Eliciting teachers' and students' technological competences:

Assessing technological skills
in practice

ELICITING TEACHERS' AND STUDENTS'
TECHNOLOGICAL COMPETENCES.
ASSESSING TECHNOLOGICAL SKILLS
IN PRACTICE

Maaïke Christine Heitink

ELICITING TEACHERS' AND STUDENTS' TECHNOLOGICAL COMPETENCES. ASSESSING TECHNOLOGICAL SKILLS IN PRACTICE

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Chapter 1

General introduction

Given the vast development of technological applications, education cannot ignore the use of technology in preparing students for society. Using technology in education has become both a goal and a tool, meaning that teachers need to be able to use technology as an effective tool in their teaching and students need to learn how to use technology properly in their day-to-day lives. These technological developments are resulting in organizational changes (e.g., time- and place-independent learning, tailored instruction, etc.) and changes in the educational content (Voogt, 2008).

Appropriate use of technology requires new competences from both students and teachers (Ferrari, 2013; Fraillon, Ainley, Schulz, Friedman, & Gebhardt, 2014; Kozma, 2008; Mishra & Koehler, 2006; Voogt, Knezek, Christensen, & Lai, 2018; Webb & Cox, 2004). However, several studies have shown that the adequate use of technology in day-to-day practices is not obvious and that there is still much room for improvement in the technological competences of both students and teachers (e.g., Aesaert & van Braak, 2015; European Commission, 2013; Fraillon et al., 2014; van Deursen & van Diepen, 2013). Hence, recent suggestions for future research have stressed the importance of the development of technological competences for both students and teachers, and many countries incorporate formal expectations and standards regarding technology competences in their curricula (Aesaert & van Braak, 2018; Thomas & Knezek, 2008).

Klieme, Hartig, and Rauch (2008) suggested a working definition of competences as ‘context-specific cognitive dispositions that are acquired by learning and needed to successfully cope with certain situations or tasks in specific domains’ (p. 9). Competences consist of different facets (e.g., knowledge, skills, attitudes, beliefs, self-efficacy) and are often context-dependent. Because of the rapid developments in technology, Passey, Shonfeld, Appleby, Judge, Saito, and Smits (2018) viewed technological competences from a broad perspective, in which digital competence, digital confidence and digital accountability together provide the basis for the ‘individual’s ability to control and adapt to a digital world’. This suggests that technological competences are based on a

combined package of complex knowledge and skills that are needed in reasoning, problem solving and creativity, for example. These kinds of complex knowledge and skills are referred to as cognitive skills (van Merriënboer, 1997). Although all facets of competence are important, the studies in this dissertation focus primarily on the cognitive technological skills relevant for teachers and students. Attitudes, beliefs and self-efficacy that are part of teachers' technological competences are taken into account as background variables, but are not the focus of the studies.

Measuring or mapping students' and teachers' technological skills is necessary for effective education in which using technology is either a goal or a tool. Assessment of teachers' technological skills can provide insight into how teachers use technology in their educational practice. As ineffective use of technology in teaching can lead to negative effects on student learning (Webb & Cox, 2004), it is important to make sure that teachers use technology as a tool to strengthen their pedagogical practices and foster student learning. Assessment of students' technological skills can provide insight into the extent to which students possess such skills, which in its turn can serve as a foundation for teachers and policy makers to make informed decisions about using technology in education.

There is limited research into the measurement of actual technological skills and the results are still very general (cf. Aesaert & van Braak, 2018; Christensen & Knezek, 2018). Much research about the technological skills of both teachers and students uses instruments that measure self-perception of these skills. Although these kinds of instruments can be used to measure constructs such as attitudes or beliefs, they are in general not a good match for the measurement of skills. Measuring skills through self-perceptions often causes validity problems, as these measures depend on the respondents' ability to judge their own skills (Siddiq, Hatlevik, Olsen, Throndsen, & Scherer, 2016). Likewise, several researchers have concluded that there are large inconsistencies between teachers' and students' self-reported and actual technology skills (e.g. Allayar, 2011; Hakkarainen et al., 2000; Merritt, Smith, & Di Renzo, 2005). Measuring the actual technological skills of teachers and students thus requires a different approach.

Messick (1994) provided a perspective on assessment that helps to structure ideas about assessment for different purposes and with different data: *A construct-centred approach [to assessment design] would begin by asking what complex of knowledge, skills, or other attribute should be assessed, presumably because they are tied to explicit or implicit objectives of instruction or are otherwise valued by society. Next, what behaviors or performances should reveal those*

constructs, and what tasks or situations should elicit those behaviors? Thus, the nature of the construct guides the selection or construction of relevant tasks... (p. 17)

This quote suggests that reliable and valid measurement of any construct depends, at the very beginning, on methods that successfully elicit the behavior that needs to be measured. The technological skills of students and teachers are both of a situated nature. This implies that the technological skills of students and teachers are embedded in knowledge derived from formal education, from former experiences in practice and from beliefs concerning the use of technology in daily activities (Brown, 2009; Markauskaite, 2007). Hence, direct measurement methods that focus on eliciting the technological skills that teachers and students need to use in their day-to-day practices would be an appropriate approach.

The overarching aim of this dissertation is to investigate how to elicit the actual technological skills of teachers and students in order to be able to assess their skills in authentic settings. Although the four studies in this dissertation are based on separate research projects that had distinct research questions and used different methodologies, all studies contribute to this overarching aim. To get a good understanding of how the technological skills of teachers and students can be elicited, it is necessary to have some knowledge about the technological competences students and teachers need in their day-to-day practices. Therefore, this introduction will include a short discussion about the technological skills of teachers and students. To be able to assess these (elicited) skills in the context of classroom practice, it is necessary to understand how such skills can be assessed in classroom practice. Therefore, prerequisites that are needed for assessment in classroom practice will be considered as well. Finally, it should be noted that the chapters in this dissertation describe studies that have been published or are submitted for publication and are therefore written in a stand-alone way. This means each chapter can be read independently; the theory and discussion sections in each chapter are focused on the purpose of each separate study.

1.1 Teachers' technological skills

In this dissertation, the investigation of teachers' technological skills is focused on the use of technology in their day-to-day pedagogical practices. The way teachers teach explains about 30% of the differences in student achievement (Hattie, 2012; Van de Grift, Van der Wal, & Torenbeek, 2011), meaning that the way teachers use technology in their teaching has great influence on both student achievement in general and students' technological skills in particular (European Commission, 2013; Mishra & Koehler, 2006; Webb & Cox, 2004).

Effective incorporation of technology within their educational practice requires teachers to have professional knowledge about the affordances of technology for education. A well-known framework that describes an aspect of the professional knowledge teachers need to effectively integrate technology in classroom practice is Technological Pedagogical Content Knowledge (TPCK, currently referred to as TPACK; Mishra & Koehler, 2006). TPACK assumes that technological knowledge should be an integrated part of pedagogical content knowledge. This means that teachers need more than basic technological skills. Teachers need to be able to use technology to strengthen their pedagogical approach when teaching specific subject-matter to students with different interests and capabilities. In line with the underlying ideas of TPACK, teachers who use technology successfully in their teaching need to be able to integrate pedagogy, content and technology (Schmidt et al., 2009). Hence, an important aspect of having TPACK is knowing whether and how to select technology applications that are necessary, or at least supportive, for realizing the goals in a particular learning activity focused on specific content in a specific context, and enhancing learning (cf. Britten & Cassady, 2005; Jonassen, 2000; Kennisnet, 2017; Sang, Valcke, van Braak, & Tondeur, 2010; Webb & Cox, 2004).

To translate this conceptual framework (and variants of this framework) into practice, countries have started to formulate standards for teachers (e.g., ISTE, 2017; UNESCO-ICT, 2011). For example, in the Netherlands, where all studies presented in this dissertation were conducted, ADEF (2013) and Kennisnet (2017) formulated (non-mandatory) standards for pre-service and in-service teachers that include technological skills in technology competence areas related to digital literacy, pedagogical action in practice, basic technological skills, attitudes related to technology use, on-going professional development and technology use in the school organization.

1.2 Students' technological skills

There is a broad spectrum of terms, which are used interchangeably, that describe sets of technology-related skills for students (Fraillon et al., 2014). These days, the focus of frameworks describing these technology-related skills is not technological aspects (e.g., operating a technological device); instead, technology-related skills are described as a complex whole that is based on the integration of (meta-) cognitive skills and technological skills (e.g., Aesaert, van Nijlen, Vanderlinde, & van Braak, 2014; Ertstad, 2013; Frerejean, van Strien, Kirschner, & Brand-Gruwel, 2016; Walraven, Brand-Gruwel, & Boshuizen, 2009). Likewise, technological skills are often described in relation to more general skills that are needed for active participation in current society.

These general skills are also referred to as life-long learning competences or 21st century skills. These are skills related to communication, critical thinking, problem solving, social/cultural awareness and creativity (Voogt & Pareja Roblin, 2012). Although this dissertation specifically focuses on technological skills, frameworks that describe technological skills often do so in the context of these other, more general, life-long learning competences (e.g., DIGCOMP: Ferrari, 2013; ISTE Standards: ISTE, 2016; ICILS: Fraillon et al., 2014; NAP-ICT literacy: ACARA, 2017). In the Netherlands, The Netherlands Institute for Curriculum Development formulated provisional standards for digital literacy in four domains: basic skills, information literacy skills, media literacy skills and computational thinking skills. Currently these standards are being discussed in connection with the re-design of the formal standards for primary and secondary education.

All of these frameworks define each domain separately with its own specific characteristics. However, as is inevitable with generic and complex constructs like technological skills, all domains are connected, as they overlap at some points or include skills that refer to other domains. Likewise, in practice students use the skills described in the separate domains in an integrated way. This makes students' technological skills dependent on the context and content, implicitly situated in the knowledge and attitudes that underlie students' actions in day-to-day situations. An example is reflected in the DIGCOMP framework (Ferrari, 2013). In this framework, technological competence is defined as: *“the confident, critical and creative use of ICT to achieve goals related to work, employability, learning, leisure, inclusion and/or participation in society”* (p. 4), and, accordingly, includes the following five domains for technological competences: information, communication, content creation, safety and problem-solving.

1.3 Assessment in classroom practice

Capturing the elicitation of technological skills should eventually lead to more reliable and valid assessment of these skills as used in educational practices. In educational practice, assessment is often focused on either formative or summative purposes. While summative assessment concerns the assessment of learning outcomes, formative assessment is primarily focused on gaining insights into learning processes that can be used to support further learning (Stobart, 2008).

Formative assessment can be distinguished according to the following three different approaches: data-based decision-making (DBDM), diagnostic testing (DT), and assessment for learning (AfL) (Van der Kleij, Vermeulen, Schildkamp, & Eggen, 2015). DBDM concerns the systematic collection and analysis of data to inform decisions that focus on the improvement of teaching, curricula and

(school) performance (Schildkamp & Kuiper, 2010). DT involves mapping out individual learners' task response patterns to reveal their (possibly inadequate) solution strategies and using this as an indication of each learner's developmental stage (Crisp, 2012). AfL occurs as part of ongoing classroom practices (Klenowski, 2009) and is viewed as a social and contextual event that is focused on the quality of the learning process (Stobart, 2008). Continual feedback is integrated within this process to guide future learning (Elwood & Klenowski, 2002).

Because there is a need for developing the technological skills of both students and teachers, assessments that focus on technological skills should be based on practical and authentic situations and require a personalized approach to assessment that emphasizes the learning process and not so much the eventual performance (cf. Lodge, 2018; Webb & Ifenthaler, 2018). Hence, an appropriate approach to assessment would be AfL (Webb & Ifenthaler, 2018). However, the assessment of complex constructs like technological skills faces different challenges, such as the lack of a clear operationalization, the construct's multidimensional nature and the mismatch with the assessment approaches used in formal education, such as the use of well-structured problems that are hard to transfer to real world situations (cf. Shute & Emihovich, 2018). Hence, implementing the assessment of technological skills has proven to be challenging (cf. Birenbaum et al., 2015)

Although the research has recognized formative assessment as an effective means to support learning, its implementation in practice often fails to achieve the full potential of this approach. To eventually be able to assess (elicit) technological skills in educational contexts, it is necessary to understand the conditions for implementing the assessment of technological skills in classroom practice.

1.4 Outline

The first two studies presented in this dissertation are focused on ways to elicit the technological skills of teachers. These studies were based on the argument that teachers' technological skills are elicited through their enactment of technology-infused pedagogical practices in conjunction with the professional reasoning on which their actions rely. **Chapter 2** describes a study focused on understanding teachers' reasoning about the way they use technology within their pedagogical practice. The study addressed the following research question: How do teachers reason about the use of technology in their pedagogical practice? Both teachers' professional reasoning and their technology use were investigated. One hundred fifty-seven teachers demonstrated their

technology use in practice and commented on the reasoning behind their actions in video cases. Following up on this study, **Chapter 3** presents a study in which we argue that teachers' reasoning about pedagogy elicits their knowledge about how technology can be used effectively to support and enhance student learning. Based on this understanding, we examined teachers' reasoning in relation to the pedagogical choices they make while using technology in practice. The research question for this study was: How and why do teachers use technology to facilitate their enactment of pedagogical strategies in practice? Data from 29 video cases show how primary teachers used technology to facilitate specific pedagogical strategies.

In the third study the elicitation of students' technological skills was examined through a digital assessment environment in which students had to apply their technology skills in authentic tasks. **Chapter 4** describes the development of this practical assessment environment and presents the results of a pilot study. This study was guided by two questions: (1) How do primary education, pre-vocational education and pre-university education students differ in their online information literacy skills? and (2) How do primary education, pre-vocational education and pre-university education students differ in their use of search terms and their online search strategies? A total of 1036 students from upper primary and lower secondary education participated in this study.

The fourth study is described in **Chapter 5**. This study concerns a systematic literature review that is focused on revealing the prerequisites that need to be considered when implementing on-going formative assessment with the potential to support learning in classroom practice. This review was guided by the following research question: What prerequisites regarding the teacher, student, assessment and context need to be considered when implementing assessment for learning in the classroom?

In **Chapter 6** the four studies are discussed in relation to each other and with regard to the contribution they make to the field. Furthermore, limitations and future directions are considered.

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*When you talk you are only repeating what you know, but if you listen you may
learn something new*

– Dalai Lama

Chapter 2

Teachers' professional reasoning about their pedagogical use of technology

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.

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2.1 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 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.

2.1.1 Theoretical underpinnings

2.1.1.1 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).

2.1.1.2 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).

2.1.2 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 sub-questions: *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?*

2.2 Materials and methods

2.2.1 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 to 15 minute 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"). Figure 2.1 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 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.

VIDEO PROTOCOL
Show your technology use in practice including a commentary in which you explain why you use technology this way.	Teacher:	
	Grade	
	Subject	
	Video title
Record a 10-15 minute video	Date	/ /
Video structure <i>The video should include the following three parts:</i>
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		

Figure 2.1. Overview of video protocol (translated from Dutch to English)

2.2.2 Instruments

2.2.2.1 Questionnaire

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 (Kennisset, 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, $\alpha = .78$) and teachers' perceived technological skills (8 items, $\alpha = .88$). 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, Baran, Thompson, Koehler, Mishra, & Shin, 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 ($\alpha = .91$). Table 2.1 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.

Table 2.1. Examples of items used in the questionnaire

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

2.2.2.2 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.

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 analyzed 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 2.2. 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.

Table 2.2. Categories of teachers' professional reasoning about using technology in practice

Item categories	Explanation
1. Added value for learning or teaching (6 items)	<ul style="list-style-type: none"> 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)	<ul style="list-style-type: none"> 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)	<ul style="list-style-type: none"> 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)	<ul style="list-style-type: none"> Reasoning about how technology can support the learning process (e.g., conceptualization, learning strategies, and procedures).
5. Educational goals (1 item)	<ul style="list-style-type: none"> Reasoning about how technology can support the goal of the learning activity.
6. Curriculum (3 items)	<ul style="list-style-type: none"> 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)	<ul style="list-style-type: none"> 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)	<ul style="list-style-type: none"> 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)	<ul style="list-style-type: none"> Reasoning about how technology is used for formative assessment (e.g., to monitor students' progress). Reasoning about how technology is used for summative assessment.

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 Figure 2.2.

Observation Instrument	Researcher: _____	Date _____ / _____ / _____
Learning environment characteristics		Observed?
		Practice Technology
Class organization		
Individual/independent		☐ ☐
Whole class instruction		☐ ☐
Small groups (collaborative learning)		☐ ☐
Student role		
Investigator (students experiment/research)		☐ ☐
Reviewer/evaluator (students evaluate own work or work of peers)		☐ ☐
Executer (students perform a given task)		☐ ☐
Listener (students listen to instruction)		☐ ☐
Creator/constructor (students produce their own product(s), are creative)		☐ ☐

Figure 2.2. 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 2.3 shows an overview of all variables, linked to the instruments and purpose.

Table 2.3. 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’)

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 = .68), which is substantial (Landis & Koch, 1977).

2.2.3 Data analysis

2.2.3.1 Questionnaire

Descriptive statistics were used to analyze 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 .52 and .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%, $F_1 = 37.7\%$; $F_2 = 16.2\%$). Factor analysis on the TPACK-core items suggested a one-dimensional structure (66.1% common variance) with factor loadings between .70 and .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 (Kennisset, 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.

2.2.3.2 Observation instrument

The two parts of the instrument (professional reasoning and use of technology in pedagogical practice) were first analyzed 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 analyze 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 2.2)

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 analyzed 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.

2.2.4 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 2.4).

Table 2.4. Overview of subjects taught

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

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 ($M = 3.1$; $SD = 0.57$; 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.

2.3 Results

2.3.1 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 2.5 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.

Table 2.5. Reasoning about the added value of technology use in education

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

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 2.6). 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.

Table 2.6. Reasoning about TPACK

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

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: *“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 visualize different characters and make it easier for students to understand”*.

Table 2.7 presents the results for professional reasoning that emerged from the data, organized according to the categories presented in Table 2.2. 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 ($M = 2.32$, $SD = 1.19$; $t(155) = 2.98$, $p = .003$).

Table 2.7. 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%

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."*

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"*.

2.3.2 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.

2.3.2.1 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 2.8). 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 2.8. 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 practicing 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 2.9 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.

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%

 

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 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.

2.3.2.2 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 2.10).

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).

Table 2.10. 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%

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.

2.3.3 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.

2.4 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.

2.4.1 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, 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, 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 than 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; Web & 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.

2.4.2 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).

2.4.3 Implications for practice and further research

To our knowledge this study is new in 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 technology 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 et al., 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

Teachers' educational beliefs, perceived technological expertise, and TPACK Core (translated from Dutch)

Educational beliefs (adapted from Van Gennip & Van Rens, 2011)

<i>Please indicate how often you do the following...</i>	Never/ hardly	Sometimes	Fairly often	Often	Very
1. I ask questions during class about the subject matter.	☐	☐	☐	☐	☐
2. In my teaching, students carry out assignments that match their interests.	☐	☐	☐	☐	☐
3. I summarize the subject matter during my lesson.	☐	☐	☐	☐	☐
4. Students are free to choose their learning content.	☐	☐	☐	☐	☐
5. I check if students master the subject matter.	☐	☐	☐	☐	☐
6. I take students' processes and approaches into consideration when assessing students' work.	☐	☐	☐	☐	☐
7. When I start a new subject I explain general and tricky points in advance.	☐	☐	☐	☐	☐
8. I stimulate students to set their own goals.	☐	☐	☐	☐	☐
9. I give students assignments to practice with the subject matter.	☐	☐	☐	☐	☐
10. I stimulate peer feedback.	☐	☐	☐	☐	☐

Perceived technological expertise (adapted from Kennisnet, 2012)

<i>Please indicate how skilled you are in...</i>	Not at all	Basic	Advanced	Very advanced
1. Using a computer as pedagogical tool	☐	☐	☐	☐
2. Using digital learning materials	☐	☐	☐	☐
3. Assessing the usefulness of digital learning materials	☐	☐	☐	☐
4. Using a learning management system	☐	☐	☐	☐
5. Using a digital student monitoring system	☐	☐	☐	☐
6. Adapting digital lesson materials from the internet for appropriate use in my lessons	☐	☐	☐	☐
7. Communicating with students using technology	☐	☐	☐	☐
8. To what extent are you up to date of computer applications that can be used in your education?				
☐ Poorly				
☐ Moderate				
☐ Sufficiently				
☐ Good				
☐ Excellent				

TPACK core (adapted from Schmidt et al., 2009)					
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
1. I know about technologies that I can use for understanding and doing in teaching my subject.	☐	☐	☐	☐	☐
2. I can choose technologies that enhance the content for a lesson in my subject.	☐	☐	☐	☐	☐
3. I know how to use technologies to present concepts of the subject I am teaching, in a different way.	☐	☐	☐	☐	☐
4. I can choose technologies that enhance the pedagogy of a lesson.	☐	☐	☐	☐	☐
5. I can choose technologies that enhance students' learning process.	☐	☐	☐	☐	☐
6. I am thinking critically about how to use technology in my class.	☐	☐	☐	☐	☐
7. I can teach lessons that appropriately combine content, technology and pedagogy.	☐	☐	☐	☐	☐
8. I can select technologies for my class that enhance what I teach, how I teach and what students learn.	☐	☐	☐	☐	☐

Appendix B

Observation Instrument Teachers’ Technology Use and Reasoning (translated from Dutch)	
Researcher:	Date / /
Video information	
Video number	
Video title	
Educational level	
Subject domain	
	1. ..
	2. ..
Technology application(s)	3. ..
	4. ..
	5. ..
PROFESSIONAL REASONING	
	Observed
Reasoning about the added value for learning or teaching	
Technology makes learning more attractive	☐
Technology makes learning more efficient	☐
Technology makes learning more effective	☐
Technology makes teaching more attractive	☐
Technology makes teaching more efficient	☐
Technology makes teaching more effective	☐
Reasoning about the coherence between content, pedagogy and technology	
Subject only	☐
Pedagogy only	☐
Technology only	☐
Subject and pedagogy	☐
Subject and technology	☐
Pedagogy and technology; subject, pedagogy and technology	☐
Subject, pedagogy and technology	☐

Reasoning about technology and students	
Technology contributes to learning for students from groups with particular characteristics	☐
Technology contributes to learning for students with individual needs	☐
Reasoning about technology and students' learning processes	
Reasoning about how technology can support the learning process	☐
Reasoning about technology and educational goals	
Reasoning about how technology can support the goal of the learning activity	☐
Reasoning about technology and the curriculum	
Technology is used to enrich or supplement the existing curriculum	☐
Technology is the curriculum goal	☐
Technology contributes to curriculum flexibility	☐
Reasoning about technology and instruction	
Technology is used for instructional techniques and representations regarding the chosen subject	☐
Technology is used to teach students (practical) skills and/or provide practical experience.	☐
Reasoning about technology and interaction	
Technology mediates teacher-student interaction	☐
Technology mediates student-student interaction	☐
Reasoning about technology and student progress	
Technology is used for formative assessment	☐
Technology is used for summative assessment.	☐

TECHNOLOGY USE IN PRACTICE	
<i>Learning environment characteristics</i>	
Role of technology	Observed
Information processing tool	☐
Instruction tool	☐
Drill and practice tool	☐
Information source	☐
Presentation tool	☐
Evaluation tool	☐
Communication tool	☐
Learning process support	☐
Simulation	☐
Collaboration support	☐
Other	☐
	Observed
	Practice Technology
Curriculum characteristics	
Authentic lesson	☐ ☐
Problem solving	☐ ☐
Drill and practice	☐ ☐
Metacognitive strategies	☐ ☐
Inquiry learning	☐ ☐
Class organization	
Individual	☐ ☐
Whole classroom teaching	☐ ☐
Small groups (collaborative learning)	☐ ☐
Teacher role	
Training of knowledge or skills	☐ ☐
Transferring knowledge	☐ ☐
Guiding, stimulating and advising	☐ ☐
Monitoring	☐ ☐

Student role		
Investigator	☐	☐
Reviewer/evaluator	☐	☐
Executer	☐	☐
Listener	☐	☐
Creator/constructor	☐	☐
Control of the learning activity		
Learning activity controlled by student	☐	☐
Pacing controlled by student	☐	☐
Learning activity controlled by teacher/agent	☐	☐
Pacing controlled by teacher/agent	☐	☐
Assessment and feedback		
Formative assessment	☐	☐
Summative assessment	☐	☐
Direct feedback on correctness	☐	☐
Elaborated feedback	☐	☐
Technology fit		
Coherence of technology, pedagogy and/or content	Observed	
Technological application strengthens pedagogy	☐	
Technological application strengthens subject matter	☐	
Technological application strengthens pedagogy and subject matter	☐	
No coherence	☐	
Technological dependence		
Non-essential technology component	☐	
Supporting technology component	☐	
Essential technology component	☐	

Chapter 3

Eliciting teachers' Technological Pedagogical Knowledge

This study 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 technology 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 technology to facilitate specific pedagogical strategies (e.g., activating learning, classroom management, dealing with diversity, fostering learning strategies). Findings indicate that teachers used technology mostly to promote activation of learning. Many teachers reasoned about using technology for adapting their teaching to student needs, but this was seldom observed in practice. The few teachers who showed behavior supporting adaptive teaching and fostering learning strategies almost always used technology to facilitate these pedagogical strategies. We argue that for effective teaching with technology it is important that teachers learn to reason explicitly about how technology 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.

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3.1 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 technology depends on how teachers use technology when teaching students with different interests and capabilities (Heitink, Voogt, Verplanken, van Braak & Fisser, 2016; European Commission, 2013; Mishra & Koehler, 2006; Webb & Cox, 2004).

How teachers use technology in practice is determined by their knowledge of the affordances of technology 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 technology, it is necessary to elicit teachers' professional reasoning that is focused on using technology in practice (Heitink, Voogt, Verplanken, van Braak & Fisser, 2016; Voogt, Fisser, Tondeur & van Braak, 2016). Technological Pedagogical Content Knowledge (TPACK) is a framework that describes knowledge teachers need to use technology 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 technology 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 technology 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 technology 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 technology 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 technology use in practice has not been studied much, and results are still very general (Heitink, Voogt, Verplanken, van Braak & Fisser, 2016). This research will go into more detail regarding teachers' professional reasoning in relation to the pedagogical choices teachers make while using technology in practice. Not only do the results from this study provide insight into the professional reasoning teachers rely on when using technology 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' technology use is effective and identify knowledge gaps and misconceptions.

3.1.1 Theoretical underpinnings

Several studies have shown that teachers support their pedagogical strategies by integrating technology 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 technology 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 technology uses (Yeh et al., 2017). This means teachers used their professional reasoning ability to inform their technology use in practice as a way to develop their TPACK. Moreover, the study by Hakkarainen et al. (2001) suggested that how teachers use technology in practice depends on their pedagogical thinking. This implies that in order to use technology 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; Meijer, Verloop, & Beijaard, 1999; Koh, Chai, & Tay, 2014; Voogt, Fisser, Tondeur & van Braak, 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 technology 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 technology use, not the technology 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 technology 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 realizing specific learning goals (Heitink, Voogt, Verplanken, van Braak & Fisser, 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 technology are, for example, technology 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; Van de Grift, 2013; Van de Grift, 2014; Van de Grift et al., 2011):

1. 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.

2. Efficient classroom management concerns efficient use of allocated lesson time. Effective teachers spend their time on instructional activities that lead to orderly lessons and organized classrooms with few behavior problems with students.
3. 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.
4. 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.
5. Adaptive teaching is focused on tailored instruction. The teacher adapts instruction, learning goals and lesson materials to individual students or student groups.
6. 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, Helms-Lorenz, & Maulana, 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 technology to teachers' pedagogical strategies, including student involvement in their learning as a necessary condition for effective teaching.

3.1.2 Research questions

In this study, we argue that using technology to support pedagogical strategies in teaching is based on teachers' technological pedagogical knowledge about teaching and learning with technology. To develop insights into teachers' technological pedagogical knowledge, it is

necessary to elicit teachers' professional reasoning that is focused on using technology for pedagogical strategies in conjunction with the enactment of these pedagogical strategies. Therefore, this study focused on the following research questions: *How and why do teachers use technology to facilitate their enactment of pedagogical strategies in practice?*

1. *How do teachers use technology to facilitate the enactment of pedagogical strategies?*
2. *How do teachers reason about using technology to facilitate the enactment of pedagogical strategies?*

3.2 Materials and methods

3.2.1 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 10-15 minute video clip about their use of technology and their reasons for using technology 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 technology and the need to professionalize their use of technology. 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, van Braak, Heitink, Verplanken, Fisser & Walraven, 2014). Thus, the teachers in our sample are more positive and confident regarding the use of technology in education and see more need for professionalization in the use of technology 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 analyzed (Heitink, Voogt, Verplanken, van Braak & Fisser, 2016). The following selection criteria were applied: (1) the video shows the integration of technology 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.

3.2.2 Instruments

The observation instrument used to identify the contribution of technology to teachers' pedagogical strategies was based on the instrument for assessing teaching acts (Van de Grift et al., 2011). Figure 3.1 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 technology was used for this pedagogical strategy (ICT) and whether the teacher reasoned about the use of technology 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 3.1. Part of the observation instrument. P indicates the teacher showed this pedagogical strategy in practice, ICT indicates technology was used for this pedagogical strategy and R indicates whether the teacher reasoned about the use of technology in this pedagogical strategy.

3.2.3 Data analysis

The data collected through the observation instrument were analyzed 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 technology 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 technology 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, ten 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).

3.2.4 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 technology was often presented in different subject domains (see Table 3.1). However, in a number of the video cases learning about technology was the dominant focus of the lesson. Therefore, we also distinguished technology 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 technology as a separate subject domain.

Table 3.1. Overview of subject domains presented in the video cases

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

3.3 Results

3.3.1 General results

Figure 3.2 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 technology in those pedagogical strategies or to promote student involvement and the extent to which teachers reasoned professionally about their technology 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 technology to support their teaching was shown in diverse ways. Technology 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 technology was focused on supporting adaptive teaching, followed by efficient classroom management. In the subsequent sections we further elaborate on these general findings.

Figure 3.2. Mean number of video clips rated as including indicators for pedagogical strategies (P), the use of technology to support these pedagogical strategies (ICT) and the extent to which teachers reasoned professionally about their technology use (R) (n=29).

3.3.2 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 3.2. Technology was used to foster student involvement in relatively few video clips. Teachers also rarely reasoned about the use of technology for this purpose. An illustration of the use of technology 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 technology 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 3.2. Student involvement. Number of video clips that showed students were involved in their learning (P), the use of technology to foster student involvement (ICT) and teachers' reasoning about technology 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

3.3.3 Safe learning climate

Table 3.3 presents the results on the pedagogical strategy of providing a safe learning climate. As can be seen, teachers frequently showed teaching behavior that contributes to a safe learning climate (average number of clips = 12.75), however, they did not tend to use technology for this pedagogical strategy, and rarely reasoned about the use of technology 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 technology 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 3.3. Safe learning climate. Number of video clips that showed this specific teacher behavior in their practice (P), their use of technology in this practice (ICT) and their reasoning about technology use in this practice (R)

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

3.3.4 Classroom management

The results for the pedagogical strategy of classroom management are given in Table 3.4. The results show that teachers displayed a lot of teaching behavior to manage their classroom (average number of clips = 10). They did not often use technology for promoting classroom management. An exception is the behavior “uses learning time efficiently”. Several teachers showed how they incorporate technology to use learning time in an efficient way, and even more teachers reasoned about using technology for this purpose, but did not show it in their practice. Teachers’ reasoning about the potential of technology 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 technology 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 technology in this practice: *“Since this class consists of two grades, they both need different instruction. By using technology 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 3.4. Classroom management. Number of video clips that showed this specific teacher behavior in their practice (P), their use of technology in this practice (ICT) and their reasoning about technology 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

3.3.5 Clear instruction

An overview of the number of clips concerning the pedagogical strategy of clear instruction is presented in Table 3.5. Teachers in our sample used teaching behavior to provide clear instruction relatively often (average number of clips = 8.75). They tended to use technology relatively often for involving students in their lessons and for providing feedback to students, but not much for the other aspects of teaching behavior that contribute to providing clear instruction. Teachers

reasoned more about the use of technology for providing feedback than they showed it in their practice. A teacher who used technology 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 technology 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 3.5. Clear instruction. Number of video clips that showed this specific teacher behavior in their practice (P), their use of technology in this practice (ICT) and their reasoning about technology 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

3.3.6 Activating learning

An overview of the number of clips on the pedagogical strategy of activating learning is presented in Table 3.6. Teaching behavior 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). Technology was used to support activation of student learning and in providing interactive instruction. Teachers also reasoned about the value of using technology in supporting these practices, although less than would be expected. An example of such uses of technology 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 technology 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 3.6. Activating learning. Number of video clips that showed specific teacher behavior in their practice (P), their use of technology in this practice (ICT) and their reasoning about technology 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

3.3.7 Adaptive teaching

The number of clips on the pedagogical strategy adaptive teaching are shown in Table 3.7. We observed teaching behavior that contributed to adaptive teaching in relatively few video clips (average number of clips = 4.50). However, when a teacher showed this behavior in the specific practice presented in the video clip, they almost always used technology. But, we also observed that a number of teachers reasoned about the use of technology in the video clips for adapting teaching to different student needs, without really showing this use of technology in this specific practice. The following example presents a teacher who used technology for realizing adaptive teaching. He used technology 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 technology in this way: *"I showed that a student with heavy dyslexia could use technology 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 technology 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 3.7. Adaptive teaching. Number of video clips that showed this specific teacher behavior in their practice (P), their use of technology in this practice (ICT) and their reasoning about technology 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

3.3.8 Teaching learning strategies

Table 3.8 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 behavior 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 technology to support specific teaching behaviors. An example from a kindergarten teacher illustrates how technology 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 technology 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. Technology also makes it easier for the students to look at their intermediate products and think about how they can improve the story”*.

Table 3.8. Teaching learning strategies. Number of video clips that showed this specific teacher behavior in their practice (P), their use of technology in this practice (ICT) and their reasoning about technology 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

3.4 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 technology to foster effective teaching, which we operationalized 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 technology to support effective teaching. We argued that eliciting teachers' reasoning about their use of technology to realize effective teaching in a specific practice shows teachers' Technological Pedagogical Knowledge (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' technology use is effective and identify knowledge gaps and misconceptions about their use of technology. These insights enable targeted interventions focused on preparing teachers for integrating technology 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 technology (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 technology use supporting all of the pedagogical strategies, as well as student involvement, but by far the highest level of technology 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 technology to facilitate these pedagogical strategies. Furthermore, we need to realize

that some pedagogical strategies might not be as suitable for technology 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 technology 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 technology 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 technology 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 technology for fostering these pedagogical strategies, but do not yet feel comfortable in using technology for these purposes. The latter is a concern, as the teachers in our study are more positive and confident about using technology 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.

3.4.1 Implications for teacher education programs

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

Based on a literature review, Tondeur, van Braak, Sang, Voogt, Fisser & Ottenbreit-Leftwich (2012) presented a model for effective preparation of pre-service teachers for technology integration. In this model, critical factors that needed to be considered in the constructive and iterative process of teaching teachers to use technology 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 technology, which we used in this study, can support teachers in learning how to 'operationalize' TPACK in their practice (Ertmer & Ottenbreit-Leftwich, 2010; Hofer & Harris, 2015; Tondeur, van Braak, Sang, Voogt, Fisser & Ottenbreit-Leftwich, 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 technology for specific pedagogical strategies and why. The video clips present teachers' concerns about a specific problem, and the teachers explain how technology helps them to solve this problem. Based on the findings from this study, we argue that examples of teaching with technology should present a variety of uses of technology 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 technology 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 technology 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 technology 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 technology 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 technology, 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 technology, teachers' reasoning about how the use of technology 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 technology use to support effective teaching behavior 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 realize 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 technology can support them. Only then can next steps be taken. Video clips such as the ones analyzed for this study serve as a powerful tool to further develop teachers' TPK.

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My life feels like a test I didn't study for.

- Anonymous author

Chapter 4

Authentic assessment of students' online information literacy skills

Measurement of online information literacy skills is still limited, and often done through indirect and inauthentic measures. This study's focus is based on the argument that assessment of students' online information literacy skills should involve eliciting students' skills through authentic assessment tasks. An authentic digital assessment environment for eliciting students' online information literacy skills was designed and developed. Both students' responses to the assessment tasks and their search behavior (use of search terms and search strategies) were investigated. A total of 1036 students from upper primary and lower secondary education participated in this study. Results addressed students' performance in collecting, evaluating, processing and presenting digital information. Most students searched for information predominantly with a whole sentence or question instead of using keywords, and often used ineffective search strategies. The results of this study suggest that visualization and interpretation of online information literacy skills are important to foster the development of such skills and to prevent a possible digital divide between students from different educational levels.

4.1 Introduction

Many daily activities at home, at school and at work require the use of Information and Communication Technologies (ICT) and assume the presence of skills that are necessary to be able to participate in today's society (Fraillon et al., 2014; Kozma, 2008). Although researchers acknowledge the power of technology in teaching and learning, the skills that are needed to use technology appropriately are often not adequately addressed in education (Kennisset, 2015; Kozma, 2008; Voogt & Pareja Roblin, 2012). Moreover, several studies have shown that the appropriate use of technology is not obvious, with much room for improvement in students' technological skills (e.g., Aesaert & van Braak, 2015; Fraillon et al., 2014; van Deursen & van Diepen, 2013). Hence, many researchers have emphasized the importance of the development of these skills (e.g., Frerejean, van Strien, Kirschner, & Brand-Gruwel, 2016; Van Deursen & van Diepen, 2013), and in many countries formal expectations and standards regarding technology-related skills for students are now formulated in the curricula (Aesaert & van Braak, 2018; Thomas & Knezek, 2008).

Being able to engage with digital information is key for active participation in our current society. Not only are the production and consumption of digital information high, but digital information is also often unstructured and requires students to be able to solve information-based problems independently. Much of this type of digital information is accessed through the Internet. In this chapter, technology-related skills that are specifically associated with solving information-based problems while using the Internet are referred to as online information literacy skills. Even though not using digital information from the Internet is almost unthinkable nowadays, research regarding online information literacy has shown that many students still have trouble with, for example, defining appropriate search terms, evaluating the search results or defining the information problem (Brand-Gruwel & Gerjets, 2008; Brand-Gruwel, Wopereis, & Vermetten, 2005; van Deursen & van Diepen, 2013). To prepare students for active participation in current society, their education needs to include focused instruction on the learning of online information literacy skills (Frerejean et al., 2016; Van Deursen & van Diepen, 2013; Walraven, Brand-Gruwel, & Boshuizen, 2009).

For effective instruction that is focused on the improvement of students' online information literacy skills, measuring or mapping of these skills is necessary. Assessment of students' online information literacy skills can provide insight into the extent to which students possess such skills, which in turn can serve as a foundation for teachers and policymakers to make informed decisions about using technology in education. However, research into the actual online information literacy

skills of students is still limited (cf. Aesaert & van Braak, 2018; Christensen & Knezek, 2018). Existing assessment instruments often try to elicit an evaluation of online information literacy skills through self-perception surveys. Eliciting an evaluation of skills through self-perceptions often results in a biased representation of students' skills, as the accuracy of these measures depends on the extent to which students are capable of assessing their own skills (Aesaert, Voogt, Kuiper, & van Braak, 2017; Siddiq, Hatlevik, Olsen, Throndsen, & Scherer, 2016). Much research has shown that there are often large differences between students' self-reported skills and their actual skills (e.g., Allayar, 2011; Hakkarainen et al., 2000; Meritt, Smith, & Renzo, 2005; Siddiq et al., 2016). The study by Aesaert, Voogt, Kuiper, and van Braak (2017) showed that on average, (primary school) students tend to over-estimate their online information literacy skills and that students with better-developed technological skills make more accurate judgements about their own skills than less skilled students. Another way in which online information literacy skills are assessed is through traditional paper and pencil tests. These tests also often cause validity problem through their lack of authenticity, as it can be confusing to measure online information literacy through queries on paper (e.g., searching for information on the Internet, opening a website). Measuring the actual skills students need in online information literacy thus requires a different approach.

Therefore, the focus of this study is on the assessment of students' online information literacy skills, through development of an assessment instrument in which students' actual skills are elicited through the application of these skills in authentic tasks.

4.1.1 Online information literacy skills for students

Frameworks that describe online information literacy skills use online information literacy as a sub-domain of digital literacy. Digital literacy is defined as 'an individual's ability to use computers to investigate, create, and communicate in order to participate effectively at home, at school, in the workplace, and in society' (Fraillon et al., 2014, p. 17; see also European Commission, 2007; Meelissen, Punter, & Drent, 2014). Many researchers have emphasized that digital literacy is more than being able to operate a technological device. Digital literacy (and its sub-domains) is a complex skill, based on the integration of (meta)cognitive skills and technological skills (e.g., Aesaert, van Nijlen, Vanderlinde, & van Braak, 2014; Frerejean et al., 2016; Walraven et al., 2008). Additionally, more and more researchers have stressed the importance of students' self-reliance in digital environments and being able to adapt to the quickly changing digital world (Passey et al., 2018). Hence, digital literacy is often described in relation to more general skills that are needed for active participation in current society. Thus, online information literacy skills concern not only the

skills needed to solve information problems using the Internet, but also general skills such as those related to communication, critical thinking, problem solving, social/cultural awareness, creativity and basic technology skills (Voogt & Pareja Roblin, 2012).

Brand-Gruwel, Wopereis, and Walraven (2009) described a framework for the knowledge, skills and attitudes students need in solving information problems online (IPS-I; information problem solving (IPS) in which the Internet (I) is used to search information). This framework describes a process that concerns the following phases: problem definition, searching for information, selecting information, processing information, and presenting information. Similar frameworks are: DIGCOMP (Ferrari, 2013), ICILS (Fraillon et al., 2014), iSkills (ETS, 2001), ISTE Standards (ISTE, 2016) and NAP-ICT literacy (ACARA, 2017). Although these frameworks use different categories to describe the underlying skills needed in online information literacy, all seem to have the following underlying skill domains in common: collecting, evaluating, processing and presenting digital information.

Collecting digital information concerns the process of searching for and selecting digital information for a certain purpose. This is a process in which first the information-related problem is formulated and information requirements are identified. Next, a search strategy is selected and applied to search for information and, if necessary, search actions are adjusted. Finally, the presented information is scanned and relevant information is selected and collected (ACARA, 2017; Brand-Gruwel et al., 2009; ETS, 2001; Ferrari, 2013; Fraillon et al., 2014; ISTE, 2016). This process needs to be applied in a dynamic, often-changing search context in which information is stored in different media representations (e.g., texts, figures, videos, etc.). Collecting digital information also pre-supposes skills such as being able to navigate between online sources, reading non-linear texts (texts including links to other sources) and understanding how search engines work (Ferrari, 2013; Fraillon et al., 2014). ETS (2001) and ACARA (2017) also mentioned the knowledge needed to know how to collect and retrieve digital information. Collecting information online seems like an easy task, but several studies have found that students have difficulties defining the information problem and defining proper search queries to obtain a useful result (Aesaert & van Braak, 2015; van Deursen & van Diepen, 2013; Kuiper, Volman, & Terwel, 2005). Not many recent studies have focused on student online search behavior, defined as the search terms and search strategies they use to find online information (cf. Hargittai, 2002; Wang, Liu, Mandal, & Shah, 2017), although this is the main process on which everything else in online information literacy is based.

Evaluating digital information concerns being able to critically estimate the value of online information. As anyone can put information on the Internet, being able to evaluate the reliability of online information has importance for online information literacy (e.g., Walraven, Brand-Gruwel, & Boshuizen, 2009). Many frameworks describe skills that concern the evaluation of online information as involving being able to recognize characteristics that relate to the reliability of online information and applying strategies to assess validity and credibility (ACARA, 2017; ETS, 2001; Ferrari, 2013; Fraillon et al., 2014; ISTE, 2016). Examples of strategies for checking the validity and credibility of online information are examining author characteristics, considering topicality, cross-checking that information agrees with other websites, the source's reputation and website appearance (Ferrari, 2013; Walraven et al., 2009).

Processing digital information, also referred to as managing digital information, concerns skills that are related to arranging or ordering digital information from different sources in such a way that a deep understanding of the information is reached and that it can be used (in combination) for a certain purpose (ACARA, 2017; Brand-Gruwel et al., 2009; ETS, 2001; Fraillon et al., 2014; ISTE, 2016). Processing digital information also involves being able to structure the information in such a way that it can be interpreted, using strategies such as classifying, summarizing, comparing and contrasting (ACARA, 2017; Brand-Gruwel et al., 2009; ETS, 2001). Fraillon et al. (2014) also mentioned the ability to recognize the most efficient way to structure collected data for a given purpose.

Presenting digital information concerns using digital information to develop new ideas, theories or understandings (ACARA, 2017; Brand-Gruwel et al., 2009; Ferrari, 2013; Fraillon et al., 2014; ISTE, 2016). This involves combining information from several relevant sources to make meaningful connections or draw conclusions, and modifying or creating digital content in which the information is clearly presented for specific audiences and purposes. Fraillon et al. (2014) also mentioned the ability to use applications and tools to create digital content, such as digital presentations, figures, tables, videos, and so forth.

These online information literacy skills are underpinned by basic technological skills, such as being able to operate a technological device, and knowledge about the technology's functions, possibilities and limitations (Fraillon et al., 2014). Along with this, students' online information literacy skills depend on student factors and contextual factors (Aesaert et al., 2015). Contextual factors are, for example, accessibility of technology at school and at home and the school's technological infrastructure (Ferrari, 2013; Fraillon et al., 2014). Student factors that influence

information literacy skills are, for example, reading comprehension (Leu, Kinzer, Coiro, Castek, & Henry, 2013), students' attitudes and beliefs concerning the use of technology, students' socio-economic backgrounds and their level of education. Of these student factors, van Deursen and van Diepen (2013) found that level of education was the main contributor to students' Internet skills.

4.1.2 Assessment of online information literacy skills

Not many studies have used assessment methods that measure students' actual information literacy skills in a direct way. Some studies have used observational methods to obtain direct measures of a complex skill such as online information literacy by observing respondents while solving an information problem online. Hargittai et al. (2002) used observation to measure adults' ability in retrieving online information, and Walraven, Brand-Gruwel, and Boshuizen (2009) used think-aloud protocols for investigating the criteria secondary educational students use while searching the Internet for information. However, the observational methods are usually very labor-intensive and difficult to replicate, making them unsuitable for assessing large, representative, samples.

For large-scale data gathering, an appropriate approach to directly assess online information literacy skills would be a performance-based assessment in which students are required to demonstrate mastery by applying their skills in authentic settings. Such performance-based direct measures can provide opportunities to collect different types of data (e.g., direct answers to questions, process data) and enable interaction between the respondent and the assessment system (Ainley, 2018). Performing these tasks on a computer would be a better alternative than answering questions about computers on paper (cf. Aesaert et al., 2014; Ainley et al., 2016; Van Deursen & Van Dijk, 2016).

A well-known computer-based assessment that assesses the online information literacy skills of secondary education students through performance tasks has been used in the International Computer and Information Literacy Study (ICILS; Fraillon et al., 2014). Another international computer-based assessment for secondary and higher education students in which students had to apply their skills was iSkills (ETS, 2001). The Programme for the International Assessment of Adult Competencies (PIAAC) developed an international assessment in which a section about 'problem solving in a technology-rich environments' was incorporated to measure the digital skills of adults (OECD, 2016). Although these international assessments are suitable for large-scale data gathering, limitations are that the assessment tasks do not necessarily have a good match with country-specific characteristics (e.g., the curriculum), resulting in a lack of authenticity.

Aesaert et al. (2014) developed a performance-based assessment for measuring the digital information processing and communication skills of Belgian primary education students. Items were focused on both higher-order competences and technical skills that were needed in assessment tasks that required retrieval and processing of digital information, as well as communication using a computer. Van Deursen and van Diepen (2013) developed an assessment to measure the Internet skills of 54 Dutch secondary students by recording their screen actions during assignments in which they were asked to look up specific information online.

The assessments discussed above were low-stakes tests, meaning that the results gave insight into the respondents' digital skills but did not have any consequences for the respondent. An advantage of low-stakes testing is that most respondents do not experience any test-related stress, but the downside is that the validity of these assessments might be threatened by low motivation to perform well (Pintrich & De Groot, 1990; Wise & DeMars, 2005; Wolf & Smith, 1995). To keep respondents' motivation at a satisfactory level, it is important that the respondents perceive the tasks as authentic, attractive and challenging. Additionally, usability, fairness and appreciation of the assessment have an important influence on measuring the authentic actions of respondents in a valid way (Campion & Miller, 2006; Zieky, 2006).

4.1.3 Research questions

This study's focus is based on the argument that assessment of students' online information literacy skills concerns assessing students' actions through authentic assessment tasks. Both students' responses to the assessment tasks and their search behavior (use of search terms and search strategies) were investigated. Since level of education has major influence on students' online information literacy skills (van Deursen & van Diepen, 2013), students' educational level was taken into account in this study. This study was guided by two questions: (1) How do primary education, pre-vocational education and pre-university education students differ in their online information literacy skills? and (2) How do primary education, pre-vocational education and pre-university education students differ in their use of search terms and their online search strategies? To study these questions, an authentic digital assessment environment for eliciting students' online information literacy skills was designed and developed. The design and development of this environment are described first.

4.2 The design and development of the digital assessment environment

To measure online information literacy skills, a digital assessment environment was designed and developed in which students had to apply their online information literacy skills in authentic assessment tasks. This section describes the design and development of the digital assessment environment. Before describing the design and development process, first the assessment environment will be described to give a picture of what it looked like as a test-taker.

4.2.1 The digital assessment environment

The assessment started with an introduction video. In this video, actors playing students asked the test-taker for help with building a website about Bolivia, as they had to do this for a school assignment. The assignment should be finished soon, but they were having trouble with finding the right information. The digital assessment environment, which became accessible for the test-taker after the video, encompassed an offline simulated Internet environment in which to search for information, a chat, and a tool that the test-taker could use to build the website (all accessible through an application tool bar). All these applications were in Dutch. Figure 4.1 shows three screen-captures of the digital environment.

Figure 4.1 Digital assessment environment interface (top) and tool that students could use to build a website (middle and bottom). The chat is shown in the lower right corner of every screenshot. “Zoeken” means searching in Dutch.

The Internet environment was a closed and offline environment consisting of 400 webpages in which the test-taker could search for information that was needed to complete the assessment tasks. *The chat* was used to administer the assessment tasks to the test-taker through a plausible narrative, communicated by the actor-students. The test-taker could answer questions from the actor-students in the chat and could ask the actor-students for hints if he or she was not able to

finish the task. The *website* tool was used to help the test-taker to build the website. The website was already partially built (purportedly by the actor-students), so the test-taker only had to finish the uncompleted parts of the site. Every assessment task concerned a theme related to Bolivia (e.g., currency, climate) and an unfinished subpage for the entire website had been created for every theme. The test-taker was able to edit these subpages by using tools that were needed for completing specific assessment tasks (e.g., editing a table about the number of people living in Bolivia's five largest cities).

The assessment included 12 tasks that led to building the website about Bolivia. Items varied in type, length and difficulty. Examples are assessment tasks in which the test-taker only had to search for factual information in order to help the actor-students put the right information on the website (e.g., What is the capital of Bolivia?) or tasks in which test-takers had to combine information from different sources to be able to write a text for the website (e.g., Why is Bolivia called a developing country?).

4.2.2 Design and development

4.2.2.1 The design and development process

The design and development process was derived from a framework for designing and developing multimedia-based performance assessments (De Klerk, Eggen, & Veldkamp, 2015) and a four-step procedure for designing ability tests (Roid, 2006). The design of the digital environment consisted of the following stages: (1) defining assessment criteria, (2) conceptualization and operationalization of online information literacy, (3) design of authentic assessment tasks and the assessment environment, (4) determining assessment output and scoring, (5) small pilot, (6) development of final prototype. The development of the environment was carried out simultaneously with the design. This means that the *software developer* was involved from the beginning, in order to have the opportunity to review parts of the assessment environment (with their expected functionalities) and the design of the corresponding database in their early stages and to make sure the developed ideas were feasible. Furthermore, reviews by experts and revisions were carried out after each stage in order to foster the validity and practicality of the assessment, resulting in changes to the assessment environment throughout the process.

4.2.2.2 Criteria for the design of the digital assessment environment

The digital assessment environment had to meet the following criteria, which were based on both the literature described in the framework above and practical considerations:

- (a) Direct measurement of skills, in order to measure practical performance rather than an interpretation of skills. This was done by creating an environment in which students were required to apply their online information literacy skills in authentic tasks.
- (b) Authentic tasks and environment, in which the skills that must be demonstrated are relevant for the target audience and for the curriculum in which the assessment is being used.
- (c) Motivational aspects, in order to minimize the risk that students do not finish the assessment or are not motivated to do their best because of low motivation due to the low-stakes nature of the assessment.
- (d) Safety. The environment should be safe for the target audience to use.
- (e) Easy to use. The target audience should not be hindered by usability aspects, as this results in lack in motivation and validity.
- (f) Fairness. The design and administration of the assessment environment should be the same for every test-taker. This includes treating test-takers with respect, minimizing construct-irrelevant skills, avoiding unnecessary materials and balanced multicultural and gender representations (Zieky, 2006).

4.2.3 The actual design process

4.2.3.1 Conceptualization and operationalization of online information literacy

For the development of the digital environment and the assessment tasks, online information literacy and its four subdomains were clearly defined and operationalized by comparing the well-known frameworks for online information literacy that were discussed above (IPS-I - Brand-Gruwel et al., 2009; DIGCOMP - Ferrari, 2013; ICILS - Fraillon et al., 2014; iSkills - ETS, no date; ISTE Standards - ISTE, 2016; NAP-ICT literacy - ACARA, 2017). The content expert and teacher educators reviewed the conceptualization and operationalization of online information literacy and provided feedback. This resulted in the following operationalization of the four skill domains (see Table 4.1).

Table 4.1. Operationalization of skill domains for online information literacy

Skill domains	Operationalization
<i>Collecting digital information</i>	<i>Identifying, searching for, collecting and selecting digital information</i> The student can identify what information is needed for answering the search-related question. The student can formulate relevant search terms. The student can, if necessary, adjust a search query to limit the results to a specific information need. The student can apply the filters and options of search engines during a search.
<i>Evaluating digital information</i>	<i>Critical evaluation of the credibility and reliability of online information</i> The students can estimate the credibility and reliability of online information by using online information evaluation criteria.
<i>Processing digital information</i>	<i>Organizing and ordering online information for decision-making purposes or for drawing purposeful conclusions.</i> The student can sort and order online information for a specific purpose. The student can combine relevant information from different sources and different types of media to answer the search-related question.
<i>Presenting digital information</i>	<i>Modifying and constructing of (new) digital information with the purpose of transferring the information to others.</i> The student can modify existing information and reformulate it in his or her own words. The student can format texts in order to clearly display information. The student can use different types of media (e.g., figures, graphs, word webs, flow charts) to clearly present information.

4.2.3.2 Design of authentic assessment tasks and assessment environment

First, themes and narratives for the assessment and its tasks were developed in cooperation with teacher educators. The overall theme for the assessment and the themes for the individual assessment tasks were prepared beforehand, and teacher educators could review these and provide feedback. The tasks were based on an authentic theme and a linear narrative structure in which a series of assessment tasks together led to the completion of one end goal: building a website about Bolivia (criterion b). Bolivia was selected as a theme because it was expected that all students would have low prior content knowledge and similar affinity with the subject (criterion f). Furthermore, to keep students motivated and concentrating throughout the assessment, a maximum time was set (criterion c). Hints were also added to help every test-taker get to the end of the assessment, minimizing the risk of demotivation (criterion c). The use of these hints could also give an indication about the test-takers' autonomy in using digital tools to complete the assessment tasks. Although the assessment tasks were focused on building a website about Bolivia, the skills that were elicited through the tasks were concentrated on online information literacy skills only; website programming skills were not needed for completing the assessment tasks (criterion f). We decided to use an introduction video in which fellow students (actors) started the narrative by explaining the end goal and also explained how the digital environment

worked and where the test-taker could find the tools needed for the upcoming tasks (criterion e). The fellow student actors represented a mixture of genders and cultures (criterion f).

The integrated Internet environment was offline to ensure that every test-taker could search for information in a safe environment that showed exactly the same content information and options for every test-taker (criteria d and f). It included 400 websites. This website database encompassed the following types of websites: (1) websites that contained correct information to complete a task and showed characteristics of being a reliable source; (2) websites that contained information related to the assessment tasks, but that did not contain the correct answer and showed characteristics that made the reliability of the information doubtful; (3) websites that contained information related to the assessment tasks, but that were not about Bolivia; (4) websites that contained information related to Bolivia but not related to the assessment tasks, and (5) websites that contained information about related concepts that were needed to understand the information related to the assessment tasks.

Teacher educators co-designed assessment tasks using a pre-structured assessment task format template, illustrated in Figure 4.2. The template included general information (skill domain that the task should elicit and the task's theme, which were set based on the results of the previous phase of the design process, and the maximum time the task should take). The teacher educators were asked to complete the template by specifying a task that elicited the skills needed for the set skill domain (criterion a), expected actions and hints. The resulting tasks were adjusted to satisfy criteria for effective item design (Erkens & Moelands, 1991; Haladyna, Downing, & Rodriguez, 2002; Welch, 2006) when necessary. An assessment expert reviewed the tasks (which included the scoring method for each task) that resulted from this phase. The expert received information about the assessment environment design and the digital environment for which the tasks were (to be) developed. The author processed the feedback that was provided.

Assessment task [fill in title here]
General information
	<i>Skill domain</i>
	<i>Goals</i>
	<i>Max time</i>
Task
<i>Summary</i>	Summary of item narrative and tasks
<i>Starting location</i>	What should be on the screen when this tasks starts? (e.g., website tool – specific page, Internet browser – search page, Internet browser – specific page)
<i>Narrative in chat</i>	Introduction, question/task. Specify actions that should happen as a consequence of students' answers by using italics
Expected actions
<i>Actions</i>	Actions the test-taker is expected to do to complete the task correctly
<i>End-action</i>	The action that indicates the task is done
Hint
<i>Content</i>	Hint content
Data that should be saved
<i>Chat</i>	What data should be saved from the chat?
<i>Internet browser</i>	What data should be saved from the Internet browser?
<i>Website-tool</i>	What data should be saved from the website tool?
Answer and scoring
<i>Answer</i>	What is the correct answer?
<i>Scoring automatic / manual</i>	Scoring automatic or manually?
<i>Point division</i>	How should the answer be scored?

Figure 4.2. Pre-structured format for designing the assessment tasks.

4.2.3.3 Assessment output and scoring

Based on the tasks, a blueprint was prepared for the information/data that was needed for analyzing the test-takers' performance and behavior. This included the test-takers' answers, hint-requests, the time on task, input (search queries) in the integrated Internet browser, and the time spent searching for information during each task using the integrated Internet browser. Initially the blueprint also included information concerning the websites that were visited by the test-taker. However, the programmer was not able to technically implement this and therefore this information could not be included in the database.

The output data were used for scoring the tasks. Most tasks were scored automatically by assigning points as follows: correct (1), partially correct (0.5) or incorrect/skipped (0). This means that the assessment provided information about whether specific skills from the four skill domains that describe online information literacy occurred in this sample of students or not, rather than the extent to which the student had really mastered these skills. Four tasks were scored by hand. This was done by trained scorers, based on a prescribed scoring guide. Two of these tasks were scored using the same point assignment as was used for the other tasks. The remaining two tasks were supposed to elicit skills from the skill domain 'evaluating online information'. Responses to these tasks were analyzed and reported in a qualitative way. All search queries students used to find information needed to complete the assessment tasks were used to examine students' search behavior (search terms and search strategies).

4.2.3.4 Small pilot and final prototype

Finally, a small pilot was done in which three students tested the assessment environment prior to administration. The difficulty, usability, their appreciation and the technical soundness of the assessment were tested (criterion e). After revisions based on the small pilot, the final draft of the assessment environment was completed, including a final inventory of the materials and conditions needed for implementation in practice. Materials and conditions for implementation are described in the materials and methods section.

4.3 Materials and methods

4.3.1 Procedures

Through a national open call, schools were invited to participate in the study. Data were collected through the digital assessment environment in which students were engaged in responding to

authentic problems that required their online information literacy skills. Each student was assessed individually on a tablet and the assessment results did not have any consequences for their school performance results (low-stakes testing). The maximum time to complete the assessment was set at 45 minutes. Additional data about students' search actions and time on task were collected during the assessment. After the assessment, students completed a questionnaire focused on background variables that could influence their online information literacy skills. The questionnaire took about 10 minutes. Test leaders were trained to make sure data collection and scoring would be similar for every student. The test leaders provided all materials needed for data collection to the participating schools. All students received a number that they used in completing the assessment and questionnaire to make sure their personal information remained anonymous. Prior to the administration, participating schools, students and parents of participating students were informed about the study, about data collection procedures and about the way data would be stored. They were able to stop their participation at any time. The university's ethics committee approved this approach. From May through June 2017, data were collected from 1227 students (their specific characteristics are described in 4.4.1). Due to technical difficulties with some data, we ended up being able to use the data of 1036 students in the analysis.

4.3.2 Instruments

4.3.2.1 Authentic assessment environment

The authentic assessment environment was described in section 4.2. The tasks were administered in an assigned sequence and the test-taker was not able to return to completed tasks. The test-takers' responses were recorded in both the chat (e.g., answering questions from the actor-students) and the tool that could be used to build the website (e.g., writing a piece for the website). The test-takers' search behavior was recorded through the offline Internet environment that unobtrusively logged the search terms and strategies (by logging sequential actions) that the test-taker used to search for information to complete the assessment tasks. These search actions were time-stamped as well. Finally, the environment also unobtrusively logged the number of times the test-taker asked for a hint and the amount of time the test-taker spent on each task. The assessment included 12 assessment tasks that led to building a website about Bolivia. An overview of the assessment tasks can be found in table 4.2.

Table 4.2. Description of assessment tasks for every skill domain

Domain	Number of tasks	Task descriptions
1. Collecting	5	Test-takers were asked to collect information about characteristics of Bolivia. Assessment tasks were to find information about what currency is used in Bolivia, the name of Bolivia's capital and the name of one of the three Bolivian flags. Furthermore, students were asked to find out what is/are the best month(s) to go to La Paz (city in Bolivia) if you prefer as little rain as possible.
2. Evaluating	2	Test-takers were asked what criteria they applied when searching for and selecting the information that they used for the assessment task.
3. Processing	3	Test-takers had to merge information from different sources to complete the assessment task. Students were asked to make a table in which the five biggest cities were put in descending order according to their population. Furthermore, students were asked to verify three statements about public safety in Bolivia and to adjust the statement accordingly if they found the statement was incorrect.
4. Presenting	2	Tasks were focused on writing a piece of text in your own words about why Bolivia is called a developing country. Students also had to do text editing, such as using bullet points in order to present information more clearly.

4.3.2.2 Questionnaire

The questionnaire was used to collect data about background variables that could influence the online information literacy skills of students. It included questions based on existing questionnaires (IEA, 2011; 2013) relating to reading comprehension (9 items, $\alpha = 0.76$), attitudes toward the use of technology (8 items, $\alpha = 0.86$), perceived technological skills (6 items, $\alpha = 0.76$) and students' experience with the administered assessment (12 items, $\alpha = 0.85$). Items about reading comprehension were related to appreciation, perceived reading skills and perceived importance of being able to read well (3 items each). Items about experience with the assessment were related to usability and appreciation (6 items each). A separate question was focused on the perceived difficulty of the assessment. Additionally, separate questions relating to students' background characteristics (age, gender, grade and language situation at home), students' technology usage and accessibility in school and at home and prior knowledge about the assessment's subject (Bolivia) were used to collect additional information. Table 4.3 provides an overview of the items in this questionnaire along with the psychometric scale and a few exemplary items. Items that were negatively phrased were reverse-scored.

Table 4.3. Detailed information on questionnaire scales

Construct	Scale	Example items
Reading comprehension	Strongly agree (1) - strongly disagree (5)	<ul style="list-style-type: none"> • Reading is harder for me than for the other students in my class. • I only read if I have to.
Technological skills	Inadequate (1) - very advanced (5)	<ul style="list-style-type: none"> • How well can you find reliable information on the Internet? • How good are you at using technological tools and computer programs?
Attitudes toward technology	Strongly agree (1) - strongly disagree (5)	<ul style="list-style-type: none"> • It is very useful to know how to use technological devices. • I like lessons in which technological devices are used.
Assessment experience	Strongly agree (1) - strongly disagree (5)	<ul style="list-style-type: none"> • The assessment environment was easy to use. • I liked the assessment questions/tasks.
perceived difficulty of the assessment	Very hard (1) - very easy (5)	<ul style="list-style-type: none"> • How did you perceive the difficulty of the assessment?

4.3.3 Data analyses

4.3.3.1 Questionnaire

Descriptive statistics were reported and used to analyze the results regarding reading comprehension, attitudes toward the use of technology, perceived technological skills and students' experience with the administered assessment. To check the dimensionality of the items, a Principal Component Analysis (PCA) was done for all scales. According to Field (2009, p. 669), loadings above 0.4 are considered high and this was used as the cut-off score. Reading comprehension concerned items related to appreciation, perceived reading skills and perceived importance of being able to read well. This was confirmed with a PCA (oblique rotation: oblimin) that found three separate components that together explained 66.4% of the variance. For attitudes toward the use of technology, the PCA suggested a one-dimensional structure (51.3% common variance) with loadings between 0.57 and 0.81. The PCA on the items for perceived technological skills suggested a one-dimensional structure (46.7% common variance) with loadings between 0.42 and 0.83. Experience with the administered assessment concerned items related to usability and appreciation. This was confirmed with a PCA (oblique rotation: oblimin) that found two separate components that together explained 47.0% of the variance. ANOVAs were used to determine significant differences in responses to these items between the students from different educational levels.

4.3.3.2 Authentic assessment environment

The four skill domains assessed with the assessment environment were analyzed separately. Then, more detailed information on students search behavior was examined.

Descriptive statistics were reported and used to analyze the results regarding the skill domains of collecting, evaluating, processing and presenting digital information. ANOVAs were carried out to identify significant differences between students from the different educational levels. Data collected about the skill domains of collecting, processing and presenting digital information were recoded based on their score to correct (1), partly correct (0.5) or incorrect (0). A skipped item was considered as incorrect, and therefore also yielded 0 points. Closed-ended questions were scored automatically. Items with a content-related component were manually scored. Based on these separate scores, a total score for every skill domain was created by accumulating the scores for the tasks within that domain.

Data collected for the skill domain of evaluating digital information were analyzed using directed content analysis (Hsieh & Shannon, 2005). All answers were coded and clustered into categories corresponding to predetermined themes related to online information evaluation criteria (Walraven et al., 2009). Data that did not fit directly into these categories were analyzed separately to determine if they represented a new category or a subcategory. Data were quantified using descriptive statistics (counts/percentages). To foster the reliability of this data extraction process, 154 answers were double-coded by two researchers, after which differences were discussed. This process resulted in an agreement rate of 88% (Cohen's kappa = 0.84), which is very good (Landis & Koch, 1977). After this, one researcher coded the remaining data, and when in doubt consulted the other researcher.

To analyze students' search behavior, both search terms and search strategies were examined. All search queries students used to find information needed to complete the assessment tasks were coded using inductive category development. The students used search terms within seven different search categories that were coded as: (1) specific keyword, (2) broad keyword, (3) specific sentence/question, (4) broad sentence/question, (5) specific source, (6) non-related search query, (7) search terms related to definitions in the assessment task. Examples are: "capital Bolivia", which would be coded as 1 or "Bolivia", which would be coded as 2. Data were quantified using descriptive statistics (counts/percentages), and reported separately for each educational level (primary education, pre-vocational education and pre-university education students).

To foster the reliability of this data extraction process, 169 search queries were double-coded by two researchers, after which differences were discussed. This process resulted in an agreement rate of 87% (Cohen's kappa = 0.80), which is substantial (Landis & Koch, 1977). After this, one researcher coded the remaining data, and when in doubt consulted the other researcher.

Sequential analysis was done to analyze students' search strategies. This analysis examined what kinds of search queries students used consecutively, based on the coding that was applied to the search terms: (0) no following search steps, (1) specific keyword, (2) broad keyword, (3) specific sentence/question, (4) broad sentence/question, (5) specific source, (6) non-related search assignment, (7) search terms related to definitions in the assessment task. An example: a student searches for information about the population of La Paz. His first search is on: "La Paz". This would have been coded as a broad keyword (2). Next the student adjusts his search query to "population of La Paz". This search query would have been coded as a specific sentence (3). This would yield a 2-3 sequence. Another example is where a student searched for information about the currency that is used in Bolivia. His first search is on "with what kind of currency do people pay in Bolivia". Next the students adjusts his search query to 'which currency is used in Bolivia'. This would yield a 3-3 sequence. Every sequence was coded in pairs to include every adjustment. Adjustments made because of incorrect spelling, incorrect grammar or typos in the search queries were not taken into account, as this analysis was only focused on students' search behavior and not on their grammar, spelling or typing skills.

With the sequential analysis, it was possible to map whether certain sequences of adjustments to search queries occurred significantly less or significantly more than would be expected based on chance. After coding the search queries to analyze the terms used, the coded data were transformed into sequence tables that reflected the initial search query, the follow-up (adjusted) search query and the number of times that this sequence of adjustments occurred, accumulated over every assessment task. These sequence tables were transformed to crosstab tables, after which a chi-square test was used to calculate the adjusted standardized residuals (e). The adjusted standardized residuals were used to determine the reliability of the occurrence of a sequence using the cut-off value of 1.96 for a significance level of 0.05. This means that when $e > 1.96$, the sequence occurred significantly more often than would be expected based on chance, and that when $e < -1.96$, the sequence occurred significantly less often than would be expected based on chance. Thus, a value of e between -1.96 and 1.96 indicates that the sequence's occurrence was reliable. The larger the absolute value of e , the more reliable the sequence's occurrence.

To examine significant differences in search strategies between students from different educational levels, crosstab tables were made for every separate code reflecting the follow-up (adjusted) search query and the number of times a sequence was applied by primary education (PE), pre-vocational education (PVE) and general secondary education/pre-university education (PU) students. An example of a table displaying the frequencies of sequences starting with code 2 is shown in Table 4.4. Again, chi-square tests were used to calculate the adjusted standardized residuals to determine which sequences occurred significantly more often in PE, PVE or PU.

Table 4.4. Frequencies of sequences starting with code 2

2 ->	PE	PVE	PU
0	68	28	71
1	94	41	105
2	101	32	73
3	28	19	23
7	18	7	13

4.4 Results

4.4.1 Sample characteristics

In total, 1036 Dutch PE, PVE and PU¹ students participated in this study. Table 4.5 provides information about the sample characteristics as far as gender, educational level and the language students use at home.

¹ In the Dutch educational system, after having finished primary education (PE) at the age of 12, students are tracked according to ability level in either pre-vocational education (PVE) or pre-university education (PU). PU students are considered to have a higher ability level than PVE students.

Table 4.5. Sample characteristics

		n	%
Gender	Male	552	53.3
	Female	484	46.7
Educational level	PE (grades 5-6)	407	39.3
	PVE (grades 7-8)	238	23.0
	PU (grades 7-8)	391	37.7
Language at home	Always Dutch	742	71.6
	Mostly Dutch	198	19.1
	Mostly another language	75	7.2
	Always another language	21	2.0

Results for reading comprehension showed significant differences between students from different educational levels. Table 4.6 provides means and standard deviations for every construct. PVE students liked reading significantly less and perceived reading as significantly less important than the other students in this sample ($p < 0.001$ for both comparisons). Students' perceived reading skills differed significantly across all educational levels. PU students perceived themselves as more skilled readers than did PE students ($p = 0.02$) and PVE students ($p < 0.001$). Furthermore, the PVE students had significantly fewer books at home and spent significantly less time on reading than PE students ($p < 0.001$ and $p = 0.03$ respectively) and PU students ($p < 0.001$ and $p = 0.001$, respectively).

Table 4.6. Means and standard deviations for constructs that measured perceived reading comprehension²

Construct	PE		PVE		PU	
	M	SD	M	SD	M	SD
Appreciation	2.5	0.8	2.9	0.8	2.5	0.9
Perceived reading skills	1.7	0.7	2.1	0.7	1.6	0.6
Perceived importance of being able to read well	2.1	0.7	2.3	0.8	2.1	0.7

The great majority of the students had access to the Internet at home and at school (98.7% and 90.3%, respectively). Students' experience with using a tablet ranged between only a few times a month and every day, but the majority indicated that they had used a tablet before either at home or at school (66.7% and 54.4%, respectively). Furthermore, students indicated that they used technology most often for communicating through chat-software and for searching for information on the Internet. Technology was regularly used for writing essays, creating reports

² Scale from (1) strongly agree to (5) strongly disagree.

and creating presentations. Using technology for assessments, creating graphs and tables, creating a website or programming was indicated to a lesser extent.

On average, students scored themselves as advanced users when it came to their technological skills ($M = 4.1$, $SD = 0.6$)³. However, PVE students did feel significantly less skilled ($M = 3.8$, $SD = 0.7$) than PE students ($M = 4.1$, $SD = 0.6$, $p = 0.002$) and PU students ($M = 4.2$, $SD = 0.6$, $p < 0.001$). This suggests that the PVE students (in this sample) felt less self-confident about using technology than the other students. Nevertheless, students did on average show a positive attitude towards using technology ($M = 1.6$, $SD = 0.5$)⁴. Remarkably, most students indicated they would rather use pen and paper when it comes to learning vocabulary, doing math, reading books or long texts and making notes or homework. Only when it came to searching for information did students indicate preferring to use technology to do so. Of this sample, 92.6% (almost) always used the Internet to search for information and 80.4% (almost) never went to the library.

All students experienced the assessment predominantly as fun ($M = 1.9$, $SD = 0.7$)⁴ and user friendly ($M = 1.8$, $SD = 0.6$). The perceived difficulty of the assessment was rated between ‘neither too difficult, nor too easy’ and ‘easy’ ($M = 3.4$, $SD = 0.8$)⁵. Furthermore, most students indicated that they had no prior knowledge about the main subject of the assessment, Bolivia (80.8%). Only 3.6% indicated that they already knew a lot about Bolivia.

4.4.2 Online information skills

The results related to the assessment of students’ online information skills are presented in this section. In general, PVE students finished considerably fewer assessment tasks than PU and PE students. Only 16% of the PVE students finished the last assessment task, compared to 68.5% of the PE students and 51.4% of the PU students. Most PVE students predominantly completed assessment tasks that were designed for assessing the underlying skills of ‘collecting online information’ and ‘evaluating online information’. Because of the PVE students’ low response on assessment tasks that were designed to assess the other skills (processing and presenting), results for these skills were reported separately. Furthermore, due to technical difficulties, none of the students used the hints that were included in the assessment environment. Therefore, the usage of hints was not included in analyses or the interpretation of the results.

³ Scale from (1) inadequate to (5) very advanced.

⁴ Scale from (1) strongly agree to (5) strongly disagree.

⁵ Scale from (1) very hard to (5) very easy

4.4.2.1 Collecting digital information

Students were asked to collect information about specific characteristics of Bolivia. Assessment tasks were to find information about what currency is used in Bolivia, the name of Bolivia’s capital and the name of one of the three Bolivian flags. Furthermore, students were asked to find out what is/are the best month(s) to go to La Paz (city in Bolivia) if you prefer as little rain as possible.

Means and standard deviations of the scores on the skill domain of collecting digital information are shown in Table 4.7. PU students scored significantly higher on these tasks than PE students and PVE students (both $p < 0.001$). However, the PU students acquired (on average) only a little over half of the maximum amount of points that could be achieved for this skill domain.

Table 4.7. Means and standard deviations for scores on collecting digital information (maximum of 4 points)

Educational level	N	M	SD
PE	303	1.8	1.1
PVE	107	1.8	1.0
PU	307	2.3	1.0

4.4.2.2 Evaluating digital information

Students were asked what criteria they used when selecting the information that they used for the assessment task. Most students only paid attention to one aspect when evaluating the reliability of the information. Just 65 students gave two reasons and 4 students gave three reasons for selection. The majority of the students who gave more than one reason were PU students (47). Eleven different criteria for evaluating the information that was selected from the Internet for completing the assessment tasks emerged from the data. Figure 4.3 presents the results for the criteria used that emerged from the data per educational level.

Figure 4.3. Criteria students used for evaluating online information

Most students indicated that they did not know what criteria to use when evaluating information (25.9%). In general, students indicated that they paid attention to the relevance of the information for completing the assessment task (22.7%). An example is a student who said: *“I just looked at whether the site provided information about the statements mentioned in the assessment task”*. Furthermore, students indicated they thought information was reliable when the same information was presented on different websites (18.5%), when it came from a specific source that they considered reliable (16.4%), or when the website on which the information was presented appeared reliable to them (e.g., well-ordered layout, no advertisements; 11.8%). One student explained how she cross-checked information: *“I looked at different websites and used the*

matching facts in my text". Another student gave an additional explanation for the source that he considered reliable: *"The information I found came from a website on which PU student reports that were graded by a teacher are published, so [that must be reliable]"*. Only a small number of students paid attention to the author of the information (3.3%), the topicality of the information (0.2%), and the quality of sources on which the information is based (0.6%). One of the students explained why she thought the information was reliable, based on the author: *"I found the information on a website that was made by someone from Bolivia. This seemed reliable to me as he would know what he is talking about."*

Pre-vocational education students indicated more often than students from the other educational levels that they pay attention to the relevance of information needed for completing the assessment task and more often relied on their own insights or feeling when evaluating information. An example of the latter is a student who said: *"I just trusted my own gut feeling"*. PU students looked more often than students from other educational levels at whether the same information was presented on different websites, whether the source was reliable and at the website's appearance. One student explained: *"I check whether the site is real: that there is not too much advertisements and colored letters"*. Most primary education students indicated that they did not know what to pay attention to when evaluating digital information.

4.4.2.3 Processing digital information

For evaluating the skill domain of processing information, students had to merge information from different sources to complete the assessment task. Students were asked to make a table in which the five biggest cities were put in descending order according to their population. Furthermore students were asked to verify three statements about public safety in Bolivia and adjust the statement accordingly if they found the statement was incorrect. Only 34 (14%) of the PVE students completed the tasks for this skill domain. This was considerably fewer than the PE students and the PU students (51% and 57%, respectively). Because of the PVE students' low response, interpreting the significance of the differences in the results of students from all educational levels was not useful. Therefore, only the scores of PE ($M = 1.2$, $SD = 0.7$) and PU ($M = 1.3$, $SD = 0.7$) (maximum of 3 points) students were compared, but no significant difference between these means was found ($p = 0.09$).

Of the students who did complete the assessment tasks, 27.8% of the PE students, 35.3% of the PU students and 10.9% of the PVE students were able to put the cities in descending order. Furthermore, 12% of both the PE and PVE students and 6% of the PU students put the cities in

ascending order. The statements were correctly verified and adjusted by 46.2% of the PE, 46.6% of the PU and 10.5% of the PVE students who did complete the assessment task. Figure 4.4 provides an overview of the percentage of students who completed the tasks correctly per educational level.

Figure 4.4. Percentage of students who completed tasks within the skill domain of processing online information correctly.

4.4.2.4 Presenting digital information

Tasks were focused on writing a piece of text in your own words about why Bolivia is called a developing country. Students also had to do text editing, like using bullet points in order to present information more clearly. The text-editing task was completed by 72 (30%) of the PVE students. This was considerably fewer than the PE students and the PU students (61% and 63%, respectively). Presenting information clearly through a list with bullet points was done correctly by 33% of all students who were able to complete the task. Most students from PU did this correctly (37%, compared to 6.7% of the PVE students and 17% of the PE students). Furthermore, only 22% of all students wrote something about Bolivia as a developing country; most answers were too short or incomplete to be able to assess the texts' content. Therefore, reporting results on this task was considered not to be useful.

4.4.3 Online information search behavior

Students' search behavior was determined by the search terms and search strategies that students used in their search queries while searching for information (cf. Wang et al., 2017). These search terms and search strategies were analyzed to map students' information search behavior.

4.4.3.1 Search terms

In total, 7494 search queries were analyzed. Analysis of the search terms students used while searching for information showed that students used search terms within seven different search categories. An overview is provided in Figure 4.5.

Figure 4.5. Categories of search terms for every educational level.

Most students either used keywords or formulated a whole sentence/question in the search queries they used to search for information about Bolivia in the Internet environment. In these queries, broad or specific searches could be distinguished. Furthermore, some search queries did not contain assessment task-related content and some search queries were focused on finding a specific Internet source (e.g., Wikipedia) or specific terms from the assessment task (e.g., “what are bullet points?”). Results show that PU students used keywords considerably more than PVE students or PE students. PE students and PVE students mostly used whole sentences/questions while searching for information. In general, students used specific search queries more often than broad ones. However, PU students used specific keywords considerably more often than students from the other educational levels, and PVE students used broad sentences/questions in their search queries more often than the other educational levels. Table 4.8 provides examples of the search queries students used while searching for online information to complete the assessment tasks.

Table 4.8. Examples of students' search queries for every search category

Category	Examples of search queries
Specific keywords	Capital Bolivia Climate La Paz
Broad keywords	Bolivia Red, yellow, green flag
Specific sentence/question	What is the capital of Bolivia? In which months could you best go to La Paz if you want as little rain as possible? When to go to La Paz if you don't like rain
Broad sentence/question	Is Bolivia a nice country? When does it rain the most in Bolivia?
Specific source	Wikipedia Rain radar
non-related search queries	Tietatovenaar (tv program for children) What are the answers to the assessment?
Definitions in the assessment task	Bullet point

4.4.3.2 Search strategies

The results of the sequential analysis to map students' search strategies are presented in this section. The analysis showed if, and in what way, students adjusted their search queries while searching for the information they needed for completing the assessment tasks.

Search terms used to search for a specific source (5), non-related search query (6) and search terms related to definitions in the assessment task (7) occurred too rarely to be able to use them in analyses and draw conclusions about the use of these search terms in students' search strategies. Search terms with one of these codes were therefore excluded from the sequential analysis. Additionally, these terms were substantially less relevant for completing the tasks than the remaining search terms.

Figure 4.6 shows the sequences (or adjustments of search queries) that occurred significantly more (green) or significantly less (red) than would be expected based on chance; in other words, the actions students applied to adjust their search queries. The thickness of every arrow in the figure reflects the amount of times a sequence occurred (also labelled as frequency (f)). The adjusted standardized residuals (e) reflect the reliability of the occurrence of the sequence.

Figure 4.6. The actions that students applied to adjust their search queries, with reliable positive and significant negative sequences shown. Arrow thickness shows how often a sequence occurred (f). The adjusted standardized residuals (e) reflect the reliability of the sequence, with a larger absolute value of e indicating stronger reliability.

These results show the following:

- Students often reformulated their search query within the same search category (positive sequences 1-1, 2-2, 3-3, 4-4).
- Students often did not need to adjust their starting search query after using a specific keyword (positive sequence 1-0, and negative sequences 1-2, 1-3 and 1-4). The negative sequences 3-4 and 3-2 suggest that in general, a follow-up search occurred less often after a specific search query.

- After students searched with a broad keyword, adjustment to a specific keyword seemed necessary (positive sequence 2-1 and negative sequences 2-0, 2-3).
- When students started with a broad search query, a follow-up search seemed necessary (negative sequences 2-0 and 4-0).
- When students used a whole sentence/question in their search query, a shift to using a keyword occurred significantly less than would be expected based on chance (negative sequences 3-1, 3-2, 4-1). Also the other way around; when students used keywords in their search strategies, an adjustment to using whole sentences/questions occurred significantly less than would be expected based on chance.

Figure 4.7 displays the significant positive sequences for each educational level, meaning that this figure shows significant differences between the search strategies that were used more often by students from the different educational levels.

Figure 4.7. Significant differences in search strategies between educational levels

These results show the following:

- PE students reformulated their search query more often within the same search category than PVE and PU students.

- PE students adjusted their search query with a specific keyword to a specific sentence/question more often than PVE and PU students.
- PVE students adjusted their search queries with broad keywords to search queries with a specific sentence/question more often than PE or PU students.
- PU students adjusted a search query with a broad sentence/question to a search query with a specific keyword more often than PE and PVE -students
- PU students adjusted a search query with a specific keyword more often to a search query with a broad keyword than PE and PVE students.

4.5 Discussion and conclusion

Online information literacy skills are of crucial importance for participation in today's society. Focused instruction on teaching these skills is needed in education, yet research into the measurement of actual technological skills is limited (cf. Aesaert & van Braak, 2018). Measuring online information literacy skills is often done through indirect and inauthentic measures (self-report, pencil and paper tests), which measure an interpretation of skills rather than actual performance. This study focused on the assessment of students' online information literacy skills, through developing an assessment environment in which students' skills are elicited through the application of their skills in authentic tasks. Both students' answers to the assessment tasks and students' search behavior while searching the Internet were used in analyses.

Research questions focused on how students from PE, PVE and PU differ in collecting, evaluating, processing and presenting digital information, and also specifically focused on differences in search behavior. PU students scored significantly higher on tasks that were designed to measure skills related to collecting digital information. However, PU students also scored only about half of the points for these tasks. The analysis of students' searching behavior provided a more detailed picture of the way students collected information. Students do not base their search strategies on just one approach, but use a mixture of these approaches in which one approach is more dominant than others. Results showed that PVE and PE students more dominantly searched with a whole sentence or question, while PU students more often searched using keywords. Furthermore, results showed that students often use a search strategy in which they adjust their initial search query to a similar search query formulated in a slightly different way. However, these types of changes often do not lead to different search results. This search strategy occurred significantly more often with PE students than with PVE and PU students. Another strategy that occurred often was changing an initial broad search query to a specific search query. Furthermore, searching with

a specific keyword was an efficient search strategy in the Internet environment used in this digital assessment environment, as often no follow-up search was needed. PU students used this approach significantly more often than PE and PVE students. In conformity with the findings of Van Deursen and van Diepen (2013), we also found that students used too many and too broad search terms. These results suggest that it can already be useful in primary education to pay attention to reflection in instruction on the search processes and search strategies students can use while searching for online information.

Results regarding the evaluation of online information suggest that students lack a critical attitude towards the information they find online and that students do not really know what criteria can be used to evaluate the online information they find. Most students only judge whether the information is relevant for answering the question presented in the assessment task, which is not an aspect of reliability. Students also cross-checked information on several websites, looked at whether they considered a specific source reliable and checked the website's appearance. However, most students just used one criterion to judge whether the information would be true; this almost never provides enough insight to be able to judge the reliability of a source sufficiently (cf. Koot & Hovelijn, 2005; Walraven et al., 2009). This lack of a critical attitude towards the reliability of online information can lead to students who ultimately function less well in today's society, in which it is often necessary to be able to evaluate information. Therefore, it seems important to introduce strategies that can be used to evaluate online information as early as primary education.

Less than half of all students showed that they were able to process the information they collected online for a specific purpose. Combining information from different online sources to interpret its meaning and drawing conclusions also seemed hard for students. The assessment tasks that were designed to measure processing and presenting online information were inadequately completed by the students. Therefore a more elaborate or different type of measurement is advised for these skill domains.

The majority of PVE students did not finish the assessment and seemed to have trouble with assessment tasks that required skills related to evaluating, processing and presenting digital information. These skill domains require metacognitive skills, which are important for interpreting information and drawing purposeful conclusions. Although PVE students skipped these tasks remarkably more often than PE and PU students, the results show that PE and PU students also have trouble with these skill domains. Research on students' digital literacy has found similar

results (Aesaert et al., 2014; Calvani et al., 2014; Van Deursen & Van Diepen, 2013). Although students seem to be familiar with the technical and operational aspects of technological tools, it appears that the metacognitive skills required for online information literacy are underdeveloped (cf. Kong, 2014).

The questionnaire results suggested that students were not hindered by lack of a positive attitude towards using technology, experience with using technology or accessibility of technology at home or at school. Additionally, despite the technical difficulties, students experienced the digital assessment environment predominantly as user-friendly, fun and sufficiently challenging. However, the questionnaire results also showed that PVE students were less self-confident with using technology and scored themselves significantly lower on items concerning their perceived reading comprehension than PE and PU students. An example of how reading comprehension ability could influence the assessment is in both the task about finding information on the capital and the task about the flag. These tasks required students to select the right Internet sources and to read the information on the Internet carefully; the official capital of Bolivia is Sucre, but many people think it is La Paz and this 'mistake' is reflected in the search results on Internet. This means quickly looking over the search results is not enough to find the right answer. Within this skill domain (collecting online information), students scored lowest on these two tasks. Reading comprehension ability has an important influence on both reading the text of the assessment tasks themselves and on reading the information found on the Internet (Leu et al., 2013). Since PVE students scored lower on items concerning their perceived reading comprehension, this could be an explanation for why PVE students did less well. Of course, actual reading comprehension ability should be measured to be sure. Additionally, Leu et., al (2013) have suggested that reading non-linear texts (which are often found on Internet) requires different reading skills than reading linear texts (e.g., often found in books). These differences in reading need to be considered when designing instruction that is focused on developing online information literacy.

Furthermore, online information literacy concerns complex (meta)cognitive skills that are based on four underlying interconnected skill domains. To develop online information literacy, it is important that students work on authentic tasks in which they have to use all these skills and that students must apply the skills in different situations (Van Merriënboer, 1997; Walraven, Brand-Gruwel, & Boshuizen. 2013).

4.5.1 Limitations

The assessment used in this study provides information about whether specific skills from the four skill domains that describe online information literacy occurred in this sample of students or not, rather than the extent to which the student has really mastered these skills. Due to technical limitations and low response rates for some skill domains, we were unable to apply a quantitative scoring system for every task. More research into the way these kinds of skills can be scored and graded needs to be conducted. Specifically, for the domain of evaluating information, more information was needed to be able to score students' responses. All students did give an answer about what criteria they used for evaluation of the reliability of online information, but not all students linked their answer to their specific search results. For example, a student might just say that he/she knew the information was reliable because he/she checked the source and it was a reliable one. Another student would answer that the information came from Wikipedia and that information found at this source is undoubtedly reliable. In these two examples, the two students indicated that they looked at the source to judge the reliability of the information, but for the first student, it was impossible to know whether the reasoning behind using this criterion was correct. Therefore, results were reported in counts/percentages; a deeper layer of information would be necessary to score this skill domain.

Due to limitations in scoring for the domain of evaluating information and inadequate answers for the domain of presenting information, we were only able to investigate the differences between educational levels for collecting and processing information. More research with similar authentic assessments is needed to get more insight into how students from different educational levels display these skills. Furthermore, online information literacy is a sub-domain of digital literacy. Other domains, such as computational thinking or online communication and safety, seem conceptually interconnected with online information literacy. Therefore, assessing digital literacy as a whole might foster the assessment's authenticity and validity. Furthermore, more research about the relation between the different sub-domains of digital literacy is also needed.

The Internet environment in which students could search for information was offline and simulated. The Internet environment looked like Google, but it did not use the same kind of underlying algorithms. For example, Google uses learning algorithms and algorithms that enable context-specific searching. Searching in Google with a sentence, a strategy often used by PE and PVE students, could therefore work differently than searching in the simulated Internet environment with a sentence. Another example is that the order in which search results were

presented was different, because in Google, this order is based on numerous variables such as previously used search terms, popularity of websites and advertisements. The offline and simulated Internet environment was needed to make sure that the environment was safe, the results based on the searches performed would be exactly the same for every student, and the information database could be controlled by the assessment designers. At the same time, this made searching for information in the simulated Internet environment less authentic than searching online. This also makes it hard to evaluate the strategy students used to search for information. Although the use of keywords for searching online information is often emphasized (e.g., Catalano, 2013; Peter, Lechner, Mayer, & Krampen, 2017), the algorithms used in Google nowadays are so well adapted to the way people search the Internet that using a whole sentence or question will often provide more relevant results than searching with keywords. However, with the rapid development of technology, these kinds of changes are not unexpected and will not stop. Students should develop generic skills that are needed to adapt to unknown unstructured digital environments like the one used in this authentic assessment. Despite these limitations, the digital assessment environment proved to be a valuable approach to determining students' online information literacy skills.

4.5.2 Implications for practice and further research

The results of this study suggest that online information literacy is not a given for all students. Differences were found in both the assessment results and the strategies students from different educational levels apply. This suggests that being able to assess online information literacy skills is important for fostering the development of these skills and for preventing a possible digital divide between students from different educational levels. In this study, results suggest that PVE students enact skills related to online information literacy less well than PE and PU students. This result was also found in other studies focused on skills related to digital literacy (of which online information literacy skills is a sub-domain; European Commission, 2014). PVE students form the majority in Dutch society (Rijksoverheid, 2017), as in a lot of countries. Lack of these skills can lead to an imbalance between the skills that are required in the workplace and people who have actually mastered these skills. Education can play an important role in reducing, or even eliminating, this digital divide by paying attention to the development of online information literacy skills. Not only should pre-vocational education pay more attention to this skill domain, online information literacy skills should be introduced already in early primary education. In this way, the basic skills that students can use as a platform from which they can build different digital literacy skills can be developed.

The assessment used in this study was designed to measure and monitor the skills related to online information literacy in an authentic way. The way data were gathered is a first step towards identifying weak skill domains for students, which can ultimately be used to inform teachers and students about students' online information literacy, and the assessment can be integrated with teachers' instruction and students' learning processes.

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Sometimes, the most brilliant and intelligent students do not shine in standardized tests because they do not have standardized minds.

- Diane Ravitch

Chapter 5

A systematic review of prerequisites for implementing Assessment for Learning in classroom practice

Although many researchers acknowledge that Assessment for Learning can significantly enhance student learning, the factors facilitating or hindering its implementation in daily classroom practice are unclear. A systematic literature review was conducted to reveal prerequisites needed for Assessment for Learning implementation. Results identified prerequisites regarding the teacher, student, assessment and context. For example, teachers must be able to interpret assessment information on the spot, student engagement in the assessment process is vital, assessment should include substantial, constructive and focused feedback, and the school should have a school-wide culture that facilitates collaboration and encourages teacher autonomy. The results of this review contribute to a better understanding of the multiple facets that need to be considered when implementing Assessment for Learning, from both a theoretical and a practical standpoint.

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5.1 Introduction

Assessment plays a crucial role in education. A distinction is often made between formative and summative purposes of assessment. Where summative assessment primarily focuses on assessing learning outcomes, formative assessment aims to gain insights into learning processes that can be used to support learning through tailored instruction and targeted feedback (Stobart, 2008).

Formative assessment has been on policy agendas internationally for decades, but implementation has proven to be challenging (e.g., Birenbaum et al., 2015; Marshall & Drummond, 2006). Although many researchers acknowledge that formative assessment can have a positive effect on learning, the proof for this is based on limited sound scientific evidence (Bennett, 2011). Moreover, the differing conceptualizations of formative assessment have led to a wide variety of practices, and it is unclear which factors facilitate or hinder its implementation. The purpose of this review was to get a sense of the prerequisites needed for the implementation of ongoing formative assessment practice that has the potential to support learning in the classroom. This study focuses specifically on a formative assessment approach called ‘Assessment for Learning’ (AfL) (Assessment Reform Group [ARG], 1999), in order to gather information from studies that look at relatively consistent underlying principles and intentions that shape formative assessment uses. In the following paragraphs, the key terminology used throughout this paper is clarified and the research background is described.

The literature includes a wide range of definitions of formative assessment, each having different strategies for using evidence from assessment to enhance learning and with differing emphases on social dimensions (see Brookhart, 2007 for an overview of definitions). For example, a phrase often used in formative assessment literature is the use of assessment evidence to provide feedback to “close the gap” between students’ current performance and the goal (Sadler, 1989). Definitions of formative assessment differ with respect to, for example, the specific roles of not only teacher but also the student in this process as receivers, users and providers of feedback.

Three distinct approaches have evolved over time, namely: ‘data-based decision-making’ (DBDM), ‘diagnostic testing’ (DT), and ‘assessment for learning’ (AfL) (Van der Kleij, Vermeulen, Schildkamp, & Eggen, 2015). DBDM involves the systematic collection and analysis of data to inform decisions that focus on improvement of teaching, curricula and (school) performance (Schildkamp & Kuiper, 2010). DT concerns the mapping out of individual learners’ task response patterns to reveal their

(possibly inadequate) solution strategies and using this as an indication of each learner's developmental stage (Crisp, 2012). AfL is an approach to formative assessment that occurs as part of ongoing classroom practices (Klenowski, 2009), that is viewed as a social and contextual event and that focuses on the quality of the learning process (Stobart, 2008). Feedback is continually incorporated in this process to guide future learning, and is aimed at the class or individual level. Students play a vital role in AfL and are expected to engage in assessing their own and their peer's learning (Elwood & Klenowski, 2002). A major long-term goal of AfL is to foster student autonomy by helping students learn how to learn (Black, McCormick, James & Pedder, 2006; James et al., 2007; Pedder & James, 2012).

The publications of Black and Wiliam (1998a; 1998b) on formative classroom assessment were followed by a boost in research on formative assessment, especially work on AfL, with researchers reporting effects of AfL implementation in many countries. Much of this research has been centered around the five key strategies for implementing AfL identified in Black and Wiliam's and Wiliam and Thompson's (2007) work:

1. Clarifying and sharing learning intentions or goals and success criteria;
2. Generating opportunities to effectively gather evidence of student learning through informal and formal assessment, e.g., through classroom discussions, questioning or learning tasks;
3. Providing formative feedback to students to support their learning;
4. Supporting students in acting as instructional partners through discussion and peer assessment; and
5. Activating students as agents in their own learning through self-assessment and self-regulation.

These five key strategies are based on the central notion of using assessment evidence to inform learning. They have been interpreted in various ways, and numerous researchers have emphasized the need for deep engagement with these principles in order to achieve the ultimate goals of AfL; promote deep learning and learner autonomy (Hayward 2014; Marshall & Drummond, 2006; Pedder & James, 2012).

AfL can be approached from a measurement perspective or an inquiry perspective (Hargreaves, 2005). When approached from a measurement perspective, AfL is characterized by the use of formally gathered (quantitative) evidence about student learning to formulate feedback and to

inform decisions, based on assessment activities that aim to determine whether, or to what extent, a pre-set level of performance has been achieved. Approaching AfL from an inquiry perspective results in the use of primarily qualitative information (e.g., observations, demonstrations and conversations) to generate feedback, in a process of discovery, reflection, understanding and review. This perspective acknowledges the power of social interaction and student autonomy in enhancing student learning, and is more congruent with current understandings of AfL (e.g., Klenowski, 2009; Ruiz-Primo & Furtak, 2006). Researchers have emphasized that quality implementation of AfL requires adopting an inquiry approach to AfL (Hargreaves, 2005; Wyatt-Smith, Klenowski, & Colbert, 2014) and an in-depth engagement with the five key strategies (Black & Wiliam, 1998a; 1998b; Wiliam & Thompson, 2007) by both teachers and students, as an integral aspect of daily classroom practice (Pedder & James, 2012).

Although there is evidence that AfL can help students learn, a number of studies show no to little effects on student learning. For example, in a meta-analysis that studied the effects of formative assessment on student achievement, Hendriks, Scheerens and Slegers (2014) concluded that most studies found little to no effects. This is likely due to the ineffective implementation of formative assessment approaches, such as AfL (Bennet, 2011). Engaging deeply with the underlying ideas of AfL has proven to be challenging for many teachers, for example as a consequence of constraints imposed by the particular policy context (Marshall & Drummond, 2006) through, for instance, accountability pressure.

No systematic analysis has been conducted on evidence gathered from studies of AfL and identifying factors that contribute to or hinder implementation has not been a primary focus of any review study published so far. Therefore, this review study focused on identifying relevant prerequisites for effective AfL implementation. In order to systematically gather these data from selected studies, four categories often distinguished in school evaluation literature (e.g., Mandinach & Jackson 2012; Schildkamp & Kuiper, 2010) were used: the teacher, the student, assessment and the context. AfL literature emphasizes the crucial roles of both the teacher and student in teaching, learning and assessment (Elwood & Klenowski, 2002; Pedder & James, 2012). The category assessment includes the means by which evidence is gathered about student learning, this covers both assessment instruments (e.g., a test or learning task) and processes (e.g., questioning and classroom discussion). The category context includes both factors internal to the school (e.g., leadership) and factors external to the school (e.g., educational policy). In practice, a sound implementation of AfL would require a balance among factors in these interrelated categories. This review was guided by the following research question: *Which*

prerequisites regarding the teacher, student, assessment and context need to be considered when implementing AfL in the classroom?

5.2 Methods

The following paragraphs describe the methods used to conduct this review. In the literature, the terms AfL and formative assessment are often used interchangeably (Van der Kleij et al., 2015). Moreover, the specific term ‘AfL’ is not always used and operationalizations of AfL might differ throughout the research. Therefore, the literature review initially focused more broadly on studies of implementation of formative assessment in the classroom. However, the selection of studies specific to AfL suitable for identifying the prerequisites for effective implementation was the ultimate focus of this review.

5.2.1 Procedure

This review took an approach used in systematic review studies in the social sciences (Petticrew & Roberts, 2006). This stepwise process encompassed formulating research questions, defining search terms, selecting databases, conducting the literature search, formulating inclusion criteria and applying these to selected relevant literature, and the extraction of data. A library professional was consulted to ensure effective strategies for the literature search. A data extraction form was used to collect similar data from each publication. Additionally, the scientific quality of each publication was assessed; only studies that met the minimally satisfactory quality requirements were selected. Initial literature searches were conducted in March, 2014.

5.2.2 Databases and search terms

Five scientific databases were used to retrieve relevant literature: Education Resources Information Center (ERIC), Web of Science, Scopus, PsychINFO and Picarta. These databases were chosen as containing most publications regarding educational research. The same search strategy was used for every database. The search process started with broad search terms such as “formative assessment”, “assessment for learning”, and related terms as found in the thesaurus. Due to the increased popularity of formative assessment following the 1998 publications by Black and William (1998a; 1998b), the search was limited to publications after 1998. Also, words related to “feedback” and “classroom” were added to the search terms, as feedback is a crucial part of formative assessment and this review specifically focuses on the classroom level of

implementation. Finally, the search results were narrowed down by selecting only publications in the English language.

5.2.3 Selection process

All publications were exported to Thomson Reuters Endnote X7 (2013). After removing duplicates, title and abstract scans were conducted using the following inclusion criteria:

- 1) The study was published in a scientific, peer-reviewed journal or was a dissertation.
- 2) The study involved empirical research.
- 3) The study was conducted in the context of primary, secondary or vocational education.
- 4) The study focused on the use of formative assessment in classroom practice.

The first criterion aims to select studies of adequate scientific quality. Studies that were not published in a peer-reviewed scientific journal (e.g., in books, book chapters and conference proceedings) were not selected. The quality of the remaining studies was investigated more comprehensively during data extraction. Through the second criterion, theoretical articles, reviews and opinion pieces were excluded, as this review focuses on evidence-based factors that have proven to be influential for the implementation of formative assessment in practice. Although it is necessary to be careful in generalizing from the results of case studies, case studies were included in the selection for their practical examples of 'real life' contexts, an essential element in formative assessment, particularly in AfL. Furthermore, in a recent large-scale review study the majority of AfL studies were categorized as small-scale case studies (Baird, Hopfenbeck, Newton, Stobart & Steen-Utheim, 2014). The third criterion specifies the educational context of studies that were included in the review; primary, secondary and vocational education. We included these contexts based on practitioners' requests for more guidance on how to implement AfL. The fourth criterion restricted the selection to studies that focused on the use of formative assessment in classroom practice in general, which was essential in order to identify prerequisites for effective implementation of AfL in the classroom.

If it was unclear whether or not the study fully satisfied the inclusion criteria, the publication remained in the selection. After the title and abstract scan, full-text versions of the remaining publications were obtained. Only full text versions that were available through the library facilities

at hand were included. When it became clear during data extraction that a study did not match the inclusion criteria after all, the publication was removed retroactively.

5.2.4 Data extraction and data analysis

Each of the selected publications was read completely, and relevant results were recorded using a data extraction form. The data extraction form was generated over multiple trials to ensure usability and consistency in the data extraction procedures across researchers. Additionally, a coding instruction document for using the data extraction form was created in order to enhance reliability across different members of the research team. The data extraction form consisted of the following sections:

- General information: author, publication year, title, context.
- Research design: research question, methods, instruments, primary formative assessment focus.
- Research population: number of respondents, sampling method.
- Results and conclusions: answer to the research question, identified prerequisites regarding teacher, student, assessment and context.
- Quality check: clear research goal, appropriate methods used, reliability, sample quality, quality of data analysis.

Over 50% of the studies were blindly double-coded 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 80% (Cohen's Kappa =.620), which is substantial (Landis & Koch, 1977).

During data extraction, the selection of studies was further narrowed. Studies were classified as having a primary focus on AfL, DBDM or DT in the section on research design. Only studies classified as focusing on AfL were selected for this review.

The quality check consisted of 11 questions that were scored with 0, 0.5 or 1 point (cf. Petticrew & Roberts, 2006). The questions can be found in Table 5.1. Based on these questions, a quality score was assigned to every study. To be considered for inclusion in this review, the overall quality score had to be at or above the cut-off score of $0.5 * 11 = 5.5$. When multiple researchers coded the study, the quality scores were averaged. The total score for the quality check resulted in one of the following three decisions: a score below 5 meant the study was excluded from the review. Studies

with a score between 5 and 7 were discussed between researchers, which led to a decision on inclusion. Studies with a score of 7 or higher were selected for the review.

Following data extraction, the specifics of the studies were analyzed according to the predetermined categories, ‘teacher’, ‘student’, ‘assessment’ and ‘context’ and the different educational settings. Within these categories, clusters were made corresponding to themes that emerged from the data. Analysis showed that only one publication in our selection considered the context of vocational education. Additional searches were conducted to collect more studies regarding this type of school. The databases were searched again with the strategy used in the initial search, but using search terms related to “formative assessment” and “vocational education”. Additionally, a search using the names of key authors in this field of research was conducted.

Table 5.1. Quality questions

Category	Quality question
General	1. Is the research objective clear?
	2. Is the research approach in combination with the chosen method capable of finding a clear answer to the research question?
Selection sample	3. Does the study include enough data to ensure the validity of the conclusions?
	4. Is the context of the research clear (country, sampling of the schools/teachers/students)?
Method	5. Do the researchers describe the research methods used?
	6. Do the authors give an argument for the methods chosen?
	7. Do the researchers take into account other variables that might be influential?
Data analyses	8. Are the data analysed in an adequate and precise way?
	9. Are the results presented clearly?
	10. Do the researchers report on reliability and validity of the results?
Conclusion	11. Is the research question answered using empirical evidence gained from the research?

5.3 Results

5.3.1 Search and selection results

The initial search resulted in 2533 publications. After removing duplicates, conference proceedings, books, and so forth, the systematic search resulted in 1743 publications. Applying the remainder of the inclusion criteria using the information from the title and abstract scan left 117 studies available for data extraction. Because the full text documents of 15 studies could not be obtained, these studies were excluded. Upon further examination of the full text documents, another 42 studies were excluded due to a mismatch with the inclusion criteria. This process resulted in 60 publications suitable for analysis. Of the 60 publications, 26 were categorized as primarily focused

on AfL. All but two AfL publications were above 7 on the quality check ($M = 8$); those two studies each received 6.5 points. Only one study was conducted in the context of vocational education. The supplementary search for formative assessment studies in vocational education resulted in another 84 possibly relevant publications. However, only two additional publications satisfied the inclusion and quality criteria. Because of the limited availability of formative assessment literature of sufficient quality ($n = 3$) in vocational contexts and hence the limited generalizability of conclusions based on these studies' results, vocational education was not taken into consideration in this paper. Thus, the literature search resulted in 25 relevant studies for this review.

Of these 25 studies related to AfL, nine were conducted in the context of PE (ages 4-11), ten in SE (ages 12-18) and six where SE and PE overlapped. Results included data from eleven different countries, but most of the studies were conducted in the US ($n = 9$). Twelve studies used a qualitative approach, four a quantitative approach and nine studies applied a mixed methods design. An overview of the studies selected for this review can be found in Table 5.2.

Table 5.2. Overview of the selected studies

Nr	First author and publication year	Country ^a	Context		Subject	Research design ^c	Schools	Sample size		Students	Prerequisite category ^d
			Education setting ^b					Educators			
1	Aschbacher (2006)	US	PE	Science	MM	n/a	25	245	T, S, A		
2	Birenbaum (2011)	IL	PE, SE	Humanities, Math	MM	n/a	128	22	T, A, C		
3	Bryant (2010)	HK	PE	Language	QL	1	2	34	T, S, A		
4	Feldman (2008)	US	SE	Science	QT	n/a	8	n/a	T, S, C		
5	Fletcher (2012)	AU	PE	Writing	MM	1	16	256	T, S, A		
6	Fox-Turnbull (2006)	NZ	PE	Humanities	QL	6	n/a	53	T, A		
7	Furtak (2012)	US	SE	Science	QL	1	6	n/a	T		
8	Gamlem (2013)	NO	SE	n/a	QL	4	6	150	T, A		
9	Gottheiner (2012)	US	SE	Science	QL	n/a	5	n/a	T, C		
10	Hargreaves (2013)	UK	PE	Numeracy, Literacy	QL	1	n/a	9	T, A		
11	Harris (2013)	NZ	PE, SE	Language, Math	QL	1	3	99	S, A, C		
12	Harris (2014)	NZ	PE, SE	n/a	MM	11	13	193	T		
13	Havnes (2012)	NO	SE	Language, Math	MM	5	192	391	T, S, A, C		
14	Kay (2009)	CA	SE	Science	MM	6	7	213	T, A, C		
15	Lee (2011)	HK	SE	Language	MM	1	4	138	T, S, A, C		
16	Lee (2012)	US	SE	Math, Science	MM	2	18	n/a	T, S, C		
17	Newby (2011)	UK	SE	Science	QL	1	n/a	157	S, A, C		
18	Ní Chróinín (2013)	IE	PE	Physical education	QL	n/a	5	n/a	T, A, C		
19	O'Loughlin (2013)	IE	PE	Physical education	QL	1	1	22	T, A		
20	Penuel (2007)	US	PE, SE	Science	QT	n/a	498	n/a	T, A, C		
21	Phelan (2012)	US	PE, SE	Math	QT	7	36	1332	C		
22	Rakoczy (2008)	DE, CH	SE	Math	MM	n/a	n/a	1255	T, C		
23	Riggan (2011)	US	PE	Math	QL	n/a	39	n/a	A		
24	Sach (2013)	UK	PE, SE	n/a	QL	3	3	n/a	T, C		
25	Yin (2014)	US	PE	Science	QT	1	1	52	T		

Note: 'n/a' indicates information that was unavailable in the cited publication.

Note. 'n/a' indicates information that was unavailable in the cited publication.

^aCountry codes according to ISO: United States of America (US), Israel (IL), Hong Kong (HK), Australia (AU), New-Zealand (NZ), Norway (NO), United Kingdom (UK), Canada (CA), Ireland (IE), Germany (DE), Switzerland (CH). ^bPrimary Education (PE) (ages 4-11), Secondary Education (SE) (ages 12-18). ^cQuantitative research design (QT), Qualitative research design (QL), Mixed Methods (MM). ^dTeacher (T), Student (S), Assessment (A), Context (C).

The results are structured according the predetermined categories (teacher (T), student (S), assessment (A) and context (C)), beginning with the category with the most evidence for corresponding prerequisites and ending with the category with the least evidence for corresponding prerequisites. This does not imply that prerequisites related to the last category are not important, but the results suggest there is less evidence available in the literature for the importance of these prerequisites (so far). Similar sub-categories within these predetermined categories were clustered, and eight overarching aspects important in the implementation of AfL emerged. Only aspects for which there was evidence from at least two studies were included in the results. Table 5.3 shows the numbers of studies per prerequisite category and aspect. The study ID numbers correspond with the numbers used in Table 5.2.

Table 5-3. Number of studies per prerequisite category and aspect

Prerequisite category	Studies (identified by number)	Totals
Teacher		
• Teacher knowledge and skills	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 18, 19, 20, 22, 24, 25	21
• Teacher beliefs and attitudes	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 18, 20, 24, 25 2, 3, 4, 5, 10, 13, 15, 16, 18, 19, 20, 22	19 12
Assessment		
• Assessment content and presentation	1, 2, 3, 5, 6, 8, 10, 11, 13, 14, 15, 17, 18, 19, 20, 23	16
• Alignment and integration	1, 6, 8, 10, 13, 14, 15, 18, 23 1, 2, 3, 5, 8, 11, 13, 14, 15, 17, 18, 19, 20	9 13
Context		
• Leadership and culture	2, 4, 9, 11, 13, 14, 15, 16, 17, 18, 20, 21, 22, 24	14
• Support and professional development	2, 4, 11, 13, 14, 15, 16, 17, 18, 22, 24 2, 4, 9, 16, 18, 20, 21	11 7
Student		
• Student knowledge and skills	1, 3, 4, 5, 11, 13, 15, 16, 17	9
• Student beliefs and attitudes	1, 3, 5, 11, 17, 3, 4, 5, 11, 13, 15, 16, 17	5 8

Note. Boldface sections indicate category totals

As expected, based on the relatively broad inclusion criteria, the studies in this review focused on many aspects of AfL. The studies encompassed a wide variety of research contexts, dependent variables, research methods and underlying AfL philosophies. Also various depths of AfL implementation were represented by the studies, ranging from a measurement orientation to an inquiry orientation (Hargreaves, 2005). It is important to note that this review does not aim to provide a recipe for success for any and all AfL implementation. Rather, by examining which aspects have been identified as important when implementing AfL, we hope to generate a better understanding of the multiple facets that need to be considered, from both a theoretical and a practical standpoint. Some aspects identified in this review are very general in nature and may seem crucial to any educational implementation process. Wherever such universally applicable aspects are identified, we have made efforts to specify the particular relevance for AfL. In the subsequent paragraphs, the results will be reported separately for each of the categories. As no clear differences were found between the PE and SE contexts, results for both settings are presented simultaneously.

5.3.2 Teacher

5.3.2.1 Teacher knowledge and skills

Seventeen studies reported results regarding teachers' knowledge and skills related to AfL. Although only four studies explicitly used the term 'assessment literacy', many studies referred to assessment literacy in general; that is, the knowledge and skills teachers need to collect, analyze and interpret evidence from assessment and adapt instruction accordingly (Birenbaum, Kimron & Shilton, 2011; Bryant & Carless, 2010; Gottheimer & Siegel, 2012; Lee, 2011; Lee, Feldman & Beatty, 2012).

Results of multiple studies indicated that teachers need the ability to integrate AfL with pedagogical content knowledge (PCK) to be able to cater for their students' learning needs and provide useful feedback (Aschbacher & Alonzo, 2006; Birenbaum et al., 2011; Feldman & Capobianco, 2008; Fletcher & Shaw, 2012; Fox-Turnbull, 2006; Furtak, 2012; Gottheimer & Siegel, 2012; Harris, Brown & Harnett, 2014; Kay & Knaack, 2009; Lee, 2011; Lee et al., 2012; Penuel, Boscardin, Masyn & Crawford, 2007; Yin, Tomita & Shavelson, 2013). Results further suggest that teachers' pedagogical knowledge (PK) and content knowledge (CK) impact their ability to provide students with useful feedback. Without understanding a concept or without knowing common misconceptions related to a subject, teachers were not able to provide accurate and complete feedback (Furtak, 2012; Gottheimer & Siegel, 2012; Ní Chróinín & Cosgrave, 2013; Yin et al., 2013).

Teachers need to be able to create educational situations in which AfL strategies can be employed and should know the roles of students, peers and teachers in the various AfL practices. Eliciting students' thinking to reveal their learning process and common misconceptions is an important guiding strategy that teachers should master. Aschbacher and Alonzo (2006) found that using questions or directions that provide conceptual focus were most effective for eliciting students' thinking and fostering learning. This was especially true compared to overly prescriptive guidance strategies in which students were prompted to copy answers from the blackboard. Other studies specifically found that 'discussion' is a pedagogy often used in AfL. Teachers should be able to foster the participation of students in discussions about their answers, expertise or feedback (Aschbacher & Alonzo, 2006; Bryant & Carless, 2010; Feldman & Capobianco, 2008; Fox-Turnbull, 2006; Gamlem & Smith, 2013; Gottheimer & Siegel, 2012; Hargreaves, 2013; Havnes, Smith, Dysthe & Ludvigsen, 2012; Lee et al., 2012; Penuel et al., 2007). Discussion can give teachers valuable insight into students' thinking, difficulties and understanding. This information can be used in adjusting instruction and providing feedback. Because AfL takes place in everyday classroom practice, such as during discussions, it was also noted that teachers need the ability to interpret information about student learning on the spot (Birenbaum et al., 2011; Feldman & Capobianco, 2008; Lee, 2011; Lee et al., 2012).

Moreover, teachers need knowledge and skills to develop assessments that achieve the desired purpose. This includes the ability to construct questions (used in daily classroom practice) that elicit evidence about student learning and to critically evaluate assessment instruments (Feldman & Capobianco, 2008; Gottheimer & Siegel, 2012).

The need for teachers to have knowledge and skills regarding the use of hardware and software related to computer-based assessment has also been reported as vital (Feldman & Capobianco, 2008; Lee et al., 2012). This is not specific to AfL, but is important for formative assessment in general now that technology and assessment have become more integrated. An example specific to AfL is when teachers use computer response systems (CRS) for immediately gathering students' responses to short questions. Students discuss a question presented by the teacher with peers or think about it individually, and then report their answer using a CRS. After a histogram of responses is displayed, whole class discussion can take place. Teachers use the responses collected with the CRS and the classroom discussion for adjusting their teaching plan on the spot or revisit them for later use (Lee et al., 2012).

Teachers' assessment experience and confidence in their professional judgment were also identified as a feature that leads to successful implementation. Experience with AfL activities helps teachers gain a deep understanding of AfL and fosters their confidence in their instructional decisions (Birenbaum et al., 2011; Feldman & Capobianco, 2008; Fletcher & Shaw, 2012; Ní Chróinín & Cosgrave, 2013).

5.3.2.2 Teacher beliefs and attitudes

Studies that referred to teacher beliefs and attitudes mostly focused on the level of commitment to the underlying ideals of AfL, instead of merely the use of a series of techniques that are routinely applied. In these studies, knowledge, skills and attitude are often conceived of as intertwined. Fourteen studies found evidence for characteristics of teachers' beliefs and attitudes as important for 'deep' implementation of AfL.

Teachers' beliefs, attitudes, perspectives and philosophy about teaching and learning influence the quality of AfL implementation (Havnes et al., 2012; Lee et al., 2012; Penuel et al., 2007; Rakoczy, Klieme, Bürgermeister & Harks, 2008; Sach, 2013). In addition, both Aschbacher and Alonzo (2006) and Birenbaum et al. (2011) found that the quality of AfL practices is influenced by the extent to which teachers feel responsible for student attainment of goals rather than just coverage of the curriculum. Teachers with less of a feeling of responsibility also felt less inclination to evaluate student work, give effective feedback and revise teaching plans where needed.

Furthermore, several studies specifically reported that teachers should have a constructivist view of learning and pedagogical strategies when it comes to the implementation of AfL (Birenbaum et al., 2011; Penuel et al., 2007; Rakoczy et al., 2008; Sach, 2013). In addition, AfL practices that either represented features of high quality instruction or resulted in high student performance incorporated student-centred AfL activities (Birenbaum et al., 2011; Bryant & Carless, 2010; Fletcher & Shaw, 2012; Hargreaves, 2013; Havnes et al., 2012; O'Loughlin, Ní Chróinín & O'Grady, 2013). For example, Birenbaum et al. (2011) found that student-centred assessment tasks and instruction positively relate to known characteristics of AfL practices (e.g., focus on learning processes and promotion of self-regulated learning). Fletcher and Shaw (2012) showed that student-directed assessment resulted in higher achievement results and higher levels of motivation and enjoyment compared to teacher-directed assessment. As the implementation of AfL often means practical change, results also showed that teachers should be willing to change their assessment practices (Feldman & Capobianco, 2008; Lee, 2011).

5.3.3 Assessment

5.3.3.1 Assessment content and presentation

In nine studies evidence was found regarding content-related aspects of assessment tasks and feedback. Several studies emphasized the importance of substantial, constructive and focused feedback. This kind of feedback specifies incorrect responses and suggests how to improve learning based on students' progress (Hargreaves, 2013; Havnes et al., 2012; Kay & Knaack, 2009; Lee, 2011; Ní Chróinín & Cosgrave, 2013; Peterson & Irving, 2008; Rakoczy et al., 2008). These studies showed that feedback can have a substantial impact on students' motivation for learning. Overly directive, dishonest, wordy and unfocused feedback is perceived as irrelevant and frustrating by students (Hargreaves, 2013; Kay & Knaack, 2009; Peterson & Irving, 2008). The more students are provided with positive informational feedback containing cues on how to proceed, the more students feel excited, stimulated and interested in the subject, and the more deeply they tend to elaborate on the content (Rakoczy et al., 2008). Gamlem and Smith (2013) did a study on feedback and found four feedback typologies that illustrate these results. The two types that were perceived as most useful by students include active formative feedback that was given on the spot and for which opportunities (time) to work with the feedback were provided. Feedback was part of a dialogue between the teacher and the students or among students.

Assessment tasks should elicit students' pre-existing ideas in order to be able to move in the zone of proximal development. In this way prior knowledge can be addressed, which helps students to construct their own knowledge. Furthermore, assessment tasks should be meaningful and authentic, as this resulted in significantly increased performance, creativity and motivation (Fox-Turnbull, 2006). Riggan and Olah (2011) examined how teachers collect, interpret, and act on different types of assessment information. They found that assessments were used for organizational purposes, for identifying specific weaknesses of individual students, for explaining students' thinking and problem-solving processes, and for informing teachers' pacing decisions (e.g., whether the class could move on to a new unit). These assessment interactions were mostly characterized by open-ended questions.

5.3.3.2 Alignment and integration

Fifteen studies emphasized the need for alignment and integration of AfL in the curriculum and instructional tasks. Alignment of AfL with the curriculum and standards is vital; several studies show that systematic feedback procedures that include setting specific assessment goals and criteria (e.g., through rubrics) should be in place, as these help students to structure their

assessments, become aware of what is expected of them and realize how their effort contributes to their achievement (Birenbaum et al., 2011; Fletcher & Shaw, 2012; Gamlem & Smith, 2013; Havnes et al., 2012; Newby & Winterbottom, 2011; Ní Chróinín & Cosgrave, 2013; O'Loughlin et al., 2013; Peterson & Irving, 2008).

AfL practices (including feedback) need to be closely integrated into classroom instruction and should not be viewed as add-on activities (Havnes et al., 2012; Kay & Knaack, 2009; Lee, 2011; Penuel et al., 2007). This implies that assessment tasks should be integrated with teaching strategies and learning of content. Integration of AfL starts with small changes, such as giving students formal opportunities to act on feedback (Gamlem & Smith, 2013) and placing less emphasis on scores/grades than in traditional teaching methods (Lee, 2011). Furthermore, AfL integration can be fostered by using peer- and self-assessment, which helps teachers by sharing responsibilities for learning and assessment practices, and stimulates students' involvement in their own learning process (Bryant & Carless, 2010; Fletcher & Shaw, 2012; Harris & Brown, 2013; Havnes et al., 2012; Kay & Knaack, 2009; Lee, 2011; Ní Chróinín & Cosgrave, 2013).

5.3.4 Context

5.3.4.1 Leadership and culture

Eleven studies found prerequisites regarding leadership and culture. School leaders play an important role in the facilitation of AfL implementation. Leadership should focus on establishing a school-wide AfL culture with a vision, norms, goals and expectations for AfL use (Havnes et al., 2012; Sach, 2013). Most of these studies found collaboration to be an important focal point in this culture. For long-term benefits, teachers need to work collaboratively and engage in communities of practice (Birenbaum et al., 2011; Kay & Knaack, 2009; Lee, 2011). The school leader needs to facilitate AfL use by scheduling it into practical activities, providing professional development and making available the time needed for preparing AfL-based instruction and in-class pedagogical practices (e.g., discussion) (Lee et al., 2012; Ní Chróinín & Cosgrave, 2013).

Birenbaum et al. (2011) examined the impact of the school-based professional learning community using six attributes (organizational structure, professional learning, social climate, motivation, obligation/responsibility and internal regulation). They found that all six attributes affect the quality of AfL practice. Professional learning had the highest impact on the quality of AfL practice, including learning from mistakes, student-centered instruction and fostering inquisitiveness. Additionally, teachers working in positive climates were more internally motivated and committed

to improving their practices. Other authors also reported on the influence of the classroom and school atmosphere (Harris & Brown, 2013; Havnes et al., 2012; Newby & Winterbottom, 2011; Rakoczy et al., 2008). A climate with trust, mutual respect and cooperation resulted in higher quality AfL practices than a negative climate that included mistrust, disruptive competition and stress. Positive and trustful classroom relations between teacher, students and peers are also important. The classroom atmosphere needs to signal the philosophy that mistakes are an opportunity to learn and should encourage honest reflection, so that critical feedback will be perceived as constructive instead of judgmental.

Furthermore, teachers working in schools with a decentralized organizational structure showed higher quality AfL practices than teachers who worked in a centralized organizational structure. This is supported by the finding that teachers feel pressured by the accountability system. These teachers tended to have students copy the correct information that has been written on the blackboard, which yielded lower performance than when students were allowed to do their own thinking. This pleads for respecting teachers' autonomy and professionalism and giving them ownership of assessment practices (Aschbacher & Alonzo, 2006; Birenbaum et al., 2011; Sach, 2013).

5.3.4.2 Support and professional development

Eight studies identified long-term professional development as an important feature of successful implementation of AfL (Aschbacher & Alonzo, 2006; Gottheimer & Siegel, 2012; Lee et al., 2012; Penuel et al., 2007; Phelan et al., 2012). Two of these studies showed that teacher professional development has a direct positive impact on student performance (Aschbacher & Alonzo, 2006; Phelan et al., 2012). Teachers need support regarding the use of assessment results, AfL-related teaching strategies, basic principles of good feedback, and effective questioning. This support should also include instructional resources, materials, and examples (Aschbacher & Alonzo, 2006; Gottheimer & Siegel, 2012; Lee et al., 2012; Ní Chróinín & Cosgrave, 2013; Penuel et al., 2007; Phelan et al., 2012). Again, practice-centred collaboration was found to be an important means of facilitating this kind of support. Results show teachers need to engage in conversations with colleagues about formative assessment and teaching, and collaborate on shared problems and dilemmas (Birenbaum et al., 2011; Feldman & Capobianco, 2008).

5.3.5 Student

5.3.5.1 Student knowledge and skills

Only four studies referred to the abilities that students need to make effective use of AfL, specifically in peer- and self-assessment. Newby and Winterbottom (2011) studied the use of AfL strategies and found that providing assessment criteria was important for the success of peer- and self-assessment. However, without appropriate training in the use of such criteria, students only gave feedback or shared ideas that focused on relatively straightforward improvements. Similar to Newby and Winterbottom (2011), three additional studies found evidence that students require training in providing and receiving feedback and in the use of assessment criteria for peer- and self-assessment. Students should be able to accurately assess their peers' work, identify meaningful areas for improvement and provide high quality feedback (Bryant & Carless, 2010; Harris & Brown, 2013; Newby & Winterbottom, 2011). Students can become increasingly autonomous in using set assessment criteria to assess their own or peers' work. Moreover, results suggest that students benefit more from self-directed assessment than from teacher-directed assessment in terms of learning outcomes (Fletcher & Shaw, 2012).

5.3.5.2 Student beliefs and attitudes

Eight studies imply that a positive attitude and taking an active role in their own learning process fosters autonomy and responsibility in learning for students (Bryant & Carless, 2010; Fletcher & Shaw, 2012; Harris & Brown, 2013; Havnes et al., 2012; Newby & Winterbottom, 2011; Lee, 2011). The study by Havnes et al. (2012) shows that teachers believe that passive students cannot use the teachers' feedback effectively. These authors also found that students perceived their active involvement as meaningful and useful in future learning. Fletcher and Shaw (2012) found that higher levels of student autonomy in learning and assessment processes was positively related to learning. Increased levels of behavioral, emotional and cognitive engagement also resulted in a sense of responsibility for their own learning. Furthermore, inappropriate student behavior negatively affected the implementation of AfL in the classroom (Lee, 2011; Lee et al., 2012).

5.4 Conclusions and Discussion

5.4.1 Prerequisites for the effective implementation of AfL in the classroom

A meta-analysis and review conducted on the effects of formative assessment, such as AfL, shows that formative assessment often has limited to no effects (Hendriks et al., 2014). This seems to be

due to the often ineffective implementation of formative assessment (Bennet, 2011). This study focused on one specific type of formative assessment, called AfL. Prerequisites for effective AfL implementation were investigated by means of systematic review. AfL must be implemented properly to lead to increased student learning.

Of the 1743 publications initially found, only 25 studies pertained to AfL and satisfied the inclusion and quality criteria. Similar results were found for both PE and SE contexts. In this paper, VE was not considered due to the low number of studies of sufficient quality (only three) found in this educational setting. This suggests that the availability of high quality research in this field is limited, especially in VE. Results were reported from all over the world, but the US was represented most frequently. Most of the selected studies used a qualitative research design.

The identified prerequisites were grouped into the categories ‘teacher’, ‘student’, ‘assessments’ and ‘context’, where context is limited to the contextual factors internal to the school because this review identified limited evidence with respect to contextual factors external to the school. Both sets of results not only focus on the separate categories but also suggest relationships between these categories. Based on the results, Figure 5.1 visualizes a conceptual model in which the different prerequisites important in AfL implementation are brought together. The Figure shows that these prerequisites influence the establishment of an AfL-based learning environment (‘AfL in classroom practice’) and therefore, eventually, student learning. The context greatly determines how successfully the implementation of AfL is facilitated. Teachers and students are related through their interaction in practice, for example, in discussions to elicit students’ thinking or feedback as an interactive dialogue. Both students and teachers are related to assessments through ‘enactment’. The term enactment was chosen to interpret the translation of beliefs, attitudes, knowledge or skills into actions in practice. Teachers, for example, interpret assessment information on the spot and adapt instruction. Students use the assessment criteria in peer- and self-assessment.

Figure 5.1. Conceptual model for AfL implementation.

5.4.2 Implications for practice

First, the results of our study show that it is crucial to invest in professional development. Sustainable implementation of any educational change requires change beyond surface structures or procedures, focused on altering the knowledge, skills, attitudes and beliefs of all involved agents (cf. Coburn, 2003). Furthermore, the results of the literature review support the notion that attitudes and beliefs that underlie teachers' pedagogical choices have an important influence on the extent to which the teacher can implement AfL to its full potential (cf. Hargreaves, 2005). Namely, the literature on AfL suggests that beliefs and attitudes of teachers who are committed to the underlying ideas of AfL are fundamentally different from those of teachers that only use routine/procedural expertise (Bransford, 2001, in Lysaght & O'Leary, 2013; Marshall & Drummond, 2006; Pedder & James, 2012). Professional development should explicitly address how all five AfL strategies can be integrated in classroom practice in order to maximize its potential impact.

Second, although previous research shows that educational policies have major implications for the implementation of AfL (Birenbaum et al., 2015; Marshall & Drummond, 2006), only one study in our review referred to a policy-related factor external to the school, namely the pressure of the accountability system on teachers' work (Sach, 2013). This can lead to a narrow focus on the use of standardized test results, and result in practices unhelpful to student learning, such as teaching to the test, and even manipulating test scores and test samples (e.g., Booher-Jennings, 2005). The influence of factors from both school based policy and educational policy should be taken into account when implementing AfL, which will be unique for each particular context.

Third, the role of the student should be taken into account when implementing AfL. It should be noted that only a relatively small number of studies referred to prerequisites regarding students. This is remarkable, as modern assessment theory emphasizes a critical role for students in assessment (Black, 2015), particularly in AfL as its definition focuses on everyday classroom life in which teachers and students are key agents (Pedder & James, 2012). Studies that did consider the role of students all emphasized on the need for training in the use of assessment criteria for providing meaningful feedback. However, students also need to be motivated to invest effort in seeking and processing feedback (Ruiz-Primo & Furtak, 2006; Timmers & Veldkamp, 2011), which was not considered in these studies.

Furthermore, although we found no explicit differences in the prerequisites for primary and secondary education, the specific implications for practice may differ. For example, teachers in both contexts would be required to hold pedagogical content knowledge, but in primary education this knowledge would need to cover a considerable body of the curriculum, whereas in secondary education this would be specific to a particular subject area that a teacher teaches.

Finally, these results highlighted that these researchers aligned AfL with a constructivist approach to learning. The constructivist, student-centered approach to learning suggests students and teachers should work together interactively, embrace the social interaction between students, peers and teachers, and share responsibility for learning (Black & Wiliam, 1998a, 1998b; Heritage, 2010; Tunstall & Gipps, 1996). This is not to say that other learning theories are not important in AfL, for example, AfL is also underpinned by ideas from metacognitivism and social cultural theory. However, in much research on formative assessment the focus is the teacher-student interaction, and underlying theoretical assumptions about the nature of learning remain implicit (Van der Kleij et al., 2015). In practice, 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 than the others (Niederhauser & Stoddart, 2001).

5.4.3 Limitations

As with every systematic review, one limitation of this study is that it was impossible to include all relevant studies. The search strategies and selection criteria used in this review determined the selected set of studies. Furthermore, time pressure, publication bias and researcher bias were potential threats to the quality of this review. However, these threats were constantly monitored and addressed (Petticrew & Roberts, 2006). The research team frequently discussed methods and results, data extraction forms were supported by clear instructions, data were double-coded and low quality studies were excluded. Additionally, external experts were involved to verify the chosen strategies and the identified results.

5.4.4 Implications for further research

The results of this review show that most studies were based on a small-scale, qualitative research design, as was also noted by Baird et al. (2014). Few AfL studies are based on large-scale or quantitative research. When studies do focus on large-scale implementation of AfL, the results are often limited to student and teacher perceptions as the main dependent variable (cf. Hopfenbeck & Stobart, 2015). Therefore, the time has come to invest as well in large-scale quantitative studies investigating the factors that enable or hinder the implementation of AfL in the classroom. This can provide insight into which factors matter the most when using AfL in the classroom to improve student learning.

Furthermore, the results of this review can inform additional future research, as they contribute to a better understanding of the multiple facets that need to be considered when implementing AfL, both theoretically and practically. Future studies should preferably focus on large-scale research in local contexts that take a more comprehensive view and consider the prerequisites identified as important for effective AfL implementation in this study. The conceptual framework can be used to inform practical initiatives such as professional development in which the entire school is involved. It should be remembered that educational practice is greatly influenced by the dynamics of classroom life and depends on the classroom context. This means that an exact prescription for success cannot be provided, and local practitioners need to translate prerequisites important for AfL implementation to their local context for such implementation to lead to increased student learning.

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Chapter 6

General conclusions and discussion

In our current society, the use of technology for teaching and learning purposes seems to be taken for granted. However, several studies have shown that the adequate use of technology in day-to-day practices is not obvious and that there is still much room for improvement in the technological competences of both students and teachers (e.g., Aesaert & van Braak, 2015; European Commission, 2013; Fraillon, Ainley, Schulz, Friedman, & Gebhardt, 2014; van Deursen & van Diepen, 2013). Therefore, there needs to be instruction that is focused on teaching these skills. However, research into the measurement of the actual technological skills of teachers and students is limited (cf. Aesaert & van Braak, 2018). Measuring technological skills is often done through indirect and inauthentic measures (self-report, pencil and paper tests), which measure an interpretation of skills rather than actual performance. (cf. Aesaert & van Braak, 2018; Christensen & Knezek, 2018). The assessment of performance, however, depends on methods that successfully elicit the behavior that needs to be measured. Therefore, the overarching aim of this dissertation was to investigate how to elicit the actual technological skills of teachers and students for the assessment of these skills in authentic educational settings. The four studies presented in the previous chapters contributed to this overarching aim.

6.1 Eliciting teachers' technological skills

The first two studies presented in this dissertation were focused on ways to elicit the technological skills of teachers. These studies were based on the argument that teachers' technological skills are displayed through their enactment of technology-infused pedagogical practices in conjunction with the professional reasoning on which their practices rely. In the first study, the following research question was answered: How do teachers reason about the use of technology in their pedagogical practice? Sub-questions concentrated on (1) how teachers reason professionally about their use of technology, (2) how teachers use technology in their pedagogical practice and (3) to

what extent teachers' professional reasoning aligned with their use of technology in practice. Through video cases, 157 primary and secondary education teachers demonstrated their technology use in practice and commented on their actions. Most teachers used technology to support a learning activity. The underlying reasons that the teachers mentioned were related to making their teaching attractive, to facilitate the learning process, and to realizing educational goals. Most technology use was intended to strengthen both pedagogy and subject matter, or only pedagogy. The majority of teachers' technology use in practice shows aspects of the knowledge transfer model of teaching and about half of the video cases showed good alignment between reasoning and practice.

The second study provided a more detailed view of how having teachers discuss their reasoning about their pedagogical choices elicited their technological skills. Through their reasoning teachers displayed their knowledge about how technology can be used effectively to enhance student learning. The study focused on pedagogical strategies (e.g., activating learning, classroom management, dealing with diversity, fostering learning strategies) that teachers use in practice, as these reflect the teaching choices they make based upon professional reasoning. The research question for this study was: How and why do teachers use technology to facilitate their enactment of pedagogical strategies in practice? Sub-questions addressed (1) how teachers used technology to facilitate the enactment of pedagogical strategies and (2) how teachers reasoned about the use of technology to facilitate the enactment of pedagogical strategies. Data from 29 video cases showed how primary teachers used technology to facilitate specific pedagogical strategies.

The teachers who participated in this study showed their use of technology to support enactment of a variety of pedagogical strategies, namely, student involvement, a safe learning climate, classroom management, activation of student learning, clear instruction, adaptive teaching and for teaching learning-to-learn strategies. However, by far the most frequent technology use was for supporting pedagogical strategies to promote "activation of student learning". Although only a few teachers showed behavior supporting the enactment of the pedagogical strategies of "supporting adaptive teaching" and "teaching learning-to-learn strategies", if they showed this behavior, they almost always used technology to facilitate these pedagogical strategies. Although many teachers reasoned about using technology for adapting their teaching to student needs, this was seldom observed in their teaching practices.

Using video cases in which teachers explain their reasons for their practice proved to be a valuable approach to elicit teachers' technological skills. By capturing both teachers' technology use and

their reasoning about this use, we were able to portray a more precise picture of teachers' reasons for using technology than would be possible through self-reports (Christensen & Knezek, 2009) or observation only (cf. Hargittai, 2002; Schulz-Zander, Pfeifer, & Voss, 2008). Furthermore, just as in other studies (e.g. Allayar, 2011; Hakkarainen et al., 2000; Merritt, Smith, & Di Renzo, 2005), these two studies showed that there was often a mismatch between teachers' reasoning and their practice. Teachers' effective use of technology might improve if they become more able to explicitly articulate the reasoning behind the use of technology in their teaching, share this reasoning with colleagues and confront their reasoning with findings from research. Eliciting teachers' technological pedagogical knowledge can, for example, give insight into whether teachers' technology use is effective and can identify knowledge gaps and misconceptions about their use of technology. These insights enable targeted interventions focused on preparing teachers for integrating technology in their educational practice. 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. Video cases may provide such examples.

6.2 Eliciting students' technological skills

The third study examined the elicitation of students' technological skills through a digital assessment environment in which students had to apply their technology skills in authentic tasks. An authentic digital assessment environment for eliciting students' online information literacy skills was designed and developed. Both students' responses to the assessment tasks and their search behaviors (use of search terms and search strategies) were investigated. This study was guided by two questions: (1) How do upper primary and lower secondary education students differ in their online information literacy skills? and (2) how do upper primary and lower secondary education students differ in their use of search terms and their online search strategies? A total of 1036 students from upper primary and lower secondary education participated in this study. Online information literacy is not a given for all students; differences were found in the assessment results and the search behaviors of students from different educational levels. Pre-vocational education students were less competent with regard to skills related to online information literacy than students from primary education or pre-university education. Most students searched for information predominantly with a whole sentence or question instead of using keywords, and often used ineffective search strategies.

Using the digital assessment environment to assess students' online information literacy skills showed high potential. By using the digital assessment environment, we were not only able to

elicit students' skills through the authentic tasks, we were also able to track data that revealed students' search behaviors. The results of this study suggest that it is important to obtain detailed insights into the various skill domains of students' online information literacy skills as well as their search behaviors to prevent a possible digital divide between students from different educational levels. The assessment used in this study was designed to measure and monitor the skill domains related to online information literacy in an authentic way. By gathering data about students' responses to the tasks and their search behaviors, we were able to identify students' weak skill domains. This information can ultimately be used to inform teachers and students about students' online information literacy, and the assessment can be integrated with teachers' instruction and students' learning processes.

6.3 Assessment of technological skills in classroom practice

Capturing teachers' and students' technological skills in authentic settings should eventually lead to more reliable and valid assessment of these skills as used in educational practice. The studies presented in this dissertation started from the assumption that assessment of teachers' and students' technological skills should be based on practical and authentic situations and requires a personalized approach to assessment that emphasizes the learning process more than the eventual performance (cf. Lodge, 2018; Webb & Ifenthaler, 2018). Hence, an appropriate approach to assessing technological skills would be formative assessment (Stobart, 2008). The fourth study concerns a systematic literature review that is focused on revealing the prerequisites that need to be considered when implementing formative assessment, specifically Assessment for Learning, with the potential to support learning in classroom practice. Assessment for learning (AfL) is a specific approach to formative assessment in which formative assessment occurs as part of ongoing classroom practices (Klenowski, 2009) and is viewed as a social and contextual event that is focused on the quality of the learning process (Stobart, 2008). Continual feedback is integrated within this process to guide future learning (Elwood & Klenowski, 2002). An extensive literature search resulted in 25 relevant studies from primary and secondary education for this review. Results identified prerequisites regarding the teacher, student, assessment and context. This review was guided by the following research question: What prerequisites regarding the teacher, student, assessment and context need to be considered when implementing assessment for learning in the classroom? Key conditions that were found were: teachers must be able to interpret assessment information on the spot, student engagement in the assessment process is vital, assessment should include substantial, constructive and focused feedback, and the school should have a school-wide culture that facilitates collaboration and encourages teacher autonomy.

Studies regarding the implementation of AfL are still limited, and this review can be used as groundwork for further investigation of the factors that enable or hinder the implementation of AfL in the classroom. This information can provide insight into which factors matter the most when using AfL in the classroom to improve student learning.

The prerequisites identified in this study are also relevant for the assessment of technological skills in classroom practice. Further research could focus on how best to formatively assess students' technological skills and what conditions need to be in place to have students, teachers and schools engaged in the assessment. An important condition in this regard is also the need for teachers to have knowledge and skills regarding the use of hardware and software related to computer-based assessment (e.g., computer response systems for immediately collecting students' responses to short questions).

6.4 Closing remarks

In this dissertation, the study of students' technological skills was focused on only one skill domain, namely online information literacy skills. To get a complete picture of the technological skills of students, the assessment would also need to include other skill domains. Well-known frameworks that describe students' technological skills also mention areas of competence such as computational thinking and media literacy. However, because a feature of the digital world is its quickly changing nature, more and more researchers have stressed the importance of students' self-reliance and adaptability in digital environments, as well as the more ethical aspects that come with using technology (cf. Passey et al., 2018). Therefore, to get a more complete picture of students' technological skills, research also needs to incorporate other aspects of these skills, such as the use of technology to collaborate, the social skills needed in social networking and students' self-reliance in technology-rich environments.

In this study, a digital assessment environment was developed to elicit students' technological skills in authentic settings. Recent technological developments have also shown that technology can be used to integrate assessment into the learning process itself. In this approach, assessment is no longer separated from learning. Assessment as learning is also referred to as stealth assessment (Shute, 2011) or quiet assessment (Webb, Gibson, & Forkosh-Baruch, 2013). In the third study, an attempt was made to collect data about students' search behavior. An example of assessment as learning would be to provide immediate feedback to students about their search behavior in order to improve it, while they are working on the authentic tasks. In this way,

sophisticated, unobtrusive monitoring of students' development of their online information literacy skills would become a part of their learning process. However, more research with teachers and schools is needed to further expand this approach to assessment (cf. Ifenthaler, Greiff, & Gibson, 2018).

The assessment of students' technological skills depends on the technological skills of the teacher. However, the studies in this dissertation showed that teachers are often not fully equipped with the appropriate technological skills for teaching and learning with technology (cf. Lei, 2009). This also makes it hard for teachers to teach technological skills to students and to assess students' technological skills (cf. Aesaert & van Braak, 2018). In particular, teachers often do not fully possess the technological competences needed to use computer-based assessments for assessing students' technological competences. Another important step to take, therefore, is to focus on developing assessment instruments that are easy to use and accessible for teachers. These instruments should not only help teachers in identifying gaps in students' technological competences, but also inform them about the nature of these gaps.

When considering students' and teachers' technological skills, we should be aware of the rapidly changing nature of the digital world. Technological innovations often offer new possibilities for teaching and learning in the classroom, with the consequence that some skills disappear and new skills are required (ACARA, 2015). To offer relevant educational experiences for their students with technology, teachers should be able to respond to these changes in society. This is important from the perspective of teaching *with* technology as well as teaching *about* technology. In this dissertation, it was argued that a professional reasoning process is fundamental to teachers' practice; it was also suggested that elicitation of this reasoning can be facilitated by reflection on practical authentic examples. To improve effective teaching with technology, teachers' reasoning about how the use of technology may contribute to teaching and learning needs to be further developed. To do so, an approach is needed in which technology is seen as a pedagogical tool that can help realize teachers' instructional designs (cf. Angeli & Valanides, 2018). Research should focus on understanding the professional reasoning that teachers use to change the technical affordances of technological tools into pedagogical affordances, which they can use in their educational context. The instrument used in the second study focused on technology use to support effective teaching behavior related to specific pedagogical strategies. Teachers can use this instrument to learn how to change technological tools into pedagogical tools, not only for teaching with technology, but also for teaching about technology. 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. Finally, it should be remembered that teachers should not start from the idea of using technology in their teaching, but should start from the content they are going to teach, and then look for ways to use technology to strengthen their teaching and enhance student learning.

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English summary

Given the vast development of technological applications, education cannot ignore the use of technology in preparing students for participation in society. Technology use in education has become both a goal and a tool, implying that teachers need to be able to use technology as an effective tool in their teaching and students need to learn how to use technology appropriately in their day-to-day lives. In our current society, the use of technology for teaching and learning purposes seems to be taken for granted. However, several studies have shown that the appropriate use of technology in day-to-day practices is not obvious and that there is still much room for improvement in the technological competences of both students and teachers. Measuring or mapping students' and teachers' technological skills is necessary for effective education in which using technology is either a goal or a tool. However, research into the measurement of the actual technological skills of teachers and students is limited. Measuring technological skills is often done through indirect and inauthentic measures (self-report, pencil and paper tests), which measure an interpretation of skills rather than actual performance. The assessment of performance, however, depends on methods that successfully elicit the behavior that needs to be measured. Therefore, the overarching aim of this dissertation was to investigate how to elicit the actual technological skills of teachers and students for the assessment of these skills in authentic educational settings. The four studies presented in the previous chapters contributed to this overarching aim.

The first two studies presented in this dissertation were focused on ways to elicit the technological skills of teachers. These studies were based on the argument that teachers' technological skills are displayed through their enactment of technology-infused pedagogical practices in conjunction with the professional reasoning on which their practices rely. In the first study, the following research question was answered: How do teachers reason about the use of technology in their pedagogical practice? Through video cases, 157 primary and secondary education teachers demonstrated their technology use in practice and commented on their actions. Most teachers used technology to support a learning activity. The underlying reasons that the teachers mentioned were related to making their teaching attractive, facilitating the learning process, and realizing educational goals. Most technology use was intended to strengthen either pedagogy and subject matter learning, or only pedagogy. The majority of teachers' technology use in practice

showed aspects of the knowledge transfer model of teaching and about half of the video cases showed good alignment between reasoning and practice.

The second study provided a more detailed view of how teachers reason about their use of technology in the pedagogical choices they make. The study focused on pedagogical strategies (e.g., activating learning, classroom management, dealing with diversity, fostering learning strategies) that teachers use in practice, as these reflect the teaching choices they make based upon their professional reasoning. The research question for this study was: How and why do teachers use technology to facilitate their enactment of pedagogical strategies in practice? Data from 29 video cases showed how primary teachers used technology to facilitate specific pedagogical strategies. The teachers who participated in this study showed their use of technology to support enactment of a variety of pedagogical strategies, namely, student involvement, a safe learning climate, classroom management, activation of student learning, clear instruction, adaptive teaching and for teaching learning-to-learn strategies. However, by far the most frequent technology use was for supporting pedagogical strategies to promote activation of student learning. Only a few teachers showed behavior supporting the enactment of the pedagogical strategies of supporting adaptive teaching and teaching learning-to-learn strategies, however, if they did show this behavior, they almost always used technology to facilitate these pedagogical strategies. Although many teachers reasoned about using technology to adapt their teaching to student needs, this was seldom observed in their teaching practices.

The third study examined the elicitation of students' technological skills through a digital assessment environment in which students had to apply their technology skills in authentic tasks. An authentic digital assessment environment for eliciting students' online information literacy skills was designed and developed. Both students' responses to the assessment tasks and their search behaviors (use of search terms and search strategies) were investigated. This study was guided by two questions: (1) How do upper primary and lower secondary school students differ in their online information literacy skills? and (2) how do upper primary and lower secondary school students differ in their use of search terms and their online search strategies? A total of 1036 students from upper primary and lower secondary schools participated in this study. This study showed that students from different educational levels differed in their online information literacy skills and their search behaviors. Pre-vocational students were less competent with regard to skills related to online information literacy than primary or pre-university students and students from general secondary education. Most students searched for information predominantly with a whole sentence or question instead of using keywords, and often used ineffective search strategies.

Capturing teachers' and students' technological skills in authentic settings should eventually lead to more reliable and valid assessment of these skills as used in educational practice. The studies presented in this dissertation started from the assumptions that assessment of teachers' and students' technological skills should be based on practical and authentic situations and that it requires a personalized approach to assessment that emphasizes the learning process more than the eventual performance. Hence, an appropriate approach to assessing technological skills would be formative assessment. Therefore, the fourth study concerned a systematic literature review that focused on revealing the prerequisites that need to be considered when formative assessment with the potential to support learning is implemented in classroom practice. This review was guided by the following research question: What prerequisites regarding the teacher, student, assessment and context need to be considered when implementing Assessment for Learning (AfL, a formative assessment approach) in the classroom? An extensive literature search resulted in 25 relevant studies from primary and secondary education for this review. Results identified prerequisites regarding the teacher, student, assessment and context. Key conditions that were found were: teachers must be able to interpret assessment information on the spot, student engagement in the assessment process is vital; assessment should include substantial, constructive and focused feedback; and the school should have a school-wide culture that facilitates collaboration and encourages teacher autonomy. The prerequisites identified in this study are also relevant for the assessment of technological skills in classroom practice. Further research could focus on how best to formatively assess students' technological skills and what conditions need to be in place to have students, teachers and schools engaged in the assessment. An important condition in this regard is also the need for teachers to have knowledge and skills regarding the use of hardware and software related to computer-based assessment (e.g., computer response systems for immediately collecting students' responses to short questions).

When considering students' and teachers' technological skills, we should be aware of the rapidly changing nature of the digital world. Technological innovations often offer new possibilities for teaching and learning in the classroom, with the consequence that some skills disappear and new skills are required. Both teachers and students should be able to respond to these changes in society in order to adapt to and master the digital world.

Nederlandse samenvatting

Relevante informatie vinden op internet, online solliciteren, (internationaal) communiceren via technologie en digitale producten creëren zijn voorbeelden van digitale vaardigheden die zijn ontstaan door de komst van digitale technologie in onze samenleving. De toepassing van deze vaardigheden blijken nog beperkt in het Nederlandse onderwijs, terwijl deze van groot belang zijn om te kunnen functioneren in de digitale maatschappij waarin wij leven. Om leerlingen op de huidige maatschappij voor te kunnen bereiden zal het onderwijs op de snelle technologische ontwikkelingen in moeten spelen. Het gebruik van digitale technologie in het onderwijs is daarom zowel een doel als een middel geworden. Dit betekent dat docenten digitale technologie in moeten kunnen zetten als effectief middel in hun onderwijs, en dat leerlingen moeten leren hoe ze digitale technologie op een effectieve manier kunnen gebruiken in hun dagelijks leven. In onze huidige maatschappij wordt het gebruik van digitale technologie voor leren en lesgeven als vanzelfsprekend beschouwd. Echter, uit verschillende studies blijkt dat de competenties van leerlingen en docenten op het gebied van digitale technologie-gebruik vaak nog verbeterd kunnen worden.

Voor effectief onderwijs waarin digitale technologie zowel als doel en als middel gebruikt wordt, is het noodzakelijk de digitale vaardigheden van leerlingen en docenten te kunnen meten. Onderzoek naar het meten van deze vaardigheden is beperkt. Vaak worden digitale vaardigheden op een indirecte manier gemeten (bv. via zelfrapportage) en zijn de situaties waarin de vaardigheden gemeten worden niet authentiek. Deze manier van meten levert een interpretatie van vaardigheden op, maar geeft geen zicht op daadwerkelijke prestaties. Het toetsen van vaardigheden is afhankelijk van de manier waarop de respondent uitgedaagd wordt om het beoogde gedrag te laten zien. De studies in dit proefschrift zijn daarom gericht op de manier waarop leerlingen en docenten hun digitale vaardigheden uiten met als doeleinde deze vaardigheden te kunnen toetsen in authentieke onderwijssituaties. De vier studies, gepresenteerd in de voorgaande hoofdstukken, hebben bijgedragen aan dit overkoepelende doel.

De eerste twee studies gingen over de manier waarop docenten hun digitale vaardigheden uiten. Deze studies waren gebaseerd op de redenering dat de (didactische) digitale vaardigheden van de docent tot uiting komen in het didactische handelen met betrekking tot de inzet van digitale technologie in de lespraktijk en het vermogen om hierover professioneel te redeneren. De eerste

studie richtte zich op het professionele redeneren van docenten over het gebruik van digitale technologie in hun onderwijspraktijk. Zowel het redeneren van docenten als het handelen in de onderwijspraktijk werd onderzocht. Met behulp van video's lieten 157 docenten uit het basis- en voortgezet onderwijs zien op welke manier zij digitale technologie gebruikten in hun onderwijspraktijk. De onderliggende redenen die docenten gaven om digitale technologie te gebruiken waren gerelateerd aan het aantrekkelijk maken van hun onderwijs, het ondersteunen van het leerproces en het realiseren van onderwijsdoelen. Docenten gebruikten digitale technologie het meest om het overbrengen van vakinhoud te bevorderen of om hun didactische aanpak te ondersteunen. Ongeveer de helft van de video's liet een overeenkomst zien tussen de redeneringen die docenten gaven en het handelen dat docenten in de praktijk lieten zien.

De tweede studie ging verder in op het professioneel redeneren van docenten over het didactisch handelen met betrekking tot de inzet van digitale technologie in de lespraktijk. Deze studie richtte zich op didactische strategieën (bv. activeren van leren, klassenmanagement, differentiëren, leren leren) die docenten in hun onderwijs gebruiken. Deze studie richtte zich op hoe en waarom docenten digitale technologie inzetten in hun onderwijs om hun didactisch handelen te ondersteunen. Zowel het redeneren met betrekking tot hun didactisch handelen met digitale technologie als de manier waarop zij digitale technologie gebruikten om hun didactisch handelen te ondersteunen werd onderzocht. Data van 29 video's lieten zien op welke manier basisschooldocenten digitale technologie gebruikten ter ondersteuning van specifieke didactische strategieën. Strategieën die zij lieten zien waren: betrekken van leerlingen, een veilig leerklimaat, klassenmanagement, activeren van leren, duidelijke instructie, differentiëren en het aanleren van strategieën die leerlingen helpen te leren leren. De studie toonde aan dat de docenten digitale technologie het meest inzetten ter ondersteuning van didactische strategieën die het activeren van leren bevorderen. Maar een paar docenten lieten in hun didactisch handelen differentiëren of het 'leren leren' zien. Echter, als docenten dit didactisch handelen lieten zien gebruikten zij bijna altijd digitale technologie om deze didactische strategieën te ondersteunen. Ondanks dat veel docenten redeneerden over het gebruik van digitale technologie om hun lesgeven aan te passen aan de behoeften van leerlingen, werd dit zelden geobserveerd in de praktijk.

De derde studie onderzocht de manier waarop leerlingen hun digitale vaardigheden uitten met behulp van een digitale toetsomgeving waarin leerlingen hun vaardigheden moesten toepassen in authentieke situaties. Een digitale toetsomgeving gericht op de beoordeling van digitale informatievaardigheden werd ontworpen en ontwikkeld. Zowel de respons die leerlingen gaven op de toetstaken als hun zoekgedrag (gebruik van zoekopdrachten en zoekstrategieën) werd

onderzocht. Deze studie richtte zich op de manier waarop leerlingen aan het eind van het basisonderwijs en aan het begin van het voortgezet onderwijs verschillen in hun digitale informatievaardigheden en verschillen in het gebruik van zoektermen en zoekstrategieën. 1036 leerlingen namen deel aan de studie. De studie liet zien dat leerlingen uit de verschillende onderwijsniveaus verschilden in hun testresultaten en hun zoekgedrag. Leerlingen uit het vmbo scoorden hierbij minder goed dan de basisschoolleerlingen en de leerlingen uit het havo/vwo. Bij het zoeken naar informatie op internet gebruikten de meeste leerlingen een hele zin of vraag, in plaats van trefwoorden, en vaak waren hun zoekstrategieën niet erg effectief.

Het direct toetsen van digitale vaardigheden van docenten en leerlingen zou uiteindelijk moeten leiden tot een betrouwbare en valide beoordeling van deze vaardigheden zoals deze gebruikt worden in de praktijk. De studies in dit proefschrift zijn vertrokken vanuit de veronderstelling dat het toetsen van de digitale vaardigheden van docenten en leerlingen gebaseerd moet zijn op praktische en authentieke situaties, en dat het toetsen van dergelijke vaardigheden een gepersonaliseerde benadering vereist die meer nadruk legt op het leerproces dan de uiteindelijke prestatie. Daarom zou formatief toetsen een gepaste benadering voor het toetsen van digitale vaardigheden zijn. De vierde studie omvatte een systematisch literatuuronderzoek dat zich richtte op de voorwaarden die nodig zijn om formatief toetsen in de klas te implementeren. Dit literatuuronderzoek ging specifiek in op de voorwaarden omtrent de docent, leerling, toets en context die nodig zijn voor het implementeren van Assessment for Learning (AfL, een benadering van formatieve toetsen) in de klas. Belangrijke bevindingen waren dat docenten de informatie die voort komt uit de toets ter plekke moet kunnen interpreteren, de betrokkenheid van leerlingen in het toetsproces cruciaal is, toetsen inhoudelijke, constructieve en gerichte feedback bevatten en er in de school een schoolbrede cultuur is die samenwerking faciliteert en de autonomie van docenten stimuleert. De voorwaarden die in deze studie geïdentificeerd werden, zijn ook relevant voor het toetsen van digitale vaardigheden in de lespraktijk. Verder onderzoek kan zich richten op de manier waarop de digitale vaardigheden van leerlingen het best op een formatieve manier getoetst kunnen worden en welke condities belangrijk zijn om leerlingen docenten en scholen te betrekken bij het toetsproces. Een belangrijke bevinding met betrekking tot het toetsen van digitale vaardigheden is dat docenten kennis en vaardigheden nodig hebben met betrekking tot het gebruik van hardware en software gerelateerd aan computer gebaseerde toetsen.

Bij het operationaliseren van de digitale vaardigheden van docenten en leerlingen zouden we rekening moeten houden met de snelle veranderingen die de digitale wereld met zich mee brengt. Technische innovaties bieden vaak nieuwe mogelijkheden voor leren en lesgeven, met de

consequentie dat sommige vaardigheden verdwijnen en nieuwe vaardigheden vereist zijn. Zowel docenten als leerlingen moeten in staat zijn om met deze veranderingen om te kunnen gaan zodat zij zich aan kunnen passen aan de digitale wereld.

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