Promoting the development of teacher professional knowledge Integrating content and pedagogy in teacher education

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Highlights

- Only PK and CK instruction is insufficient to develop PCK in teacher education
- Only PCK instruction is insufficient to develop PK and CK in teacher education
- Explicit presentation of PCK, PK, and CK leads to optimal professional knowledge
- Integrated instruction leads to similar PCK development as segregated instruction

Abstract

The study investigates the explicit and integrated presentation of pedagogical content knowledge (PCK), pedagogical knowledge (PK), and content knowledge (CK) in teacher education. We compare learning environments to study whether only presenting PK and CK is sufficient for PCK development, whether only presenting PCK is sufficient for PK and CK development, and whether PCK development is affected by integrating PCK, PK and CK. We find that only presenting two knowledge domains to students is insufficient to develop the third one, and integrating knowledge domains does not impact PCK development.

1. Introduction

Teacher professional knowledge is assumed to be central to student learning (Connelly, Clandinin, & He,1997). Empirical studies have shown the importance of teachers' professional knowledge, and more specifically of their pedagogical content knowledge (PCK), pedagogical knowledge (PK), and content knowledge (CK) for educational quality and student outcomes (Baumert et al., 2010; Kunter et al., 2013; Konig € & Pflanzl, 2016; Sadler, Sonnert, Coyle, Cook-Smith, & Miller, 2013; Voss, Kunter, & Baumert, 2011). It is therefore an important task of teacher education to facilitate the development of pre-service teachers' professional knowledge (Kleickmann et al., 2013). Until now it is unclear how teacher education programs should be organized in order to optimally develop pre-service teacher knowledge (with the ultimate goal to improve educational practice) (Ball, 2000; Zeichner, 2012). At least the following two issues are subject of debate. A first issue concerns the necessity to explicitly provide all three knowledge domains (PCK, PK and CK) in teacher education curricula in order to develop pre-service teacher knowledge. According to Gess-Newsome (1999), conceptualizations of teacher professional knowledge and their views on knowledge development in teacher education can be positioned on a continuum. Both ends of this continuum represent extreme views that claim that certain knowledge categories automatically develop when others are presented. On the one hand, integrative models claim that PCK will automatically develop when only PK and CK are presented to pre-service teachers, and therefore explicit PCK instruction is unnecessary in teacher education. On the other hand, transformative models claim that only PCK should be presented in teacher education (without an explicit focus on PK and CK), which will cause pre-service teachers to automatically develop PK and CK (GessNewsome, 1999). Second, although currently most teacher education institutions present courses on PCK, PK and CK separately (Ball, 2000; Harr, Eichler, & Renkl, 2014), the question could be asked whether or not this segregated presentation of knowledge categories is the most optimal way to develop teacher professional knowledge. Until now, some studies have shown positive effects of an integrated presentation of knowledge domains (Harr, Eichler, & Renkl, 2015; Harr et al., 2014; Janssen & Lazonder, 2016). However, none of these studies addressed all three knowledge categories (PCK, PK and CK). The present study empirically investigates these two issues. Several variations of a systematically designed computer-based learning environment are compared with regard to their effect on teacher professional knowledge. The learning environments vary with respect to whether knowledge domains (PCK, PK and CK) are explicitly presented, and concerning the integration of knowledge categories.

2. Theoretical framework

2.1. Teacher professional knowledge

Research on teacher professional knowledge is mainly inspired by the work of Shulman (1986, 1987). In 1986 Shulman introduced the concept PCK as an answer to the so-called "missing paradigm" in research and practice on teaching, which until then was biased towards either knowledge about content or knowledge about pedagogy. Shulman defined PCK as "that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (Shulman, 1987, p. 8). Shulman (1987) claimed that PCK allows to distinguish the understanding of a content specialist from the understanding of a teacher. He considered PCK as the most important category of teachers' professional knowledge base. Shulman (1986) distinguished two main components that constitute PCK: the most regularly taught topics in one's subject area and their most useful forms of representation, and an understanding of what makes the learning of several topics easy or difficult for students. Since its introduction, PCK has often been studied, and Shulman's conceptualization has been adapted by several scholars. For instance, Grossman (1990) added two components to Shulman's original PCK components, that is, knowledge of curriculum and knowledge of purposes for teaching. Another widely used conceptualization of PCK is the Magnusson model (Magnusson, Krajcik, & Borko, 1999). In this model PCK is defined as "a teacher's understanding of how to help students to understand one specific subject matter" (Magnusson et al., 1999, p. 96). The Magnusson model added three components to the original ones of Shulman, that is, orientations to teaching subject matter (i.e., purposes and goals for teaching), knowledge of curricula, and knowledge of assessment. According to this model, orientations to teaching subject matter interact with all other components. Currently, educational research considers PCK, PK and CK as the most important categories of teachers' professional knowledge base (Krauss, Baumert, & Blum, 2008a). CK was originally defined by Shulman (1987) as the knowledge that should be learned by students. Most authors agree on the idea that teachers should know the learning content at a more advanced level than their students (Baumert et al., 2010; Kleickmann et al., 2013), and that CK is knowledge that can be positioned in between academic knowledge generated at universities and everyday knowledge that is taught in schools (Krauss et al., 2008b). In Shulman's definition, PK includes "broad principles and strategies of classroom management and organization that appear to transcend subject matter" (Shulman, 1987, p. 8). According to Voss et al. (2011), definitions of PK converge on the idea that PK is generic and domain general, but disagree on the components that are part of PK. During the last decade, two research groups developed conceptualizations of PK (Konig, Bl € omeke, Paine, Schmidt, € & Hsieh, 2011; Voss et al., 2011). Konig et al. (2011) €

included the domains ‘structure’ (i.e., how to prepare, structure and evaluate lessons), ‘motivation and classroom management’ (i.e., how to motivate and support students as well as manage the classroom), ‘adaptivity’ (i.e., how to deal with heterogeneous learning groups), and ‘assessment’ (i.e., how to evaluate students). Voss et al. (2011) included the domains ‘teaching methods’ (i.e., how to use a repertoire of methods appropriately in any given educational setting), ‘classroom management’ (i.e., how to organize and manage the classroom and keep groups of students on task), ‘classroom assessment’ (i.e., how to judge students' progress toward their goals) and ‘students’ heterogeneity’ (i.e., knowledge about learning processes and individual characteristics) in their conceptualization of PK (which they called general pedagogicalpsychological knowledge). Across definitions, there seems to be agreement that PK comprises at least knowledge on teaching methods and on classroom management, which are the two PK components originally distinguished by Shulman (1987). Teacher professional knowledge has been studied from at least two perspectives, a situated and a cognitive one (Depaepe, Verschaffel, & Kelchtermans, 2013). Researchers who study teacher knowledge from a situated perspective consider teacher professional knowledge as dynamic knowledge in action. Studies following this perspective are mainly small scale and aim at capturing knowledge that is closely connected to the classroom context, for instance through interviews and observations. On the other hand, in a cognitive approach teacher professional knowledge is studied from a more static point of view. This perspective mainly results in generalizable large-scale studies, and measures teacher knowledge by means of quantitative instruments (Depaepe et al., 2013). The distinction between situated and cognitive perspectives can also be framed within the recent model of teacher professional knowledge and skill, a consensus model reached by international experts in the PCK domain on the PCK summit 2012 and described by Gess-Newsome (2015). This model distinguishes several types of teacher professional knowledge, two of which are topic-specific professional knowledge and personal pedagogical content knowledge and skill. Topic-specific professional knowledge is static knowledge on how to teach a specific topic, that is public and visible, and can easily be recorded (Gess-Newsome, 2015). It is the kind of knowledge that is studied in a cognitive perspective on teacher professional knowledge. Personal pedagogical content knowledge and skill, on the other hand, is the (knowledge of) teaching in a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes (Gess-Newsome, 2015) and is therefore similar to how situated perspectives consider PCK. Although we recognize the importance of studying teacher professional knowledge from both perspectives as they complement each other, the present study takes a cognitive perspective on teacher professional knowledge. The advantage of this perspective is that it enables studying teacher knowledge on a large scale and thus might lead to more generalizable results (Stahnke, Schueler, & Roesken-Winter 2016).

2.2. Importance of teacher professional knowledge

Shulman's (1986, 1987) claim about the importance of teacher professional knowledge has been empirically validated by several studies showing a positive impact of teacher professional knowledge on educational quality and student learning (Baumert et al., 2010; Kunter et al., 2013; Sadler et al., 2013; Voss et al., 2011). The importance of PCK, PK and CK has been empirically shown in the domain of mathematics, a domain in which a lot of research on teachers' professional knowledge has been conducted (Ball, Thames, & Phelps, 2008). Baumert et al. (2010) showed that mathematics teachers' CK and especially their PCK had a significantly positive impact on instructional quality (i.e., the degree of cognitive challenge and activation offered to students, the degree of learner support provided, and efficient classroom management, measured by means of student ratings, teacher self-reports, and task analyses) and on student achievement (assessed by means of a pre- and posttest). Sadler et al. (2013) showed a positive impact of teachers' ability to recognize student misconceptions (as a part of PCK) and CK on student achievement on standardized mathematics posttests (after controlling for pretest scores). Again, PCK had the largest influence on student achievement. Furthermore, using the same dataset as Baumert et al. (2010), Kunter et al. (2013) showed that teachers' PCK not only positively impacted cognitive outcomes, but also student motivation (measured by means of an enjoyment questionnaire). Concerning PK, Voss et al. (2011) found that teachers' PK was positively associated with student ratings of instructional quality. Furthermore, in the study of Konig and P € flanzl (2016), PK was found to be a significant predictor of instructional quality (as perceived by students) after controlling for teachers' grades in teacher education, their personality, and teaching experience. 2.3. Models on the development of teacher professional knowledge As a way to provide clarity on the variety of models on teacher professional knowledge, Gess-Newsome (1999) created a continuum of conceptual models (see Fig. 1), that have implications for the organization of teacher education. Although Gess-Newsome already created this continuum in 1999, and in more recent work she emphasizes other issues (see section 2.1), several positions on the continuum are still advocated in the educational field today. At the one end of the continuum, she positioned integrative models, stating that PCK is not a separate knowledge category and that PCK lies at the intersection of CK and PK. Hence, PK and CK are considered as sufficient conditions for the presence of PCK and, according to these models, it is sufficient for teacher education to focus on the separate development of CK and PK. At the other end of the continuum, in transformative models it is claimed that PCK is the synthesis of all knowledge that is needed by effective teachers. PCK is considered as the transformation of CK and PK into a unique amalgam. From this perspective, PK and CK are only useful when transformed into PCK, so teacher education should promote the development of pre-service teachers' knowledge domains symbiotically, while mainly focusing on PCK. New knowledge in one domain (i.e., PCK) then results in knowledge development in the other domains as well (i.e., PK and CK). Gess-Newsome recognized that many positions are possible in between the two extremes. The most common position is to recognize both the foundational knowledge categories PK and CK, and their mutual relationship with PCK (Gess-Newsome, 1999). Integrative and transformative models differ in whether or not PCK, PK and CK should be explicitly addressed in teacher education in order to develop teacher professional knowledge. First, while teacher education according to integrative models should only present PK and CK (because pre-service teacher will in this way automatically develop PCK), according to transformative models PCK should be part of the curriculum. Second, while integrative models stress the importance of an explicit presentation of PK and CK in teacher education, according to transformative models, it is sufficient for teacher education to only present PCK because PK and CK will develop simultaneously. Until now, there is no research empirically addressing the claims of both models. However, in a study of Kleickmann et al. (2017), preliminary results are described on similar research questions. In a randomized controlled trial with pre-service teachers, these authors compared PCK development in several conditions, each representing a different pathway to the development of PCK. The results show that presenting CK and PK to students leads to some PCK development, but explicitly addressing PCK or PCK and CK is more effective for PCK development. Furthermore, these authors found that CK is to a certain degree sufficient for PCK development, but PK is not. The authors even explain that the finding that CK and PK amalgamate into PCK can mainly be explained by the development of PCK from CK only.

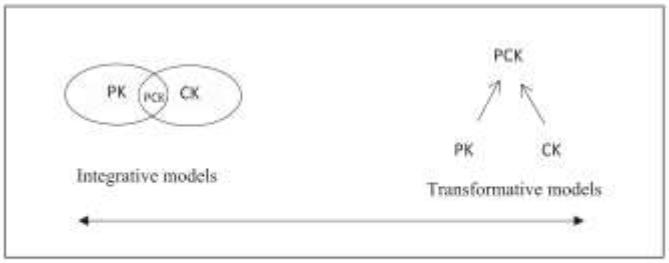


Fig. 1. Conceptual models of Gess-Newsome (1999) on the development of teacher professional knowledge.

2.4 Integration of knowledge categories

While Kleickmann et al. (2017) studied whether knowledge domains (PCK, PK and CK) should be explicitly presented to preservice teachers to develop PCK, these authors only focused on a segregated presentation of knowledge domains in separate courses. As these authors indicate, "an investigation of integrated CK and PCK instruction would also be worthwhile" (Kleickmann et al., 2017, p. 127). In most teacher education institutions, courses on PCK, PK and CK are offered in a segregated way (Ball, 2000; Harr et al., 2014). This situation has been criticized because it is based on the assumption that the combination of different types of teacher professional knowledge automatically happens in teachers' heads (Ball, 2000). As PCK consists of an integration of PK and CK (Shulman, 1986, 1987), it could be questioned whether an integrated approach in teacher education would be better for PCK development than a segregated approach. Some attempts have been made to (partially) study whether or not knowledge domains should be presented in an integrated way in teacher education. Firstly, Harr et al. (2014) compared the effect on pre-service teachers' PCK and PK of two computer-based learning environments (i.e., integrated or segregated PCK and PK) on mathematics. Teacher professional knowledge was measured by means of PCK and PK rapid-assessment items and on open-ended questions (i.e., solving cases from teaching practice) that could be answered using both PCK and PK. The results showed that the integrated learning environment was the most effective in increasing the application of PK aspects by pre-service teachers, while not impairing the application of PCK aspects (i.e., no significant differences on PCK between the integrated and the segregated condition were found). The integrated learning environment also increased simultaneous application of both PCK and PK when solving a particular case from teaching practice. Harr et al. (2015) also did another study in which the same methodology was used, but a condition was added in which pre-service teachers received prompts to integrate separately taught PCK and PK. The learning results of the prompted integration condition were similar to the results of the integrated condition in the 2014 study, but a larger amount of learning time was invested by the learners in the prompted integration condition. Secondly, in a study focusing on technological pedagogical content knowledge (TPACK, Mishra & Koehler, 2006), Janssen and Lazonder (2016) compared the effects of two computer-based learning environments (i.e., integrated or segregated support on PK, CK and knowledge about technology) on pre-service teachers' justifications when designing a lesson plan. While participants from the integrated condition did not show more TPACK-related justifications than participants from the segregated condition, they did show more PCK-related justifications, providing more evidence in favor of integrated support.

2.5. Present study

The present study empirically investigates two issues pertaining to the organization of teacher education: whether PCK, PK and CK should all be part of the learning environment if one aims to develop these knowledge domains, and whether an integrated presentation of PCK, PK and CK leads to more knowledge development than a segregated presentation. In a quasi-experimental study several computer-based learning environments are compared based on their effects on a PCK, PK and CK posttest and retention test. The computer-based learning environments are systematically designed, using instructional design principles of the four-component instructional design (4C/ID) model (van Merrienboer, 1997 €) (cf. infra). First, concerning the issue of whether all knowledge domains should be part of the learning environment, the present study includes two research questions (RQs), each aiming to validate the claims of one of the conceptual models of Gess-Newsome (1999). RQ1: Is a focus on PK and CK sufficient for the development of PCK? Learning environments that address PCK are compared with a learning environment that only addresses PK and CK, and a control group (that did not get any PCK, PK or CK instruction). It is expected that only presenting PK and CK to learners (cf. integrative model, Gess-Newsome, 1999) is less functional for PCK development than presenting PCK. More specifically, students taking part in a learning environment only focusing on PK and CK are not expected to get better PCK results than students in a control group that do not get any PCK, PK or CK instruction (Hypothesis 1). The integrative model is expected to be ineffective because it assumes that the difficult task of combining knowledge domains will automatically happen in teachers' heads (Ball, 2000). RQ2: Is a focus on PCK sufficient for the development of PK and CK? For RQ2 learning environments that explicitly address PK and CK are compared with a learning environment that only addresses PCK, and a control group (that did not get any instruction on PCK, PK or CK). It is expected that a learning environment only addressing PCK will be insufficient for PK and CK development. Hence, students in a learning environment only addressing PCK are expected not to get better results than students in a control condition (that have no instruction on PCK, PK and CK). They are also expected to get weaker results than students in learning environments presenting PK and CK (Hypothesis 2). This hypothesis is based on the assumption of Gess-Newsome (1999) that new knowledge, acquired by teachers in teacher education and experienced in practice, increases the organization and depth of PCK, PK and CK, although changes in one of the knowledge domains (i.e., PCK) do not necessarily imply changes in other knowledge domains (i.e., PK and CK). RQ3: Is a learning environment in which PCK, PK and CK are integrated more effective for PCK development than a learning environment in which PCK, PK and CK are segregated? To address RQ3, a learning environment in which PCK, PK and CK are presented in an integrated way is compared with a learning environment in which these knowledge domains are presented in a segregated way. Hypothesis 3 states that learning environments in which PCK, PK and CK are integrated are more functional for PCK development compared to learning environments in which these knowledge domains are segregated. This expectation is based on findings of research on teacher professional knowledge development (Harr et al., 2015, 2014; Janssen & Lazonder, 2016). These findings are in line with findings in other domains (e.g., critical thinking, learning to learn) showing that an instructional approach in which different knowledge domains are integrated leads to better learning results than when subdomains are taught in separate subjects (e.g., Angeli & Valanides, 2009; Waeytens, Lens, & Vandenberghe, 2002). The present study focuses on the domain of French as a foreign language. In this domain large-scale research on teacher professional knowledge is scarce (Atay, Kaslioglu, & Kurt, 2010; Johnston & Goettsch, 2000; Konig et al., 2016 € ; Velez-Rend on, 2002). This disciplinary domain is distinct from the domains in which research on teacher professional knowledge is more prevalent, such as mathematics and sciences. Unlike other domains, in foreign language teaching the content and the medium of instruction are the same. In the foreign language classroom teachers actively use the target language (i.e., the medium of instruction) while simultaneously teaching language skills to students (i.e., the content of

instruction) (Hlas & Hildebrandt, 2010). The topic that the study focuses on is oral interaction, one of the five skills that should be mastered by students according to the Flemish attainment targets (along with listening, reading, speaking and writing) of French (and other languages) in all levels of education. Oral interaction consists of an alternation of production and reception. While person A is speaking, person B is already forecasting the rest of the message and planning a response. This is in contrast to the skill 'speaking', that includes monologues or dialogues in which speakers know in advance what the other person will say (Council of Europe, n. d.). Oral interaction has become important in the field of foreign language education since communicative and task-based language teaching are getting more attention in foreign language educational research and practice (Gonzalez Humanez & Arias, 2009; Herazo Rivera, 2009).

3. Methodology

3.1. Participants and context

In total, 174 first year educational sciences students of one university in Flanders, Belgium, took part in the study. The participants were recruited through a course on educational psychology. In order to get course credits, students were expected to participate in research. The participants were randomly assigned to four experimental groups and one control group, that differed according to which knowledge domains were presented (PCK, PK and/or CK), and concerning the integration of these knowledge domains. Specific characteristics of each condition are described in section 3.2. An overview of participants' sex, and whether or not they had dyslexia can be found in Table 1. Chi-square tests found no significant differences between conditions according to these background characteristics. 95% of the participants were female. Students with dyslexia (n = 6) were not included in the analyses because of possible bias of their test results due to difficulties with reading the questions and writing their answers. Participants' average age was 19.5 years old; conditions also did not significantly differ with respect to participants' age. The learning environments used in the study are developed for students in primary teacher education. In Flemish primary teacher education, students are prepared to teach all courses that are part of primary education. French is one of the courses that is taught in primary education because it is one of the country's official languages. French is part of the curricula in Flemish primary teacher education institutions. In the present study, French is considered as a foreign language, following the definition of Diao, Chandler, & Sweller, 2007, (p. 297): "Second language learning occurs in an environment where the language is used by the majority of people, whereas foreign language learning occurs in an environment where the language is not a vehicle of ordinary communication." As French is spoken in Wallonia, the southern part of Belgium, it is considered as a foreign language in Flanders, in which Dutch is the first language.

3.2. Computer-based learning environments

The present study used computer-based learning environments to address the three RQs. This choice was based on the idea that the use of a computer allows to develop learning environments that perfectly fit the requirements of the different conditions that are part of the study. By using computer-based environments the circumstances are the same in every condition, leaving out potential confounding effects of a teacher. Underlying instructional design. Four versions of a computerbased learning environment were developed for the study. The learning environments teach students competencies that are related to preparing and conducting lessons on oral interaction in French. Therefore, they can be considered as environments for complex learning. An instructional design model that has been shown to be very effective for developing learning environments that aim at complex learning is the four-component instructional design (4C/ID) model (van Merrienboer, 1997 € ; van Merrienboer € & Kirschner, 2007). Hence, all learning environments used in the present study are based on the 4C/ID model. The central idea behind the 4C/ID model is that environments for complex learning contain four interrelated blueprint components, that is, learning tasks, supportive information (SI), procedural information (PI) and part-task practice (PTP). Firstly, learning tasks are authentic wholepractice tasks that aim at the integration of skills, knowledge and attitudes. They are congruent with reality, show a high variability and are organized in easy to difficult task classes. Scaffolding is provided throughout each task class. In the present study, in all learning environments tasks about teaching oral interaction in French are used. Each task class consists of three learning tasks with diminishing learner support. The first learning task is a worked-out example, the second is worked out to some extent, and the third has to be entirely completed by the student. An overview of the differences between the learning tasks can be found in Fig. 2. Appendix A shows an example of a learning task. Secondly, SI is helpful for performing the problem-solving and reasoning parts of learning tasks. It explains how to approach problems in a domain and how this domain is organized. The information is task-specific and always available to the student. In the present study, in the beginning of each task class students are directed towards the SI. Depending on the condition, the SI consists of related PCK (e.g., theoretical frameworks on how to teach oral interaction in French), CK (i.e., related vocabulary and grammar) and/or PK (e.g. theoretical frameworks on how to prepare a lesson). Thirdly, PI is prerequisite to the learning and the performance of routine aspects of learning tasks. It is presented precisely when learners need it and it quickly fades away as learners gain more expertise. In the present study, PI is presented as pop-up windows that appear when students click on specific words. The information is schematic and related to PCK, CK and/or PK. It is presented in both the instructions of learning tasks and the feedback on learning tasks. PTP, finally, is provided to learners to help them reach a very high level of automaticity for routine aspects of a task. In the learning environments of the present study, links to these exercises (on PCK, CK and/or PK) are always provided in the second learning task of a task class. Following the idea of diminished learner support, these exercises are never part of the third learning task (van Merrienboer € & Kirschner, 2007; van Merrienboer, 1997 €). Conditions. In total there were four experimental conditions and one control condition. Each experimental condition had its own learning environment. The learning environments differed regarding the two issues that are under study, that is, whether or not knowledge domains are presented in an integrated way, and concerning which knowledge domains (PCK, PK and/or CK) are included in the environment (see Table 2). To address the first and second RQ that focus on the issue whether PCK, PK and/or CK should be part of the learning environment in order to develop them, two specific learning environments were made. These two learning environments are based on the conceptual models of GessNewsome (1999). Condition 1 (the PK-CK condition) took part in a learning environment that followed an integrative model. This learning environment consisted of a first part with learning tasks and support about PK, and a second part about CK. The learning environment of the second condition (the PCK-only condition) was based on the transformative model. In this learning environment only learning tasks and support about PCK were provided. Concerning integration, there was one learning environment in which PCK, PK and CK were presented in an integrated way (condition 3), and one learning environment in which PCK, PK and CK were presented in a segregated way (condition 4). In the learning environment of the integrated PCK-PK-CK condition, each learning task started with a problem statement from educational practice, that was approached from three different points of view (i.e., PK, CK and PCK). The learning environment of the segregated PCK-PK-CK condition consisted of three modules. Each module included learning tasks and support about one of the three knowledge domains. Appendix B displays the structures of the learning environments. The overall instructional design (4C/ID model) and the learning content provided within one knowledge domain (PCK, PK, CK) was the same across learning environments. Furthermore, every learning environment required the same amount of work, and the total time-on-task was the same in every condition. Participants in the control condition did not take part in any learning environment. They only completed the pretest, posttest and retention test. Because all participants studied educational sciences some PK was part of their regular curriculum.

Table 1
Overview of students' background characteristics within conditions.

	Sex		Dyslexia		Age		Sample size
	Male	Female	Yes	No	M	SD	
Condition 1	0	36	2	34	19	1.52	36
Condition 2	1	35	2	34	20.57	3.41	36
Condition 3	1	34	1	34	18.2	1.34	35
Condition 4	3	34	1	36	19.4	1.75	37
Control condition	3	26	0	29	19.4	1.60	29

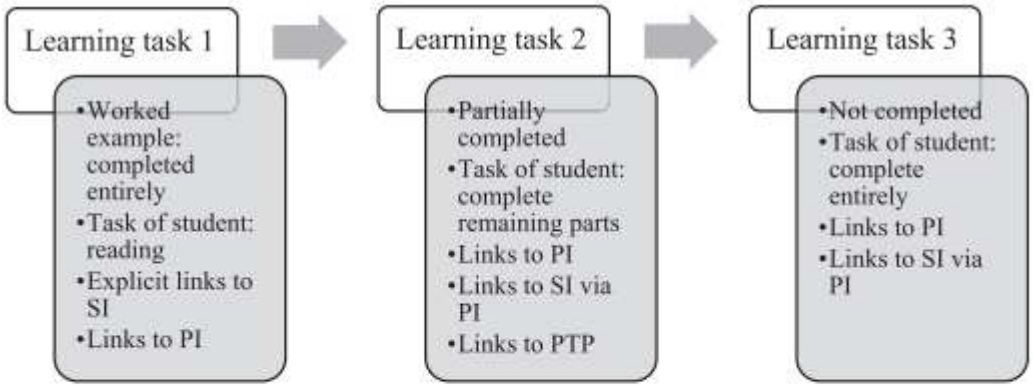


Fig. 2. Overview of differences between learning tasks within one task class.

Table 2
Overview of the learning environments of the different conditions.

Condition	1: PK-CK	2: PCK	3: Integrated PCK-PK-CK	4: Non-integrated PCK-PK-CK	Control
Model Gess-Newsome (1999)	Integrative	Transformative	/	/	/
Learning tasks	Module 1: PK Module 2: CK	Module 1: PCK	Module 1: PCK + PK + CK	Module 1: PCK Module 2: PK Module 3: CK	/
SI, PI, PTP	PK, CK	PCK	PCK, PK, CK	PCK, PK, CK	/
Integration of knowledge domains	No integration	No integration	Direct integration of PCK, PK and CK	No integration	/

3.3. Instruments

To measure PCK, PK and CK three quantitative paper-and-pencil instruments were developed, in line with a cognitive perspective on teacher professional knowledge. The instruments focus on declarative knowledge, and consist of both short-answer and multiple-choice questions. The same instruments were used at the pretest, posttest and retention test. More information about the instruments can be found in Evens, Elen, and Depaepe (2017). Sample items are displayed in Fig. 3. The PCK instrument is based on the components by Shulman (1986, 1987), Magnusson et al. (1999) and Grossman (1990), and focuses on oral interaction in French. It contains 10 main questions, each consisting of four sub-questions. The PK instrument is based on the components of Konig et al. (2011) € and Voss et al. (2011). It consists of 16 questions, each composed of five sub-questions. The CK focuses on French grammar and vocabulary. The level of difficulty of the CK test is aligned with the level that students are expected to reach at the end of primary education (i.e., level A2 of the Common European Framework of Reference). All answers on the three instruments could be rated as right or wrong, according to a correction key that was based on related literature. To ensure content validity, the instruments were developed in close cooperation with and adapted to the feedback of experts such as educational researchers, teacher educators (French and general pedagogy), and primary school teachers. The instruments' reliability was tested by means of interrater reliability and internal consistency. To calculate interrater reliability, 10% of the data was rated by two independent raters using the same correction key. Cohen's K of .90 for PCK, .84 for PK, and .85 for CK were found, indicating high agreement. Disagreements were discussed, the scoring key was adapted and the remaining data were scored by one rater. The measures of internal consistency (Cronbach's alpha) of the three instruments can be found in Table 3. On the PK and CK instruments, good internal consistency is found on all measurements. On PCK, internal consistency is low on the pretest, but gets better on the posttest and the retention test. The low alpha on the pretest might be caused by the fact that the participants were not very familiar with PCK contents when they filled in the pretest, which also led to lower variation on the PCK pretest than on the PK and CK pretest and the PCK posttests. In contrast, as first year educational sciences students they had some prior knowledge on PK (because of their current educational program) and on CK (because of their French courses in secondary education). As teachers' professional knowledge becomes more integrated when gaining more expertise (Gess-Newsome, 1999; van Driel, Verloop, & de Vos, 1998), it seems understandable that the internal consistency of the PCK pretest is lower.

3.4. Procedure

All participants of all experimental conditions had 3 h to complete the learning environment. They could go through the learning environment at their own pace, and they were free to use as much SI, PTP and PI as they considered necessary. All participants were ready with the learning environment within 3 h. Some finished earlier than others, but there were no notable differences between the groups. The control group did not take part in any intervention.

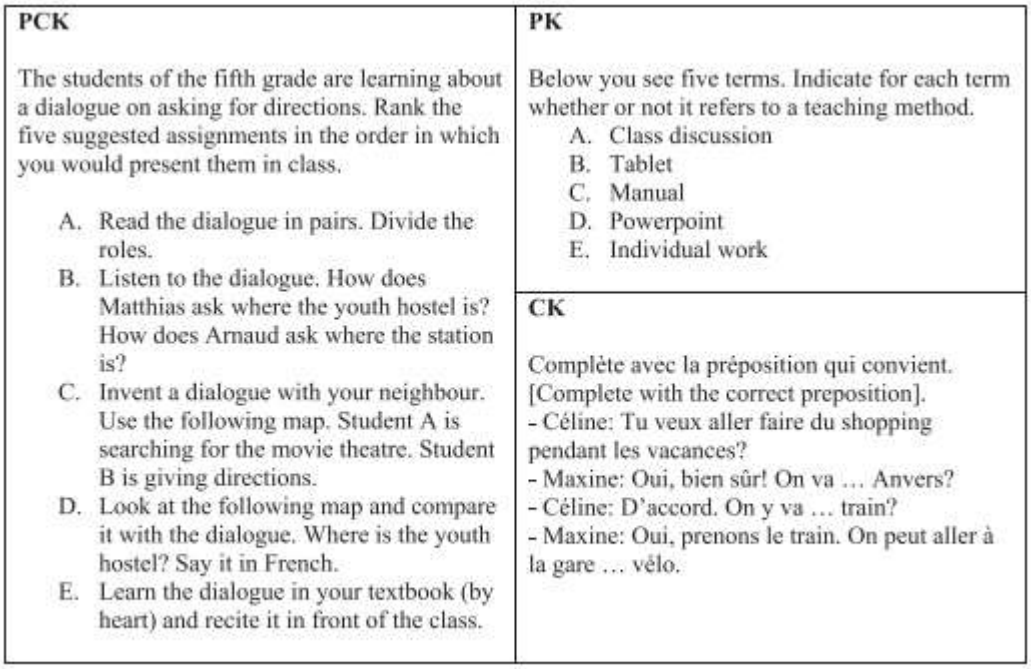


Fig. 3. Sample items of the PCK, PK and CK instrument.

Table 3
Internal consistency of the instruments.

	PCK	PK	CK
Pretest	α = .42	α = .72	α = .86
Posttest	α = .68	α = .78	α = .88
Retention test	α = .62	α = .80	α = .87

All participants took part in a pretest, a posttest a few days after the intervention, and a retention test one month later. Each test administration took approximately 90 min. All participants signed informed consent documents stating that their participation was anonymous and voluntary.

3.5. Analyses

For all RQs ANCOVA was used. Pretest scores were used as covariates to control for prior knowledge. Posttest scores and retention test scores were used as dependent variables. RQ1 used PCK posttest and retention test scores as the dependent variable and PCK-group as the independent variable, comparing three groups: groups who had explicit PCK instruction (i.e., condition 2, 3 and 4), participants who only had PK and CK instruction (i.e., condition 1), and the control condition. Simple contrast analyses were used to study the differences between the specific groups. The dependent variables used in RQ2 were PK posttest and retention test scores (RQ2a) and CK posttest and retention test scores (RQ2b). The PK/CK-group that participants were part of was used as the independent variable. Three groups were compared, that were the same in RQ2a and in RQ2b because the focus on PK was the same as the focus on CK in every condition: groups who had explicit PK and CK instruction (i.e., condition 1, 3 and 4), participants who only had PCK instruction (i.e., condition 2) and the control condition. RQ3 compared the two learning environments that included all three knowledge domains based on their integration of PCK, PK and CK, that is, conditions 3 and 4. The independent variables of RQ3 are the PCK posttest and retention test scores. Effect sizes (partial eta squared) are calculated for all ANCOVAs.

4. Results

4.1. Background

An overview of descriptive statistics of all measures in all conditions can be found in Table 4. The maximum scores of all instruments were converted to 100. For each knowledge domain, the mean scores increased between pretest and posttest, and slightly decreased between posttest and retention test. Assumptions for applying ANCOVA were checked, none of them were violated. First, potential group differences in prior knowledge on PCK, PK and CK were tested. There were no significant differences on pretest performance between conditions.

4.2. RQ1: is a focus on PK and CK (cf. integrative model) sufficient for the development of PCK?

Fig. 4 shows the mean scores of the three groups that were compared for RQ1: the control condition, the group that only got PK and CK (condition 1), and the group with an explicit focus on PCK (condition 2, 3 and 4) on posttest and retention test (cf. infra). There was a significant, large effect of the independent variable (in which PCK-group the participants were) on posttest PCK after controlling for the effect of pretest PCK, $F(2, 163) = 48.29$, $p < .001$, $\eta^2 = .37$. Simple contrasts revealed that the group taking part in a learning environment with an explicit focus on PCK significantly outperformed the control group ($p < .001$, $d = 1.19$) and the group that only got PK and CK instruction ($p < .001$, $d = 1.19$). The PK-CK group did not significantly outperform the control condition ($p = .91$, $d = .02$). Also on the retention test, a significant, large effect was found after controlling for PCK pretest scores, $F(2, 156) =$

23.33, p < .001, h2 P =.23. The explicit-PCK group significantly outperformed the group that only had PK and CK instruction (p < .001, d = .6) and the control condition (p < .001, d = 1.11). However, different from the posttest, the PK-CK group scored significantly higher than the control condition (p = .04, d = .55) on the retention test.

Table 4
Descriptive statistics of all measures.

		N	Min	Max	*M*	*SD*	Skewness (*SE*)	Kurtosis (*SE*)	Kolmogorov-Smirnov test of normality
Pretest	PCK	168	26.25	77.50	48.08	8.82	.32 (.19)	.55 (.37)	D (156) = .06. p = .20
	PK	168	40.00	83.75	59.83	9.04	.40 (.19)	-.36 (.37)	D (156) = .10, p < .001
	CK	166	17.80	79.66	45.30	13.33	.22 (.19)	-.45 (.38)	D (156) = .09, p = .01
Posttest	PCK	167	30.00	85.00	58.17	11.74	.10 (.19)	-.70 (.37)	D (156) = .08. p = .03
	PK	167	42.50	91.25	69.73	9.86	-.22 (.19)	-.27 (.38)	D (156) = .06, p = .20
	CK	166	22.03	91.53	55.77	15.84	.01 (.19)	-.61 (.38)	D (156) = .06, p = .20
Retention test	PCK	160	32.50	82.50	56.30	10.91	.04 (.19)	-.75 (.38)	D (156) = .06. p = .20
	PK	161	42.50	91.25	69.13	10.14	.02 (.19)	-.58 (.38)	D (156) = .06, p = .20
	CK	160	20.34	93.22	55.29	15.13	.07 (.19)	-.41 (.38)	D (156) = .06, p = .20

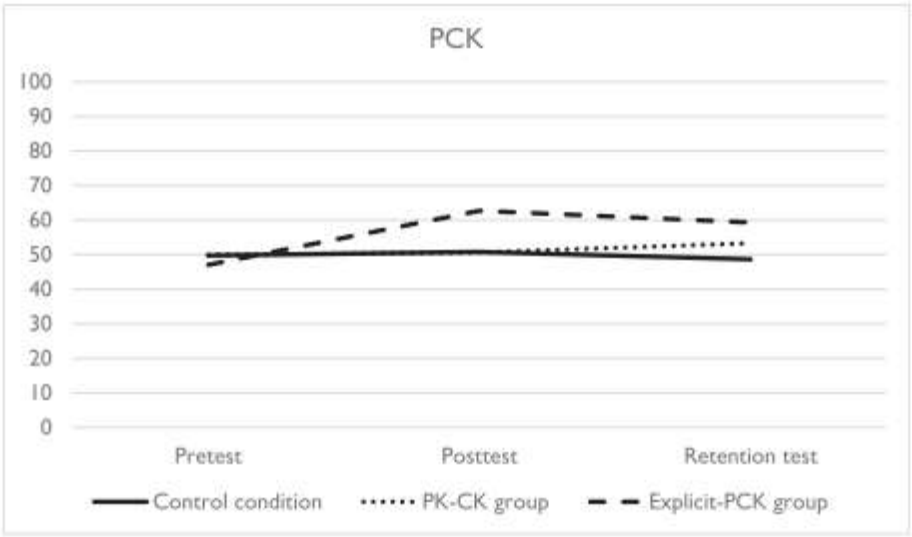


Fig. 4. Comparison of PCK posttest and retention test results based on whether PCK is explicitly presented in the learning environment.

4.3. RQ2: is a focus on PCK (cf. transformative model) sufficient for the development of PK and CK?

Figs. 5 and 6 show the PK and CK posttest and retention test scores of the three groups that were compared for RQ2 (i.e., explicit focus on PK/CK, only focus on PCK, control condition). On PK there was a significant and large effect of the group participants were part of on posttest results after controlling for pretest results, with a large effect size, F (2,163) = 37.00, p < .001, h2 P =.31. Contrast analyses revealed that the explicit-PK group significantly outperformed the control condition (p < .001, d = 1.07) and the PCK only group (p < .001, d = .97). No significant differences were found between the PCK-only group and the control condition (p = .18, d = .05). After controlling for pretest PK performance, a significant and large effect was also found on PK retention test scores, F (2, 157) = 21.39, p < .001, η^2 =.21. More specifically, the explicit-PK/CK group significantly outperformed the control condition (p < .001, d = .77) and the PCK-only group (p < .001, d = .64). No significant difference was found between the PCK-only group and the control condition (p = .08, d = .07). Also on posttest CK scores a significant effect was found, after controlling for pretest scores, with a medium to large effect size, F (2, 160) = 10.85, p < .001, η^2 =.12. The explicit-CK group significantly outperformed the control condition (p < .001, d = .47) and the PCK-only group (p < .01, d = .49). Again, no significant differences were found between the PCK-only group and the control condition (p = .69, d = .01). An effect was also found on the CK retention test, after controlling for pretest scores, with a medium to large effect size, F (2, 154) = 11.50, p < .001, η^2 =.13. More specifically, the explicit-PK/CK group significantly outperformed the control condition (p < .001, d = .42) and the PCK-only group (p = .02, d = .42). Again, no significant difference was found between the PCK-only group and the control condition (p = .07, d = .05).

4.4. RQ3: is a learning environment in which PCK, PK and CK are integrated more effective for PCK development than a learning environment in which PCK, PK and CK are segregated?

An overview of the mean scores of the two compared groups can be found in Fig. 7. After controlling for pretest PCK scores, no significant differences on posttest PCK were found between the integrated PCK-PK-CK learning environment and the segregated PCKPK-CK learning environment, F (1,67) = 1.65, p = .20, η^2 =.02.

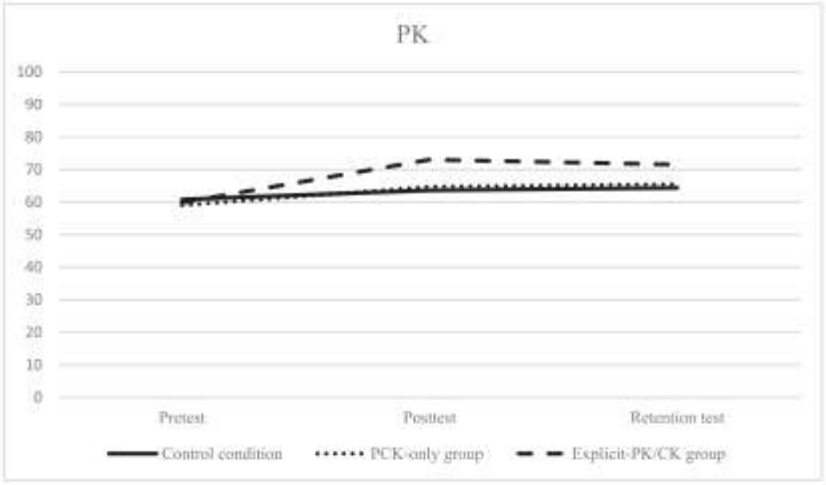


Fig. 5. Comparison of PK posttest and retention test results based whether PK and CK are presented in the learning environment.

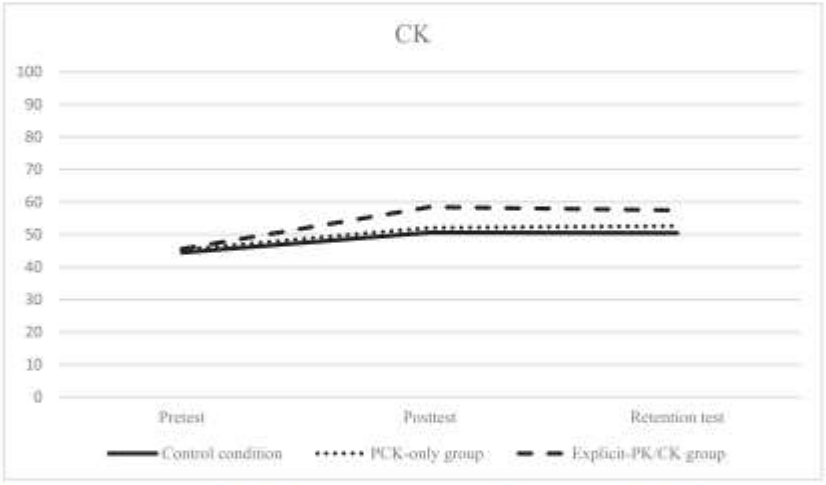


Fig. 6. Comparison of CK posttest and retention test results based on whether PK and CK are presented in the learning environment.

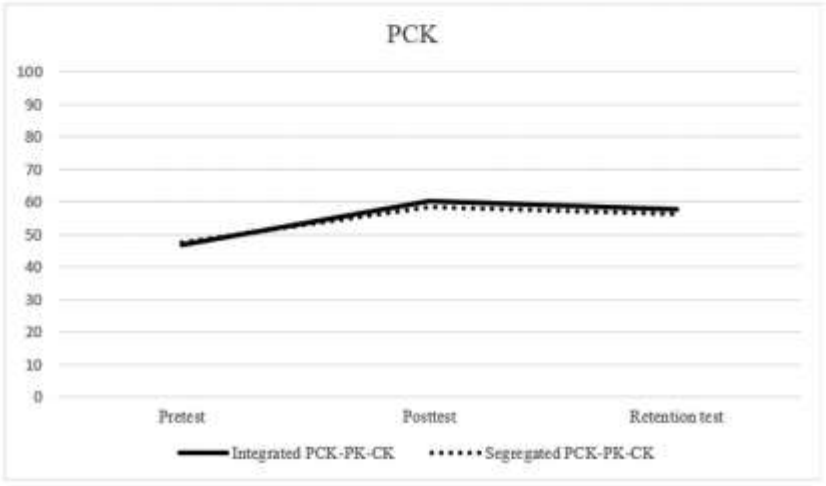


Fig. 7. Comparison of PCK posttest and retention test results based on integration of knowledge domains.

Also on the retention test no significant differences on PCK were found between the integrated and the segregated group, after controlling for pretest scores, $F(1, 64) = .79$, $p = .38$, $\eta^2 = .01$.

4. Discussion and conclusion

The present study investigated the effectiveness of several systematically developed learning environments in a quasi-experimental design. Four experimental conditions and one control condition are compared on PCK, PK and CK posttest and retention test scores, after controlling for pretest scores. More specifically, the study focused on three RQs, that is, (1) Is a focus on PK and CK (cf. integrative model) sufficient for the development of PCK?, (2)

Is a focus on PCK (cf. transformative model) sufficient for the development of PK and CK?, and (3) Is a learning environment in which PCK, PK and CK are integrated more effective for PCK development than a learning environment in which PCK, PK and CK are segregated? Hypothesis 1 postulated that a learning environment that only focuses on PK and CK is less functional for PCK development than a learning environment explicitly presenting PCK, and that it even does not lead to better PCK development than a control environment without PCK, PK and CK. This hypothesis was confirmed by the results, showing that the group that only got PK and CK instruction was significantly outperformed by the explicit-PCK group. At the same time the PK/CK group did not significantly differ from the control condition. This finding provides evidence against the view of the integrative model on teacher education (GessNewsome, 1999) that claims that offering PK and CK alone is sufficient for the development of PCK. On the PCK retention test, the PK/CK group did outperform the control condition. This means that condition 1, based on the integrative model of Gess-Newsome (1999), did develop more PCK than the control condition, but needed some time to process these knowledge domains. However, the explicit PCK group still outperformed the PK/CK group on the PCK retention test, which shows that an explicit focus on PCK is still most beneficial for PCK development. This finding corresponds with the finding of Kleickmann et al. (2017) that explicitly addressing PCK is the most effective pathway to the development of PCK. The study also focused on the question whether a learning environment that only addresses PCK, as advocated by the transformative model (Gess-Newsome, 1999), is sufficient for PK and CK development. It seems clear from the results with regard to RQ1 that the transformative model, that explicitly focuses on PCK, contributes to PCK development. However, with regard to PK and CK, hypothesis 2 was confirmed. Learning environments only presenting PCK were as functional for PK and CK development as learning in the control condition. Meanwhile, PCK-only learning environments were less functional for PK and CK development than learning environments explicitly focusing on PK and CK. These results were found on both the posttest and the retention test. The idea that PK and CK are transformed into PCK, and that changes in PCK will automatically lead to changes in PK and CK, is doubtful given the data. While the transformative model might be a good way to develop PCK, the present study shows that it is not recommended as a basis to develop PK and CK. Consequently, a model combining the strengths of integrative and transformative models might be fruitful if teacher education aims at promoting not only teachers' PCK, but also their PK and CK. It should be noted that on PK and CK the control group also improved between pretest and retention test. This might be caused by students' regular courses on PK that took place during, but were not part of, the study. A testing effect might also have played a role because the same tests were used three times. Hypothesis 3 expected that learning environments in which PCK, PK and CK are integrated would lead to better results on PCK than learning environments in which these knowledge domains are segregated. However, this hypothesis was not confirmed, as no differences were found between groups on both posttest and retention test based on the integration of knowledge domains. This finding deviates from the findings of earlier research showing that an instructional approach in which different knowledge domains are integrated leads to better learning results than when subdomains are taught in separate subjects (Angeli & Valanides, 2009; Harr et al., 2015, 2014; Janssen & Lazonder, 2016; Waeytens et al., 2002). There are several possible reasons for this finding. A first explanation is that participants were overwhelmed by the integrated information in the learning environment, as most participants can be considered as novices. They were not that familiar with the PCK learning content, and as a consequence probably had rather fragmented and incomplete PCK. Previous research has shown that beginning teachers tend to rely more on separate domains of knowledge than on all domains at the same time (Ball & Bass, 2003; Davis, 2003; Lee & Luft, 2008). The simultaneous learning of several knowledge domains in teacher education can be too difficult for pre-service teachers (Brush & Saye, 2009). It would be interesting to conduct a similar study with expert teachers in order to verify this explanation. Lee and Luft (2008) have for instance shown that experienced teachers have both separate and integrated knowledge bases. A second explanation pertains to the way in which teacher knowledge was measured in the present study. The instrument contained a separate PCK, PK and CK part, which did not allow to measure whether participants could use their knowledge in an integrated way. Instruments that integrate PCK, PK and CK might have found different results. Studies using integrated instruments mainly found positive effects of integrated learning environments on integrated knowledge application (Harr et al., 2015, 2014; Janssen & Lazonder, 2016). However, although an instrument was used that provided PCK, PK and CK in a segregated way, the segregated condition did not outperform the integrated condition. This finding provides some evidence in favor of an integrated learning environment. It is possible that the participants, even though their prior knowledge was fragmented, were sufficiently able to make efficient use of integrated information (Janssen & Lazonder, 2016). A third explanation is that the design of previous studies was different, which might impact the results. For instance, Harr et al. (2014, 2015) measured the impact of integration on PK, while the present study focused on PCK. There are some limitations to the present study with related suggestions for further research. Firstly, as mentioned before, the instrument consisted of three segregated parts, and did not assess an integrated application of PCK, PK and CK. When it comes to the application of knowledge, participants who took part in an integrated learning environment could possibly perform better than participants of a segregated learning environment (Harr et al., 2014). Secondly, because the study used a quasi-experimental design comparing randomly selected experimental and control conditions, it was highly internally valid. However, high internal validity is often at the expense of ecological validity, which was the case in the present study. For future research it would be interesting to conduct a similar study with pre-service or in-service teachers instead of bachelor students in educational sciences (because in Flanders educational sciences and teacher education are different fields of study). Thirdly, the Cronbach's alpha values of the PCK instrument did not meet the cutoff level of .7. This should be taken into account when interpreting the results of the present study. On the other hand, the usefulness of Cronbach's alpha as a measure of internal consistency is questionable, as several assumptions have to be met before alpha gives a good indication of internal consistency. For instance, items should use continuous scales (McNeish, 2017). However, our items are binary and as a consequence the chances are higher that the alpha coefficient underestimates the real internal consistency of our instruments (McNeish, 2017). Fourthly, the present study only approached teacher professional knowledge from a cognitive perspective. It does not focus on what Gess-Newsome (2015) called personal pedagogical content knowledge and skill. The classroom context, that plays a major role in personal pedagogical content knowledge and skill, is not taken into account in the present study. We only measured PCK in a quantitative way. Cauet, Liepertz, Borowski, and Fischer (2015) question the measurement of teacher professional knowledge through paper-and-pencil tests. Therefore, it would be interesting to complement the findings of the present study with findings from studies that are more situated in nature, for instance by using qualitative methods that also take into account the classroom context. Cauet et al. (2015) furthermore recommend the use of vignettes (written descriptions of authentic classroom situations) to replace paper-and-pencil tests. Fifthly, in the PK-CK learning environment no attention was given to fostering participants' integration skills. If this learning environment would for instance have prompted the learners to integrate separately presented contents, the development of PCK could have been better in this condition. Future research could focus on the question whether teaching separate knowledge domains in combination with integration skills would help students to integrate knowledge domains. Harr et al. (2015) for instance already showed positive effects of presenting PK and PCK separately to pre-service teachers, but with integration prompts. Finally, a possibility for future research would be to study the exact difference between the effects of integrated and segregated learning environments. An interesting path to explore in this respect is the influence of individual differences on the effects of learning environments, such as prior knowledge, beliefs, motivation, individual learning paths in the learning environment, etc. The present study has led to at least two theoretical implications. The findings are shown on both a posttest and a retention test, indicating lasting effects. Firstly, the study investigated whether the claims regarding the organization of teacher education of integrative and transformative models (Gess-Newsome, 1999) could be empirically validated. The findings are not in accordance with the claims of both models. In order to develop PCK, PK and CK, these knowledge domains should be explicitly presented to students. A mid-position in between transformative and integrative models, in which all three knowledge domains are recognized, seems an appropriate guideline to optimally develop teacher professional knowledge. Secondly, the study showed that an integrated presentation of knowledge domains is not better or worse than a segregated presentation of knowledge domains for the development of

professional knowledge in novices. Starting from these theoretical implications, guidelines can be formulated for teacher education. The present study has shown that teacher professional knowledge is optimally promoted when courses about PCK, PK and CK are included in the curriculum. According to our results it does not matter whether knowledge domains are presented in an integrated or a segregated way. This means that PCK, PK and CK each could have their own courses, or that courses could combine learning content from all three knowledge domains.

References

Angeli, C., & Valanides, N. (2009). Instructional effects on critical thinking: Performance on ill-defined issues. Learning and Instruction, 19, 322-334. https://doi.org/10.1016/j.learninstruc.2008.06.010.

Atay, D., Kaslioglu, O., & Kurt, G. (2010). The pedagogical content knowledge development of prospective teachers through an experiential task. Procedia Social and Behavioral Sciences, 2, 1421-1425. https://doi.org/10.1016/ j.sbspro.2010.03.212.

Ball, D. L. (2000). Bridging practices: Intertwining content and pedagogy in teaching and learning to teach. Journal of Teacher Education, 51, 241e247. https://doi.org/ 10.1177/002248710003013.

Ball, D. L., & Bass, H. (2003). Toward a practice-based theory of mathematical knowledge for teaching. In B. Davis, & E. Simmt (Eds.), Proceedings of the 2002 annual meeting of the canadian mathematics education study group (pp. 3e14). Edmonton, Canada: Canadian Mathematics Education Study Group.

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? Journal of Teacher Education, 59, 389e407. https://doi.org/10.1177/0022487108324554.

Baumert, J., Kunter, M., Blum, W., Brunner, M., Voss, T., Jordan, A., et al. (2010). Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress. American Educational Research Journal, 47, 133e180. https:// doi.org/10.3102/0002831209345157.

Brush, T., & Saye, W. (2009). Strategies for preparing pre-service social studies teachers to integrate technology effectively: Models and practices. Contemporary Issues in Technology and Teacher Education, 9(1), 46e59.

Cauet, E., Liepertz, S., Borowski, A., & Fischer, H. E. (2015). Does it matter what we measure? Domain-specific professional knowledge of physics teachers. Schweizerische Zeitschrift für Bildungswissenschaften, 37(3), 462e479.

Connelly, F. M., Clandinin, D. J., & He, M. F. (1997). Teachers' personal practical knowledge on the professional knowledge landscape. Teaching and Teacher Education, 13, 665e674. https://doi.org/10.1016/S0742-051X(97)00014-0. Council of Europe. (n.d.).

Common European Framework of Reference for languages: Learning, teaching, assessment. Retrieved on March 15, 2015 from http://www.coe.int/t/dg4/linguistic/Source/Framework_EN.pdf. Davis, E. A. (2003). Knowledge integration in science teaching: Analysing teachers' knowledge development. Research in Science Education, 34, 21e53. https:// doi.org/10.1023/B: RISE.0000021034.01508.b8.

Depaepe, F., Verschaffel, L., & Kelchtermans, G. (2013). Pedagogical content knowledge: A systematic review of the way in which the concept has pervaded mathematics educational research. Teaching and Teacher Education, 34, 12e25. https://doi.org/10.1016/j.tate.2014.12.009.

Diao, Y., Chandler, P., & Sweller, J. (2007). The effect of written text on comprehension of spoken English as a foreign language. American Journal of Psychology, 120(2), 237e261.

van Driel, J. H., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. Journal of Research in Science Teaching, 35, 673e695. https://doi.org/10.1002/(SICI)1098-2736(199808)35:63.0.CO;2-J.

Evens, M., Elen, J., & Depaepe, F. (2017). Effects of opportunities to learn in teacher education on the development of teachers' professional knowledge of French as a foreign language. Journal of Advances in Education Research, 2, 265e279. https://doi.org/10.22606/jaer.2017.24007.

Gess-Newsome, J. (1999). Pedagogical content knowledge: An introduction and orientation. In J. Gess-Newsome, & N. G. Lederman (Eds.), Examining pedagogical content knowledge (pp. 3e17). Dordrecht, the Netherlands: Kluwer Academic Publishers.

Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK: Results of the thinking from the PCK summit. In A. Berry, P. Friedrichsen, & J. Loughran (Eds.), Re-examining pedagogical content knowledge in science education? (pp. 29e45). New York, NY: Routledge.

Gonzalez Humanez, L. E., & Arias, N. (2009). Enhancing oral interaction in English as a foreign language through task-based learning activities. Latin American Journal of Content & Language Integrated Learning, 2, 1e9. https://doi.org/10.5294/ laclil.2009.2.2.10.

Grossman, P. L. (1990). The making of a teacher: Teacher knowledge and teacher education. New York, NY: Teachers College Press.

Harr, N., Eichler, A., & Renkl, A. (2014). Integrating pedagogical content knowledge and pedagogical/psychological knowledge in mathematics. Frontiers in Psychology, 5, 1e10. https://doi.org/10.3389/fpsyg.2014.00924.

Harr, N., Eichler, A., & Renkl, A. (2015). Integrated learning: Ways of fostering the applicability of teachers' pedagogical and psychological knowledge. Frontiers in Psychology, 6, 1e16. https://doi.org/10.3389/fpsyg.2015.00738.

Hattie, J. (2012). Visible learning for teachers: Maximizing impact on learning. London, England: Routledge. Herazo Rivera, J. D. (2010). Authentic oral interaction in the EFL class: What it means, what it does not. Profile - Issues in Teachers' Professional Development, 12(1), 47e61.

Hlas, A., & Hildebrandt, S. (2010). Demonstrations of pedagogical content knowledge: Spanish liberal arts and Spanish education majors' writing. L2 Journal, 2(1), 1e22.

Janssen, N., & Lazonder, A. W. (2016). Supporting pre-service teachers in designing technology-infused lesson plans. Journal of Computer Assisted Learning, 32, 456e467. https://doi.org/10.1111/jcal.12146.

Johnston, B., & Goettsch, K. (2000). In search of the knowledge base of language teaching: Explanations by experienced teachers. The Canadian Modern Language Review, 56, 437e468. https://doi.org/10.3138/cmlr.56.3.437.

Kleickmann, T., Richter, D., Kunter, M., Elsner, J., Besser, M., Krauss, S., et al. (2013). Teachers' content knowledge and pedagogical content knowledge: The role of structural differences in teacher education. Journal of Teacher Education, 64, 90e106. https://doi.org/10.1177/0022487112460398.

Kleickmann, T., Trobst, S., Heinze, A., Bernholt, A., Rink, R., & Kunter, M. (2017). € Teacher knowledge experiment: Conditions of the development of pedagogical content knowledge. In D. Leutner, J. Fleischer, J. Grünkorn, & E. Klieme (Eds.), Competence assessment in education. Methodology of educational measurement and assessment (pp. 11e128). Cham, Switzerland: Springer International Publishing. https://doi.org/10.1007/978-3-319-50030-0.

Konig, J., Blömeke, S., Paine, L., Schmidt, W. H., & Hsieh, F.-J. (2011). General pedagogical knowledge of future middle school teachers: On the complex ecology of teacher education in the United States, Germany, and Taiwan. Journal of Teacher Education, 62, 188e201. https://doi.org/10.1177/0022487110388664.

Konig, J., Lammerding, S., Nold, G., Rohde, A., Strauß, S., & Tachtsoglou, S. (2016). € Teachers' professional knowledge for teaching English as a foreign language: Assessing the outcomes of teacher education. Journal of Teacher Education, 67, 320e337. https://doi.org/10.1177/0022487116644956.

Konig, J., & P € flanzl, B. (2016). Is teacher knowledge associated with performance? On the relationship between teachers' general pedagogical knowledge and instructional quality. European Journal of Teacher Education, 39, 419e436. https://doi.org/10.1080/02619768.2016.1214128.

Krauss, S., Baumert, J., & Blum, W. (2008a). Secondary mathematics teachers' pedagogical content knowledge and content knowledge: Validation of the COACTIV constructs. ZDM Mathematics Education, 10, 873e892. https://doi.org/ 10.1007/s11858-008-0141-9.

Krauss, S., Brunner, M., Kunter, M., Baumert, J., Blum, W., Neubrand, M., et al. (2008b). Pedagogical content knowledge and content knowledge of secondary mathematics teachers. Journal of Educational Psychology, 100, 716e725. https:// doi.org/10.1037/0022-0663.100.3.716.

Kunter, M., Klusmann, U., Baumert, J., Richter, D., Voss, T., & Hachfeld, A. (2013). Professional competence of teachers: Effects on instructional quality and student development. Journal of Educational Psychology, 105, 805e820. https:// doi.org/10.1037/a0032583.

Lee, E., & Luft, J. A. (2008). Experienced secondary science teachers' representation of pedagogical content knowledge. International Journal of Science Education, 30, 1343e1363. https://doi.org/10.1080/09500690802187058.

Magnusson, S., Krajcik, J. C., & Borko, H. (1999). Nature, sources and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome, & N. G. Lederman (Eds.), Examining pedagogical content knowledge (pp. 95e132). Dordrecht, the Netherlands: Kluwer Academic Publishers.

McNeish, D. (2017). Thanks coefficient alpha, we'll take it from here. Psychological Methods. https://doi.org/10.1037/met0000144. Advance online publication.

van Merrienboer, J. J. G. (1997). Training complex cognitive skills: A four-component instructional design model for technical teaching. Englewood Cliffs, NJ: Educational Technology Publications.

van Merrienboer, J. J. G., & Kirschner, P. A. (2007). € Ten steps to complex learning. Mahwah, NJ: Lawrence Erlbaum Associates. Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. Teachers College Record, 108, 1017e1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x.

Sadler, P. M., Sonnert, G., Coyle, H. P., Cook-Smith, N., & Miller, J. L. (2013). The influence of teachers' knowledge on student learning in middle school physical science classrooms. American Educational Research Journal, 50, 1020e1049. https://doi.org/10.3102/0002831213477680.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15, 4e14. https://doi.org/10.3102/0013189X015002004.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. Harvard Educational Review, 57, 1e22. https://doi.org/10.17763/ haer.57.1.j463w79r56455411.

Stahnke, R., Schüler, S., & Rosken-Winter, B. (2016). Teachers' perception, interpretation, and decision-making: A systematic review of empirical mathematics education research. ZDM Mathematics Education, 48, 1e27. https://doi.org/ 10.1007/s11858-016-0775-y.

Velez-Rend on, G. (2002). Second language teacher education: A review of the literature. Foreign Language Annals, 35, 457e466. https://doi.org/10.1111/j.1944- 9720.2002.tb01884.x. Voss, T.,

Kunter, M., & Baumert, J. (2011). Assessing teacher candidates' general pedagogical/psychological knowledge: Test construction and validation. Journal of Educational Psychology, 103, 952e969. https://doi.org/10.1037/a0025125.

Waeytens, K., Lens, W., & Vandenberghe, R. (2002). 'Learning to learn': Teachers' conceptions of their supporting role. Learning and Instruction, 12,

305e322. https://doi.org/10.1016/S0959-4752(01)00024-X.

Zeichner, K. (2012). The turn once again toward practice-based teacher education. Journal of Teacher Education, 63, 376e382.