technology this way.	**Teacher:**	
	Grade	
	Subject	
Record a 10-15 minute video	**Video title**	
	Date	/ /

Video structure

The video should include the following three parts:

Introduction (introduce your example practice, include…)

- Explain the learning activity and technology use
- Explain the goal of technology use
- Explain the nature and function of technology use
- Explain the added value of technology use

Technology practice (show your technology use in practice, include…)

- Technology application and its added value
- Learning activities in which technology is used
- Classroom organization
- Role of teacher and student
- Assessment and feedback, if applicable

Commentary (provide a commentary on your technology use, include…)

- Explain why this example was chosen
- Explain the combination of the chosen technology tool, pedagogy and content
- Explain why you use technology this way
- Explain what would be different without this technology application

Final check

☑ Check that the video's content, image and sound quality are satisfactory

Fig. 1. Overview of video protocol (translated from Dutch to English).

video quality check excluded 14 video cases from the study due to poor sound- or image-quality. This left a total of 157 video cases that were suitable for analysis.

2.2. Instruments

2.2.1. Questionnaire

2.2.1.1. Educational beliefs, perceived knowledge and skills, and TPACK. The questionnaire served two purposes: (1) to determine the extent to which teachers' knowledge and beliefs influenced their pedagogical use of technology and professional reasoning, and (2) to compare the sample to a national benchmark to get an indication of the sample's representativeness. The questionnaire was based on a combination of two existing questionnaires, namely, a national monitoring instrument about technology use (Kennisnet, 2012; adapted from; Van Gennip & Van Rens, 2011) and TPACK-core (Fisser, Voogt, Van Braak, & Tondeur, 2013). The national monitoring instrument about technology use is a nation-wide questionnaire that is administered every two years with the aim of monitoring the use of technology in Dutch education. Items selected from this questionnaire focused on teachers' educational beliefs (10 items, $\alpha = 0.78$) and teachers' perceived technological skills (8 items, $\alpha = 0.88$). Items about educational beliefs were related to both knowledge construction and knowledge transfer (5 items each). For the TPACK-core questionnaire we used a selection of items from the TPACK survey (Schmidt et al., 2009). In previous research we could not reproduce the original factor structure Schmidt et al. (2009) reported. In fact we only found factors for the contributing knowledge domains (technological knowledge, content knowledge and pedagogical knowledge) and a one-dimensional factor structure for the items that related technology with pedagogy and/or content only, which we defined as TPACK-core (Fisser, Voogt, Van Braak, & Tondeur, 2013). We decided to only use the TPACK core items for the present study. The TPACK-core questionnaire had 8 items ($\alpha = 0.91$). Table 1 provides an overview of the items selected for this questionnaire along with a few examples and the psychometric scale. The instrument can be found in Appendix A.

2.2.2. Observation instrument

An observation instrument was developed to extract relevant information from the video cases. The instrument consisted of two parts: professional reasoning and technology use in practice. The observation instrument can be found in Appendix B.

2.2.2.1. Professional reasoning. Qualitative data analysis was done on 14 pilot video cases to develop items for the part of the observation instrument that was intended to record teachers' professional reasoning. All professional reasoning was transcribed and coded using Atlas-ti©. Quotes were clustered into categories corresponding to predetermined themes related to teachers' practical knowledge (Meijer, 1999) as applied to using technology in education. Data that did not fit directly into the categories were analysed separately to determine if they represented a new category or a subcategory. Based on this analysis, 20 dichotomous items were formulated, divided over 9 categories. As a whole, they represented teacher's professional reasoning about the use of technology in their practice as presented in the video case. The categories and contents of the corresponding items can be found in Table 2. An item was checked (yes/no) on the observation instrument when the corresponding form of reasoning occurred in teachers' commentaries (implying that more than one item could be checked). Except for the second item category (coherence between technology, pedagogy and content) where only one of the seven alternatives could be selected. It should be noted that teachers were specifically prompted about the first two categories (added value and coherence between technology, pedagogy and content), but not for the other categories.

2.2.2.2. Use of technology in pedagogical practice. The items that were developed to record teachers' use of technology in their pedagogical practice focused on the learning environment and 'fit'. Learning environment characteristics were recorded by items that focused on role of technology, curriculum characteristics, class organization, teacher role, student role, control of the learning activity, and assessment and feedback. Within these categories (except for role of technology) items corresponded to one of two pedagogical approaches: knowledge construction or knowledge transfer. For each item, observers checked whether the item was present (yes/no) and whether technology was used in relation with this item (yes/no). Examples of this part of the instrument are presented in Fig. 2.

Table 1
Examples of items used in the questionnaire.

Categories (and scale)	Example items
Educational beliefs *Never or rarely (1) – very often (5)*	• I summarize the content during my lesson. • I stimulate students to set their own learning goals
Technological skills *Not at all (1) – very advanced (4)*	• Can you indicate the level of expertise at which you can use … o … a computer as a pedagogical tool o … a virtual learning environment
TPACK-core *Strongly disagree (1) – strongly agree (5)*	• I can choose technologies that enhance the teaching approach for a lesson. • I can teach lessons that appropriately combine content, technologies and teaching approaches.

Table 2
Categories of teachers' professional reasoning about using technology in practice.

Item categories	Explanation
1. Added value for learning or teaching (6 items)	Reasoning about how technology makes teaching and/or learning more (a) attractive, (b) efficient or (c) effective.
2. Coherence between content, pedagogy and technology (1 item, 7 answer options)	Reasoning at the level of: subject only; pedagogy only; technology only; subject and pedagogy; subject and technology; pedagogy and technology; subject, pedagogy and technology.
3. Students (2 items)	Reasoning about how technology can contribute to learning for students from groups with particular characteristics (e.g., socio-economic background) or with individual needs (e.g., differentiated instruction).
4. Students' learning processes (1 item)	Reasoning about how technology can support the learning process (e.g., conceptualization, learning strategies, and procedures).
5. Educational goals (1 item)	Reasoning about how technology can support the goal of the learning activity.
6. Curriculum (3 items)	Reasoning about how technology is used to enrich or supplement the existing curriculum. Reasoning about technology as the curriculum goal. Reasoning about how technology can contribute to curriculum flexibility (e.g., learning that is independent of time and place).
7. Instruction (2 items)	Reasoning about use of technology for instructional techniques and representations regarding the chosen subject. Reasoning about use of technology to teach students (practical) skills and/or provide practical experience.
8. Interaction (2 items)	Reasoning about how technology mediates interaction between teacher and student (e.g., chat systems). Reasoning about how technology mediates interaction between students.
9. Student progress (2 items)	Reasoning about how technology is used for formative assessment (e.g., to monitor students' progress). Reasoning about how technology is used for summative assessment.

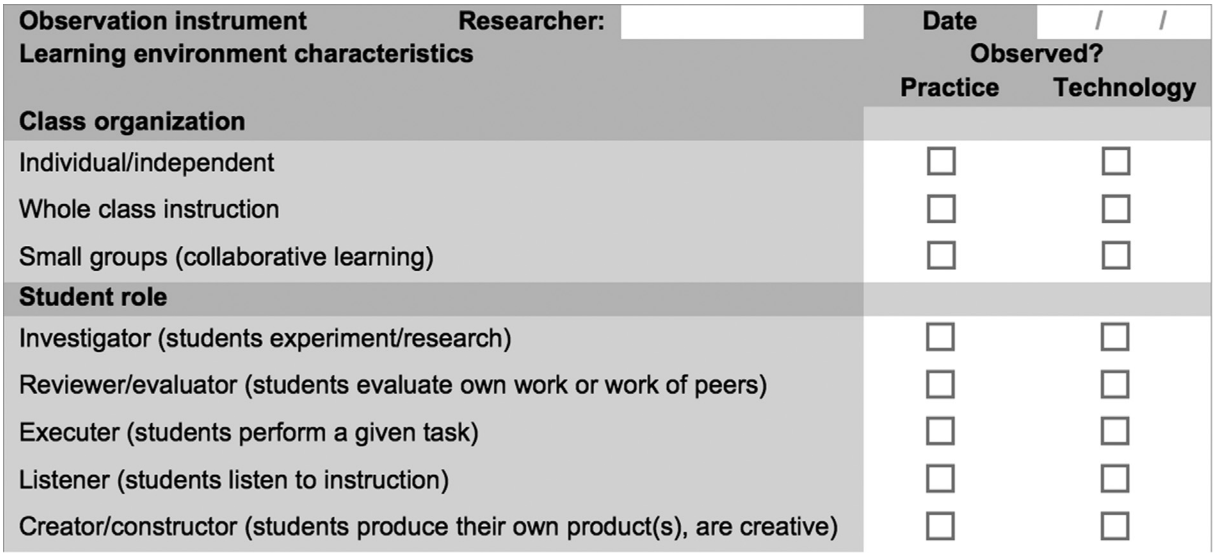

Fig. 2. Example of items concentrating on learning environment characteristics in the observation instrument.

The 'technology fit' records how teachers integrated technology in their practice. Items were based on two variables: the underlying ideas of TPACK and the 'fit' of the chosen technology. One set of items determined whether the specific technological application used strengthened pedagogy, subject matter, both, or neither (cf. Mishra & Koehler, 2006). The second set of items focused on the extent to which the learning activity depended on the technological application. Items were divided into "non-essential technology component", "supporting technology component" and "essential technology component" (cf. Britten & Cassady, 2005). Every technology application used by a teacher was rated for both variables. Table 3 shows an overview of all variables, linked to the instruments and purpose.

To assure the quality of the observation instrument a three-step procedure was followed. First, the observation instrument was developed based on an extensive review of the literature and further refined in discussions within the research team based on trial video clips. Second, to ensure usability and consistency in the data extraction procedures the instrument was piloted with 14 video cases. Third, after data collection, 35% of all video cases were blindly double-coded for both professional reasoning as technology use in practice to confirm the reliability of the data extraction process. All differences were discussed between researchers and subsequently adjusted. This process resulted in an agreement rate of 74% (Cohen's Kappa = 0.68), which is substantial (Landis & Koch, 1977).

Table 3
Overview of variables linked to instruments and purposes.

Instrument	Purpose	Variables
Questionnaire	Sample characteristics (Section 2.4)	Educational beliefs, perceived knowledge and skills, TPACK
Observation Instrument	RQ 1 (professional reasoning) (Section 3.1)	Added value for learning or teaching, coherence between content/pedagogy/technology, students, students' learning processes, educational goals, curriculum, instruction, interaction, student progress
Observation Instrument	RQ 2 (technology use) (Section 3.2)	Role of technology, curriculum characteristics, class organization, teacher role, student role, control of the learning activity, and assessment and feedback. depended on the technological application
Observation Instrument	RQ 3 (alignment) (Section 3.3)	Match ('technology fit' and 'coherence between content, pedagogy and technology'

2.3. Data analysis

2.3.1. Questionnaire

Descriptive statistics were used to analyse the results regarding perceived knowledge and skills, educational beliefs and TPACK. To check the dimensionality of the items, a factor analysis (maximum likelihood rotation) was done for all scales. According to Field (2009, p. 669) factor loadings above 0.4 are considered high and we used this as cut-off score. For perceived knowledge and skills, factor analysis suggested a one-dimensional structure (51.6% common variance) with factor loadings (between 0.52 and 0.86). Educational beliefs concerned items related to knowledge construction or knowledge transfer. This was confirmed with a factor analysis that found two separate factors (common variance = 50.9%, F1 = 37.7%; F2 = 16.2%). Factor analysis on the TPACK-core items suggested a one-dimensional structure (66.1% common variance) with factor loadings between 0.70 and 0.85. Chi-square tests were done for every category of results in order to determine any significant differences between primary and secondary education teachers.

Responses on the online questionnaire were also used to compare the teachers in this sample to a national benchmark (Kennisnet, 2012). ANOVA's was used to determine significant differences on responses to these items between the teachers in this sample and the average Dutch teacher.

2.3.2. Observation instrument

The two parts of the instrument (professional reasoning and use of technology in pedagogical practice) were first analysed separately. Next, the alignment between teachers' reasoning and the actual use of technology in teachers' pedagogical practice was examined. Finally, chi-square tests were carried out to identify significant differences between primary- and secondary education teachers.

Descriptive statistics (counts/percentages) were used to analyse teachers' professional reasoning. Additionally, the breadth of the professional reasoning was examined by considering the number of categories that were addressed in teachers' commentaries. Categories 1 and 2 (see Table 2) were excluded from these calculations, as teachers were prompted to reason about this through the video protocol. Scores on the remaining professional reasoning categories were added, which led to a total score between 0 and 7 that indicates the extent to which teachers demonstrated different types of professional reasoning about integrating the technology application into their practice.

The items that were used to record teachers' use of technology in their pedagogical practice were also analysed with descriptive statistics (counts/percentages). Percentages are reported, along with illustrative examples.

To determine the alignment between reasoning and practice ('match'), the results for the items in reasoning category 2 ('coherence between content, pedagogy and technology') and the items about technology fit ('technology strengthens pedagogy, subject matter, both, or neither') were compared. A new dichotomous variable ('match') was created to reflect whether the results on these items corresponded. A match was recorded when a teacher reasoned about the coherence between technology and pedagogy *and* that teacher also showed a 'fit' between technology and pedagogy in their educational practice.

2.4. Sample characteristics

157 Dutch teachers participated in this study. Of this sample, 117 teachers provided video cases with lessons for students in primary education and 40 teachers submitted video cases with lessons taught in secondary education. Teachers used 339 technology applications in these 157 video cases. Teachers presented the use of technology in different subject domains (see Table 4).

Of the 157 teachers, 28 did not finish the questionnaire, which means that the responses from 129 questionnaires were used for analysis. Primary and secondary education teachers did not differ significantly with regard to their educational beliefs, perceived level of technological expertise and their score on TPACK core. Results regarding *educational beliefs* show that teachers' educational beliefs more strongly reflect knowledge transfer ($M = 3.9$; $SD = 0.56$) than knowledge construction ($M = 3.1$; $SD = 0.65$; five-point Likert scale). A higher scale value for knowledge construction compared to knowledge transfer was found for 19.1% of the teachers. The results show that teachers' *perceived level of technological expertise* is high ($M = 3.1$;

Table 4
Overview of subjects taught.

Subject domains	% of total video cases
Primary education (N = 117)	
Reading and Literacy	45%
Math	25%
Social studies and Science	25%
Arts	3%
Other	13%
Secondary education (N = 40)	
Vocational courses	26%
Social studies	18%
Science	15%
Language	13%
Physical education	8%
Math	3%
Arts	13%
Other	10%

$SD = 0.57$; four-point Likert scale) indicating that they feel confident about using technology in educational practice. A 'highly advanced level' was reported by 32% of the teachers and 51% reported being at an 'advanced level'. The results of the *TPACK core* items also show that teachers feel knowledgeable and suggest high confidence in their ability to integrate technology, pedagogy and content in practice ($M = 4.2$; $SD = 0.53$; five-point Likert scale).

The results regarding the sample's representativeness showed that the teachers included in this study scored significantly higher on the comparison items than the teachers in the national benchmark sample (see Voogt et al., 2014). This implies that the teachers in our sample are more positive and confident regarding the use of technology in education than the average Dutch teacher.

3. Results

3.1. Teachers' professional reasoning about technology use

The results related to teachers' professional reasoning are presented in this section. Results for primary and secondary education are taken together. Results are reported separately only where there are notable differences between primary and secondary education teachers in the observation results. Furthermore, examples taken from the video cases are used to illustrate the results.

Table 5 provides results regarding teachers' reasoning on the added value of the technology use they displayed in the video. It should be noted that teachers could mention more than one reason for the added value of the technology application used. Teachers reasoned about the added value of their technology use in terms of attractiveness, efficiency and effectiveness for either the students' learning process or their teaching. Most teachers said they used technology to make the learning process more attractive and motivating for students.

One of the teachers explained why the technology use in her example made learning more effective. In her video, 4 and 5 year old students worked on a digital picture story for which they had to create the pictures and record the story text that went with these pictures by reading it aloud. The teacher stimulated students to replay their spoken words and listen to see whether the words are correct. She explained that: "by using technology students can replay their own spoken words. Replay and listening to your own reading has a real added value for students who are still learning to read". Another teacher talked about the way technology made her teaching more efficient. Students in her class used drill and practice software that automatically provides feedback. This makes it easier for students to work on the assignments independently. Along with the individual feedback, the software provides teachers with color-coded feedback about the progress of all students. She explained:

> This way, one glance at my screen is enough to see which assignments students struggle with. Let's say a dozen or so students did not understand one assignment, then a lot of red dots appear. I can stop the whole class in order to provide some additional instruction for this particular assignment.

Reasoning about the coherence between the selected technology, pedagogy and content was mentioned by 39% of the teachers (see Table 6). In 40% of the video cases, teachers reasoned about how the use of technology strengthened their pedagogy and in 16% of the video cases they talked about how the use of technology strengthened specific subject matter. In 5% of the cases, teachers' reasoning did not address any coherence between the technology application and either the pedagogy or subject matter they used.

For example, one of the teachers explained the coherence between the selected technology, pedagogy and content while she showed how she used students' personal photos to foster communication skills with 4-year-old students:

Table 5
Reasoning about the added value of technology use in education.

	Attractiveness	Efficiency	Effectiveness
Learning process	86%	31%	42%
Teaching	12%	36%	15%

Table 6
Reasoning about TPACK.

TPACK elements	% of total (N = 157)
TCK	16%
TPK	40%
TPCK	39%
No TPACK reasoning	5%

> The students are more involved because they are talking about their own personal experiences that are shown in the pictures. Showing their pictures to the class on the smartboard makes it easier for other students to understand what the story is about and this way we can help students learn to ask better questions. The pictures help them to ask better questions.

A Dutch language teacher reasoned about using technology to strengthen the subject taught: "We were doing lessons about characters [in novels], which is a very abstract concept for students, but videos are a great way to visualise different characters and make it easier for students to understand".

Table 7 presents the results for professional reasoning that emerged from the data, organized according to the categories presented in Table 2. Results show that teachers mostly related their use of technology to supporting educational goals (65%) and facilitating the learning process (54%). Other reasons for using technology in practice were formative assessment (32%) and tailoring education to specific individual student needs (e.g., dyslexics, excellent students; 29%). Teachers' professional reasoning was less focused on the use of technology to facilitate learning for specific groups of students, to enrich the curriculum, to foster flexible learning opportunities, to enhance practical skills, to enhance interaction and to employ summative assessment (between 10% and 20% of the teachers). Results regarding the breadth of teachers' professional reasoning show that on average teachers covered between 2 and 3 (2.85) of the 7 distinctive categories (excluding those that were prompted) in their professional reasoning. Teachers in primary education ($M = 3.03$, $SD = 1.33$) mentioned more reasons than teachers in secondary education ($M = 2.32$, $SD = 1.19$; $t(155) = 2.98$, $p = 0.003$).

One teacher explained how she uses technology to support the students' learning process. In her lesson on reading comprehension, low achieving students could use software that supports their reading by reading the text out loud and highlighting words that are read. The teachers explained:

> Using technology this way makes learning more effective for these students because they can focus on comprehending the text at the same pace as the rest of the students. Without the application, these students will only be able to focus on decoding and technical reading of the text, which leaves no room for comprehending the text.

Table 7
Teachers' professional reasoning about technology use.

Reasons about technology use and …	% of total (N = 157)
Students	
Specific groups	10%
Individual needs	29%
Learning process	54%
Educational goal	65%
Curriculum	
Enrichment	13%
Technology skills as curriculum goal	22%
Flexibility	16%
Instruction	
Representations	22%
Practical skills	12%
Interaction	
Teacher – student	10%
Student – student	10%
Student progress	
Formative assessment	32%
Summative assessment	11%

A physical education teacher provided an example of reasoning about the flexibility of the curriculum in his explanation of an instructional video that he made for student to use. Students can review this instruction video whenever they want and where they want. The teacher said:

> The nice thing about using technology this way is that students can decide for themselves when and where they would like to watch the instruction. Additionally they can replay the instruction if needed. This way the instruction becomes more tailored to the student's need than when I would have shown the way to do this exercise in a whole classroom teaching setting.

Another teacher used digital images in computer assignments and instruction for students who need to learn English as a second language. She explained: "students have no experience with, for example, the word 'pouring'. The images used in these computer assignments are universal and make it easier for students to comprehend, especially when the images match with students' daily experiences".

3.2. Teachers' use of technology in pedagogical practice

Two indicators were used to collect data about teachers' pedagogical use of technology: characteristics of the learning environment created and 'technology fit'. These indicators were determined for 157 teachers using 339 technology applications, meaning that more than one technology application was used in most of the video cases.

3.2.1. Characteristics of technology use in learning environments

The characteristics of the learning environments in the teachers' video cases refer to the role of technology, curriculum characteristics, class organization, teacher role, student role, control of the learning activity and use of assessment and feedback.

Regarding the role of technology, some variation in technology functions was seen (see Table 8). Most teachers used technology as a processing tool. Other frequently mentioned functions were instruction tool, drill and practice tool, information source and presentation tool.

Table 9 provides an overview of the other observed characteristics of the learning environment. Items are identified as corresponding to knowledge construction (KC), knowledge transfer (KT), or both. A distinction was made between characteristics that were observed in general and characteristics related to technology use by teachers. As technology practices are the focus of this study, the description of the results will concentrate on the use of technology in learning environments. Examples taken from the video cases are used to illustrate the results.

The most frequently observed type of curriculum was knowledge transfer oriented lessons in which students used technology to practice knowledge and skills (29%). In 15% of the lessons, technology fostered the authenticity of the lesson, which corresponds to the knowledge construction model of teaching. An example of the latter is a lesson in which students wrote blogs with students from India. Students wrote stories about what happened in their lives and responded to the blogs of the Indian students. Less frequently observed types of curriculum were problem solving, discovery learning and metacognitive strategies. However, where problem-solving activities or metacognitive strategies were observed, teachers almost always used technology to support these processes (100% and 80% respectively).

Results regarding social classroom organization show that technology was used in individual teaching (50%), whole classroom teaching (46%) and for cooperation in small groups (39%), indicating that the classroom organization mostly matched the knowledge transfer model of teaching. Examples include using the smartboard to provide whole classroom instruction, stepwise instruction on a tablet for individual teaching and using cloud software to support the production of collaborative products.

Observations show that the roles assumed by teachers and students were not often related to the use of specific technologies. In some cases, however, their roles were supported or defined by technology use. Most teachers assumed a guiding teaching role (69%; KC), which was rarely supported by technology use (6%). Knowledge transfer oriented roles, in which the

Table 8
Technologies used by teachers in this sample organized by function.

Technology function	% of total technology applications used (N = 339)
Information processing tool (e.g., Word)	45%
Instruction tool (e.g., web lectures)	38%
Drill and practice tool (e.g., software for practising vocabulary)	31%
Information source (e.g., Internet)	27%
Presentation tool (e.g., PowerPoint)	27%
Evaluation tool (e.g., computerized test)	9%
Communication tool (e.g., blog)	8%
Learning process support (e.g., mind maps)	6%
Simulation (e.g., software simulating physical or societal phenomena)	2%
Collaboration support (e.g., cloud software)	2%
Other (e.g., administration or stopwatch)	3%

Table 9
Overview of observed learning environment characteristics.

	Observed	Observed with technology
	% of total cases (N = 157)	% of observed
Curriculum characteristics		
Authentic lesson (KC)	16%	92%
Problem solving (KC)	10%	80%
Drill and practice (KT)	34%	87%
Metacognitive strategies (KT/KC)	2%	100%
Inquiry learning (KC)	7%	55%
Classroom organization		
Individual (KT)	54%	92%
Whole classroom teaching (KT)	58%	80%
Small groups (KT/KC)	43%	90%
Teacher role		
Training of knowledge or skills (KT)	26%	68%
Transferring knowledge (KT)	29%	60%
Guiding, stimulating and advising (KC)	69%	9%
Monitoring (KT/KC)	9%	64%
Student role		
Investigator (KC)	18%	89%
Assessor (KT/KC)	3%	75%
Executer (KT)	69%	86%
Listener (KT)	46%	25%
Constructor (KC)	33%	94%
Control of the learning activity		
Learning activity controlled by student (KC)	18%	54%
Pacing controlled by student (KC)	68%	19%
Learning activity controlled by teacher/agent (KT)	88%	54%
Pacing controlled by teacher/agent (KT)	38%	20%
Assessment and feedback		
Formative assessment (KT/KC)	18%	75%
Summative assessment (KT)	3%	60%
Direct feedback on correctness (KT)	26%	98%
Elaborated feedback (KT/KC)	13%	10%

Note: Items correspond to knowledge construction (KC), knowledge transfer (KT), or both (KT/KC).

teacher focused on transferring knowledge or training of knowledge and skills, were observed to a lesser extent (29% and 26%, respectively). However, technology influenced these roles in 68% and 60%, respectively, of the cases in which they were observed. One example was a physical education lesson in which the teacher made an instructional video to teach students how to leapfrog. Students needed to watch the video before the lesson in order to be able to practice the skill during the lesson ('flipped instruction'). The role of 'assessor' was observed in only 9% of the cases. When this role was assumed, 64% of the teachers used technology to carry it out. Most of the observed roles for students matched the knowledge transfer model of teaching. The role that occurred most for students was the 'executer' (69%), which was associated with technology use in 86% of these cases. In almost half of the cases (46%) students were 'listeners'; 25% of these listeners used technology. Individual instruction provided through a tablet was one example of this. Other observed student roles were 'constructor' (33%), 'investigator' (18%) and 'assessor' (3%). Technology was used as a support in most of the cases where these roles were observed. Examples included a reading lesson in which students produced a stop-motion video story or a vocational lesson in which students assessed one another by watching a video in which they showed their skills at bandaging an arm.

Control of the learning activity by teachers (or teaching agents) was observed in the great majority of the cases (88%; KT). In 54% of these cases, technology was used to do so. One example was a lesson in which students learned to draw the isometric orientation of a building (e.g., Big Ben). Every student used software to practice with the isometric orientation of shapes while drawing. This software gave students short puzzles that they had to solve. Students determined the pacing of learning activities in 68% of the cases (KC), 19% of which involved the use of technology. Several teachers showed how students could use instructional videos or stepwise instruction created by the teacher. Students were able to change the speed of play or play back as much as they needed. Another example was from a reading comprehension lesson in which low-achieving students were supported by software in reading a text. The software read the text out loud and highlighted the words that were read. Students were completely in control of the pacing and could go back or change the speed if needed.

Regarding assessment and feedback, teachers used technology to provide feedback that informed students whether their answer was correct or not in 25% of the video cases. The use of elaborated feedback (in contrast to feedback that only provided correct/incorrect information) was observed in 20% of the video cases, but only 1% of the teachers used technology to support this. The use of technology for formative assessment was observed in 13% of the cases, whereas summative assessment was only seen in 2%. Teachers used computer response systems to evaluate students' knowledge and built on this information to adapt their instruction to the students' needs. One example was a teacher who asked students what they remembered about the human body during a science lesson. Students used laptops to type words associated with the human body, which appeared directly in a word cloud on the smartboard. An example of summative assessment was a physical education lesson in which students learned how to juggle. The students recorded each other's juggling skill with a camera, after which the teacher used the video for summative assessment purposes.

3.2.2. Technology fit

Technology fit was determined by two variables. The first variable referred to whether the use of the technological applications (n = 339) strengthened the pedagogy, subject matter, both, or neither. The second variable regarded the extent to which the educational activity depended on the technological application ("non-essential technology component", "supporting technology component" and "essential technology component") (see Table 10).

In primary and secondary education, most technology applications used by teachers either strengthened their pedagogy and the subject matter or else strengthened only the subject matter. A minority of the technology applications used by teachers were observed to strengthen only their pedagogy (11%). No coherence between technology, pedagogy and/or content was observed in a few of the technology applications used by teachers (2%). Examples are the physical education teacher who made an instructional video for a leapfrog exercise that students could watch at their own pace (including playback) before the lesson in which they had to practice the actual exercise (strengthening pedagogy and subject). An example of the use of technology to strengthen pedagogy only was a teacher who used computer response systems in history class. Students had to use the computer response systems to answer questions that were projected on a smartboard. Based on the displayed results for each question, the teacher decided whether or not to elaborate on the underlying topic of the question.

Regarding the dependence of the instructional activity on the technological application, results show that most teachers used technology to support the implementation of the learning activity to some degree. For 18% of the technology applications that were used by teachers, the learning activity would not have been possible without the chosen technology, which made its use essential. Non-essential use of technology was found for only a small number of technology applications (3%). Related examples include a teacher's use of a tablet from which she read test questions to students who then wrote down the answer on paper (non-essential), or a physics teacher who let students experiment with sensors on arm muscles that were linked to measurement software (essential).

A similar trend for both primary and secondary education emerges when these two components of technology integration are taken together. Teachers who showed coherence between the use of technology and either the taught subject or the chosen pedagogy mostly used technology in a supportive way. However, when coherence between technology, pedagogy and subject matter was demonstrated, technology was often used in an essential way.

3.3. Alignment between reasoning and practice

The results presented above already indicate a mismatch between teachers' reasoning and their pedagogical use of technology in some cases. For example, the use of technology-based assessment tools was hardly observed, but teachers mentioned this in their professional reasoning in 32% of the cases. Teachers also reasoned more about how the use of technology to strengthen their pedagogy than to strengthen the subject matter being taught, while in practice, technology use to strengthen subject matter was observed more often. The calculated alignment between reasoning and practice also confirms this notion, as a match was found between teachers' professional reasoning and their pedagogical use of technology for 57% of the cases. One example of good alignment was a teacher who used computer response systems to determine students' prior knowledge, and said in her commentary on the video that she used this application of technology to adapt her teaching to the students' level. An example of no alignment was when a teacher said she used tablets in her lessons to support the students' learning process by guiding them through assignments, but in practice the students just used the tablet to locate the assignment descriptions in a database.

4. Discussion and conclusion

Decisions about how to use technology in education are up to teachers (Ertmer, 2005). The way teachers use technology in their teaching and learning practices is based on their reasoning about their professional work (Brown, 2009). This study focused on how teachers reason about the use of technology in their pedagogical practice.

Table 10
Integration of technology.

Technology fit	% of total technology applications used (N = 339)
Strengthens pedagogy	11%
Strengthens subject matter	22%
Strengthens pedagogy and subject matter	21%
No coherence	2%
Non-essential	3%
Supporting	35%
Essential	18%

4.1. Professional reasoning and technology use in teachers' pedagogical practices

The first research question focused on teachers' professional reasoning about their pedagogical use of technology. Although every category of professional reasoning (Meijer, 1999) was mentioned by teachers, on average, teachers covered only a limited number of reasoning categories when explaining their enactment of technology use in their practice. Most uses of technology were justified by reasoning about how their technology use strengthened both pedagogy and content or else pedagogy only. Overall, most teachers' reasons for using technology were related to the attractiveness of the technological tool, realization of educational goals and facilitation of the learning process. A minority of teachers mentioned other reasons to use technology. Although most teachers reasoned about using technology to make the learning process more attractive for students, they indirectly assumed that technology's ability to make teaching attractive contributes to its effectiveness for student learning. The same is true for teachers' reasoning about efficiency. This suggests that teachers view efficiency and attractiveness as components that both lead to effectiveness of technology use for education. Other studies have also found evidence for a positive effect of technology on student learning that was linked with student engagement and motivation (e.g., Papastergiou, 2009). However, these studies have often focused on short-term effects. Concerns have been raised about the long-term effects, because increased motivation might arise from the novelty of technology use in the classroom. More research is needed to draw solid conclusions.

The second research question concentrated on teachers' use of technology in their pedagogical practices. The findings showed that the majority of the learning environments created by teachers indicated aspects related to a knowledge transfer model of teaching (e.g., practicing knowledge and skills, whole classroom teaching). Several other studies have also found that teachers are more oriented toward using technology in teacher-centered environments (cf. the knowledge transfer model) (Ertmer et al., 2012). Although knowledge transfer was the dominant educational approach, teachers showed some elements of knowledge construction. This mainly concerned the role of the teacher as a guide, collaboration in groups (in a minority of the cases) and the provision of authentic instruction. In most of these cases, technology was used to establish these elements only for authentic instruction and collaboration in groups. In line with these findings, the data on the characteristics of the sample also showed that teachers' educational beliefs matched their enactment shown in practice, as their beliefs more often matched the knowledge transfer model than the knowledge construction model of teaching. While many researchers favor the latter for technology-rich education (e.g., Ertmer et al., 2012), it does not mean technology cannot be used effectively in more traditional ways of teaching. Teachers usually do not base their teaching on just one educational approach or philosophy, but use a mixture in which one approach is more dominant then the others (Niederhauser & Stoddart, 2001).

The way teachers integrated technology was mainly focused on strengthening both subject matter and pedagogy or else on strengthening only the subject matter being taught. Coherence between the use of technology and either the subject matter or the chosen pedagogy typically resulted in technology use that supported the implementation of the learning activity. An important finding was that coherence between technology, pedagogy and subject was often related to essential uses of technology. It implies that technology use was necessary to realize the teachers' educational goals and/or pedagogical practices. More research is needed to understand the types of uses of technology that make it essential for teaching and learning.

Finally, the last research question regarded the alignment between teachers' professional reasoning and their technology use in their pedagogical practice. A little over half of the cases showed alignment between reasoning and practice. Often studies find a mismatch between what teachers think they (can) do in practice and what is actually observed in the practical setting (e.g., Chen, 2008). Observations frequently show more traditionally oriented practices than teachers actually reported using (e.g., Hennessy, Deaney, Ruthven, & Winterbottom, 2007; Webb & Cox, 2004). Furthermore, most teachers seemed to be able to explain why the chosen technology fit with the subject matter and/or pedagogy, but only half of the teachers reflected this in their pedagogical enactment. It should be kept in mind that the TPACK model presented by Mishra and Koehler (2006) is a conceptual model. In practice, teachers do not think in separate domains of knowledge, as these do not occur separately in practice (cf. Kafyulilo, Fisser, Pieters, & Voogt, 2015). In this study as well, reasoning about the separate domains did not occur. This means that teachers do, to some extent, already think about technology use in an integrated way.

4.2. Limitations

In order to collect data from a reasonable large sample that allowed for observation of teachers' professional reasoning and corresponding pedagogical use of technology, it was decided to use video cases in this study. A trade-off is that only a snapshot of teachers' practice was used, which could lead to a limited view of reality. However, we believe that this snapshot is informative, because it was based on teacher's deliberate choice of practice. This also ensured that teachers' professional reasoning was focused on the actions they showed in the video. We have no indications that teachers felt hampered by the limited length of the video.

Teachers in our sample are more positive and confident regarding the use of technology in education than the average teacher. Although this means that the sample used does not represent the average Dutch teacher, it does indicate that teachers' pedagogical use of technology and corresponding professional reasoning were not hindered by lack of self-confidence or positive perceptions (cf. Ertmer, 2005; Hermans, Tondeur, Van Braak, & Valcke, 2008).

4.3. Implications for practice and further research

To our knowledge this study is new in that it conscientiously explored the way teachers reason about using technology in their practice in a rather large number of cases. By capturing both teachers' technology use and their reasoning about this use we were able to extract a more precise picture of teachers' reason to use technology than would be possible through self-report (Christensen & Knezek, 2009). Several studies have shown that there could be a significant difference between what teachers think about their own abilities and the abilities they actually show in practice (e.g., Allayar, 2011; So & Kim, 2009). Also in this study in many cases showed a mismatch between teachers' reasoning and their practice. This is worrisome for the intended effectiveness of using ICT in teaching and learning. For effective integration of technology in practice, it is important that teachers' practical actions and professional reasoning match and that teachers make choices based on knowledge about which technology is effective in realizing specific learning goals (cf. Britten & Cassady, 2005). The results of our study gives reason to call for explicit attention to teacher's reasoning about their technology use in practice. In addition to emphasizing the coherence between technology, pedagogy and content (cf. Mishra & Koehler, 2006), teachers also need to learn to consider whether their use of technology is essential, supportive or non-essential (cf. Britten & Cassady, 2005). Teachers' effective use of technology might be improved if they become better able to articulate the reasoning behind the use of technology in their teaching, share this reasoning with colleagues and confront their reasoning with findings from research. To support teachers in this process teachers need authentic, practical examples of teaching with technology (Ertmer & Ottenbreit-Leftwich, 2010), to learn from and reflect upon; such examples were the main data source in this study. Furthermore, the examples are authentic, as teachers will be able to recognize the daily practices and needed infrastructure within which the technology use is shown. Such cases invite teachers to discuss the examples in a critical manner. However, it should be noted that the videos in this study include relatively few aspects of the pedagogical use of technology that correspond to the knowledge construction model. This leaves these possible uses of technology under-represented. Therefore, more practical examples are needed that show innovative technology practices based on the knowledge construction approach to teaching. Additionally, the data did not provide enough information to make a value judgement of teachers' teaching practices. Further research is needed to incorporate assessment of the quality of the pedagogical practices as well.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.compedu.2016.05.009.

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