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The relevance of general pedagogical knowledge for successful teaching: Systematic review and meta-analysis of the international evidence from primary to tertiary education

Hannah Ulferts

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The relevance of general pedagogical knowledge for successful teaching: Systematic review and meta-analysis of the international evidence from primary to tertiary education

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Hannah Ulferts, OECD

This working paper has been authorised by Andreas Schleicher, Director of the Directorate for Education and Skills, OECD.

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Abstract

This systematic review investigates the relevance of general pedagogical knowledge for successful teaching. It synthesises the empirical evidence of 10 769 teaching professionals and 853 452 students from primary to tertiary education in 21 countries. The meta-analysis of 20 quantitative studies revealed significant effects for teaching quality and student outcomes (Cohen's d = .64 and .26), indicating that more knowledgeable teachers achieve a three-month additional progress for students. The three themes emerging from 31 qualitative studies underline that general pedagogical knowledge is a crucial resource for teaching. Results also show that teaching requires knowledge about a range of topics, specific skills and other competences to transform knowledge into practice. Teachers need training and practical experience to acquire knowledge, which they apply according to the pedagogical situation at hand. The results allow for important conclusions for policy, practice and research.

Résumé

Cette revue systématique examine la pertinence du savoir pédagogique général pour un enseignement fructueux. La revue synthétise les preuves empiriques de 10 769 professionnels de l'enseignement et 853 452 élèves allant de l'école primaire à l'enseignement supérieur, dans 21 pays. La méta-analyse de 20 études quantitatives montre des effets significatifs sur la qualité de l'apprentissage et les résultats des élèves (Cohen's d = .64 et .26) indiquant que les professeurs avec plus de connaissance accomplissent une marge de progrès supplémentaire de 3 mois pour les élèves. Les trois thèmes émergents des 31 études qualitatives soulignent que le savoir général pédagogique est une ressource cruciale pour l'enseignement. Les résultats montrent également que l'enseignement nécessite un savoir varié dans divers domaines, des compétences spécifiques et d'autres capacités pour passer du savoir à la pratique. Les professeurs ont besoin d'entrainement et d'expériences pratiques afin d'acquérir le savoir, qu'ils peuvent ensuite appliquer à la situation pédagogique à l'étude. Les résultats permettent d'établir des conclusions importantes pour les politiques, la pratique et la recherche.

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1. Introduction

Maximising the positive impact of education is at the top of the policy agenda in most OECD countries (OECD, 2018[1]). Research has increasingly identified teachers as the main contributors to student outcomes in schools (Burroughs et al., 2019[2]; Clinton, 2016[3]). After all, it is the teacher who orchestrates interactions with and between students in the classroom and is responsible for creating a classroom climate favourable for learning and personal growth. This in turn can have a major impact on students' learning as well as their well-being and socio-emotional development.

Teachers also play a key role in educational equity and inclusion. They can provide struggling students with the extra support needed to face educational or social challenges in the classroom, helping them to catch up with their peers and integrate well (Schleicher, A., 2016[4]; Mitchell, 2007[5]; Burns and Shadoian-Gersing, 2010[6]). The role of teachers and instructors may change as students progress from primary to secondary and then tertiary education but without doubt, it will still be an important one (Schneider and Preckel, 2017[7]). Irrespective of the subject taught and the educational setting (whether schools, vocational colleges or universities), instructors need to be professionals of pedagogy and base their everyday practice on a regularly updated, coherent and integrated knowledge base to fulfil their roles as learning and equity agents (Baumert and Kunter, 2006[8]; Guerriero, 2017[9]).

Surprisingly, this kind of cross-curricular knowledge has received little attention in policy-making and research for a long time (Guerriero, 2017[9]; Patrick et al., 2011[10]) compared to subject-specific knowledge of teachers: content knowledge (e.g. knowledge of mathematics; and pedagogical content knowledge (e.g. knowledge on how to teach mathematics) (Burroughs et al., 2019[2]; Guerriero, 2017[9]; Greenberg, Walsh and McKee, 2013[11]). It is not entirely clear why general pedagogical knowledge has remained rather untargeted by research efforts, even though it has been widely acknowledged as an important prerequisite for successful teaching. It may simply seem self-evident that teachers should know how students learn or how to teach and manage the classroom (Cochran-Smith, 2003[12]). It may also be that to date the body of evidence linking general pedagogical knowledge to high-quality teaching and student outcomes has not been convincing enough.

Given the great relevance of this question for anyone in a teaching position and anyone researching or providing support for teaching professionals, this review sets out to clarify what is known from empirical research about the relevance of teachers' general pedagogical knowledge for their teaching success. In this review, "teacher" is understood in a broader sense to include anyone who is teaching in a classroom context - whether in primary, secondary or tertiary education. More specifically, this review seeks to:

- systematically summarise the international evidence on how teachers' general pedagogical knowledge is associated with teaching and student outcomes
- identify strengths, weaknesses and knowledge gaps in existing research, in order to help inform decisions about future research
- inform policy, practice and research about the current state of empirical knowledge in order to facilitate 'evidence-based' or 'evidence-informed' decision-making

(Davies et al., 2013[13]; Gough, 2004[14]; Nelson and Campbell, 2017[15]; Henry et al., 2013[16]).

This paper first provides readers with an overview on how research conceptualises teachers' general pedagogical knowledge, outlines the value of the review and provides the background for the review questions. It then moves on to explain the review approach and summarises the review questions. The paper then presents and discusses key findings for each review question, which is followed by an evaluation of the generalisability and quality of the available research. The paper ends with implications for policy-makers, practitioners and researchers.

1.1. Teachers as professionals of pedagogy

The scientific work on teacher professionalism builds the foundation for this review with its underlying assumption that successful teachers are professionals of pedagogy and pedagogical knowledge is seen as an essential element of professional competence. Though different conceptualisations exist, developed framework and models overlap in terms of defined professional competence: usually comprising professional knowledge along with teaching skills as well as various beliefs, attitudes and motivation. Most models distinguish generic from subject-specific competences (Baumert and Kunter, 2006[8]; Guerriero, 2017[9]; Baumert and Kunter, 2013[17]; Tatto et al., 2012[18]; Blömeke et al., 2014[19]). For example, highlighting that being a professional math teacher involves both a) knowledge, skills and beliefs about mathematics and math teaching as well as b) general pedagogical knowledge and more general beliefs about the value of teaching and how students learn.

Undoubtedly, effective teaching evolves from a dynamic interplay of generic beliefs, skills and knowledge and subject-specific competences (Baumert and Kunter, 2006[8]; Tatto, 2013[20]; Blömeke et al., 2014[19]). It is a shared assumption that teaching competences such as general pedagogical knowledge can be learned. During their professional careers, teachers acquire and refine their competence portfolio in and outside of formal teacher education.

General pedagogical knowledge: A common foundation of professional teaching across subjects and settings

Successful teaching requires pedagogical professionalism, no matter the subject or teaching setting. General pedagogical knowledge, thus, can be thought of as a foundation of teaching that is shared by teaching professionals across disciplines and educational levels. The concept of general pedagogical knowledge stems from a taxonomy of teacher knowledge introduced by Shulman in the late 80s (1987[21]; Shulman, 1986[22]), summarised in Box 1.1.

Box 1.1. Shulman's taxonomy of teacher knowledge

Shulman divided teacher knowledge into seven distinct categories; three of which have been widely used in scientific literature and are commonly referred to as follows (Guerriero, 2017[9]; König, 2014[23]):

- **General pedagogical knowledge (GPK)** describes the knowledge of principles and strategies of classroom management and organisation that transcend subject matter.
- **Content knowledge (CK)** comprises the knowledge of subject matter and its organising structures.
- **Pedagogical content knowledge (PCK)** encompasses the knowledge of content and pedagogy and is often described as the "special amalgam of content and pedagogy" that is needed for teaching a subject (Shulman, 1987, p. 8[21]).

Shulman's taxonomy has given rise to a number of empirical studies and has been further developed over time. Researchers generally viewed Shulman's definition of general pedagogical knowledge as restricted to knowledge about classroom management and organisation (Voss et al., 2015[24]; Guerriero, 2017[9]) but Morine-Dershimer and Kent (1999[25]) criticised this as a misinterpretation of his work.

Research evolving from Shulman's work expanded the definition to include further cross-curricular areas, such as knowledge about teaching-learning processes or ways of assessing student's learning and outcomes (e.g. (Voss et al., 2014[26]; Brühwiler et al., 2017[27]). As a result, slightly different terminologies and definitions have emerged with time, and, thus, the knowledge investigated in empirical studies vary in that regard (Voss et al., 2015[24]; König, 2014[23]). Guerreiro (2017, p. 80[9]) proposed a definition that seems broad enough to capture such related but slightly differing concepts:

> *General pedagogical knowledge is "the specialised knowledge of teachers for creating effective teaching and learning environments for all students independent of subject matter."*

1.2. Value of this review for policy, practice and research

Theory positions general pedagogical knowledge as a crucial prerequisite for effective teaching, which is a widely accepted claim. As policy and research increasingly have to justify decisions by referring to empirical evidence (Davies et al., 2013[13]; Gough, 2004[14]), it is surprising how little this claim is positioned on solid empirical grounds. Accumulating what is known about the practical relevance of general pedagogical knowledge means closing a gap in teacher research that is long overdue and of great value for policy-making, practice and research.

1.2.1. Value of this review for policy-making and practice

Numerous reviews have summarised the evidence from studies on *the effectiveness and quality of teachers and teaching* generally implying that students benefit from effective and good teachers in their learning and development, even after taking students' prior skill levels and family background into account (Burroughs et al., 2019[2]; Creemers, 1994[28]; Seidel and Shavelson, 2007[29]; Qu and Becker, 2003, April[30]; Creemers and Kyriakides,

2007[31]; Muijs et al., 2014[32]). This systematic accumulation of evidence has certainly been the cornerstone of the immense interest in research on teachers. It is also true that the compelling evidence has paved the way for a range of policy initiatives around the globe aimed at improving teacher quality. Several countries have enacted legislation to improve teacher recruitment, education, certification and professional development (OECD, 2005[33]; OECD, 2018[34]; Musset, 2010[35]; Clinton, 2016[3]).

Naturally, policies need to be geared towards those professional competencies that matter most for teaching and learning outcomes in order to have their intended effects (OECD, 2018[34]; Darling-Hammond, 2000[36]; Henry et al., 2013[16]; Fallona and Johnson, 2017[37]; Scheerens and Blömeke, 2016[38]). Simply put:

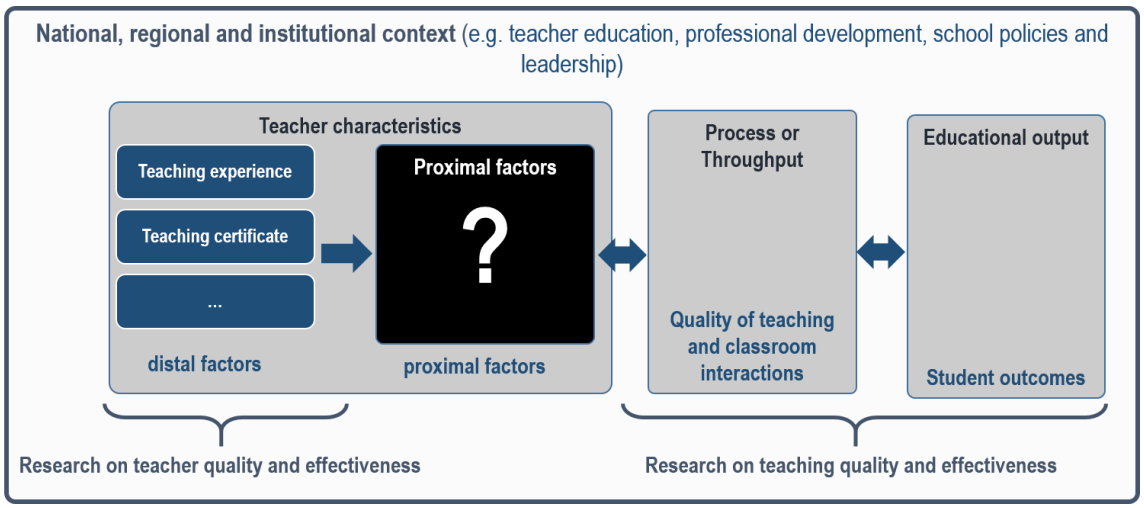
> *"Teachers shouldn't be asked to expend effort to improve something that doesn't help them achieve better outcomes for their students. If a measure is to be included in formal evaluation, then it should be shown that teachers who perform better on that measure are generally more effective in improving student outcomes" (Kane and Staiger, 2012, p. 15[39]).*

Equally important, sufficient attention should be given within programme accreditation to ensure that teachers have sufficient opportunities to acquire these competencies.

The bulk of research on effectiveness, however, provides little guidance for policy-making. As a consequence, the search for means to increase teacher effectiveness has turned into what some argue is an endless journey for the "Holy Grail" (Warwick, November 21st, 2008, p. 22[40]), with an elusive promise of an augmentation of the output of educational systems (Terhart, 2011[41]).

Figure 1.1 illustrates the research foci of effectiveness research and Box 1.2 provides further explanation of the basic approach of this research. As highlighted, effectiveness research has left an important black box largely untouched, despite enormous contributions to the current focus on teacher and teaching in research and policies. On the one hand, research on *teacher effectiveness and quality* investigated whether teachers with longer teaching experience or specific teaching certificates achieve higher learning gains of students, focusing on teacher characteristics that are rather distal determinants of classroom processes (Scheerens and Blömeke, 2016[38]; Kane, Rockoff and Staiger, 2008[42]; Darling-Hammond, 2000[36]). Research on *teaching effectiveness and quality,* on the other hand, was restricted mostly to observable aspects of teaching (Seidel and Shavelson, 2007[29]; Muijs et al., 2014[32]).

Figure 1.1. Main focus of effectiveness research on the classroom-level



Research on *teacher professionalism* opens a 'black box' within effectiveness research. This 'black box' concerns the more proximal determinants of instructional quality and classroom processes (such as general pedagogical knowledge and other teaching competences). For this reason, summarising what is known from professionalism research fills a pressing gap in the review literature.

Box 1.2. Closing a 'black box' of effectiveness research through research on teacher professionalism

Main focus of research on teacher and teaching effectiveness

According to the basic idea of educational effectiveness, educational systems are viewed as a 'black box', within which processes or 'throughput' transform inputs into outputs (Scheerens and Blömeke, 2016[38]). Figure 1.1 illustrates this basic idea of effectiveness research. Financial or personal resources and the background of students etc. represent the input, whereas outputs are the knowledge and skills students have acquired at the end of an academic career. Context covers the socio-economic and educational context of education, for example, teacher policies, guidelines and regulations for schools and other characteristics of the national and regional education systems. Effectiveness research has successively opened up the 'black box' and discovered factors contributing to the effectiveness of educational systems.

At the institutional and classroom level, teachers and their teaching practice have been identified as key ingredients to educational effectiveness. Teachers with certain given characteristics are envisioned as inputs and main determinants of what happens in classrooms (Creemers and Scheerens, 1994[43]). *Teacher effectiveness and quality* focused on teaching experience or specific teaching certificates and other rather distal determinants of classroom processes (Scheerens and Blömeke, 2016[38]; Kane, Rockoff and Staiger, 2008[42]; Darling-Hammond, 2000[36]). In comparison, *teaching effectiveness and quality* was limited to observable aspects of teaching, in spite of acknowledging teacher knowledge and further characteristics as important determinants (Seidel and Shavelson, 2007[29]; Muijs et al., 2014[32]).

Complementary focus of professionalism research

Research on *teacher professionalism* fills an important gap in effectiveness research by unravelling more proximal determinants of instructional quality and classroom processes. Studies of this research strand apply a more direct and fine-grained approach towards investigating teacher quality and effectiveness (König, 2014[23]; Voss et al., 2014[26]; Schmidt et al., 2011[44]; Baumert and Kunter, 2013[17]). The researchers actually measured the various competences required for teaching, for example general pedagogical knowledge, instead of taking competences as a given result of a teaching certificate or a long work experience (Guerriero, 2017[9]; Baumert and Kunter, 2013[17]; Baumert and Kunter, 2006[8]; Tatto et al., 2012[18]). Professionalism research helps shift the view of teachers –from 'cogs in a machine' to "active designers of learning environments and experts in the art and science of teaching" (Paniaguai and Istance, 2018, p. 21[45]). For this reason, the evidence allows for a deeper understanding of what teacher quality and effectiveness means, and for new insights into the effectiveness of various teacher policies (Scheerens and Blömeke, 2016[38]).

1.2.2. Existing reviews and value of the review for research

While there is a substantial body of research on pedagogical content and content knowledge, scientific interest in general pedagogical knowledge has been limited for a long time (Guerriero, 2017[9]). After Shulman's seminal work research on pedagogical content knowledge proliferated the field, there have unsurprisingly been numerous reviews summarising studies on pedagogical content knowledge. These are offered with a focus on

various subjects such as music (Grieser, 2018[46]), English as a foreign language (Gitomer and Zisk, 2015[47]; Evens, Elen and Depaepe, 2016[48]), geography (Roehrig and Nam, 2011[49]), math and science (Baxter and Lederman, 1999[50]; Hashweh, 2013[51]; Schneider and Plasman, 2011[52]; Evens, Elen and Depaepe, 2015[53]; Depaepe, Verschaffel and Kelchtermans, 2013[54]) and, more recently, technological pedagogical content knowledge (TPACK, (Willermark, 2018[55]; Rosenberg and Koehler, 2015[56]; Kasim and Singh, 2017[57]).

Generic teaching competences including general pedagogical knowledge had a revival in empirical research several years ago. A recent international review of existing measures of general pedagogical knowledge by (König, 2014[23]) showed that various instruments are now available; overlapping in conceptualisation and operationalisation. The review, however, does not systematically tackle empirical results for these measures.

Some overviews of the conceptual work on generic competences include a few key research findings mostly concluding that general pedagogical knowledge relates to teaching and student outcomes (Baumert & Kunter, 2006; Guerriero, Sonia, 2017; Südkamp & Praetorius, 2017). However, these overviews are neither comprehensive nor systematic. A section in an excellent review by Voss and colleagues (2015[24]) lists promising evidence for the practical significance of general pedagogical knowledge but the review faces several limitations. Firstly, it only considered German studies. Secondly, only quantitative studies were considered for review. Lastly, the review explicitly excluded self-ratings of knowledge and knowledge-related beliefs but beliefs are important for understanding how teachers use knowledge in the classroom (e.g. (Graber, 1995[58]; Merk et al., 2017[59]).

Similarly, the meta-analyses of D'Agostino and Powers (2009[60]) and Klassen and Kim (2019[61]) focused on quantitative studies almost exclusively from the United States. Both studied how teacher assessment related to student outcomes, resulting in significant overall effects of $d = .12$ (for 32 studies) and $d = .17$ (for 75 studies). Klassen and Kim (2019[61]), however, mix findings for pedagogical content knowledge and general pedagogical knowledge. D'Agostino and Powers (2009[60]) combine results for professional knowledge with further assessment results (e.g. on teachers' personality, grade point average and basic skills). Additionally, the analysis contains a lot of findings from the early 20th century. Research methods and teacher policies have changed and, unsurprisingly, effect sizes were found to differ significantly across studies.

To sum up, content and pedagogical content knowledge still dominates research on teacher knowledge (Guerriero, 2017[9]). Evidently, over 30 years on from Shulman's publication, there is still a great need to underline to the importance of general pedagogical knowledge for both research and policy.

1.3. Developing a roadmap for a review on the practical relevance of general pedagogical knowledge

This review addresses several pressing review questions (RQ) concerning the practical relevance of teachers' general pedagogical knowledge. In this section, the basic model of effectiveness research (as shown in Figure 1.1) will be built upon to produce a roadmap for the review, based on the existing effectiveness research, related reviews and the theoretical work on teacher knowledge.

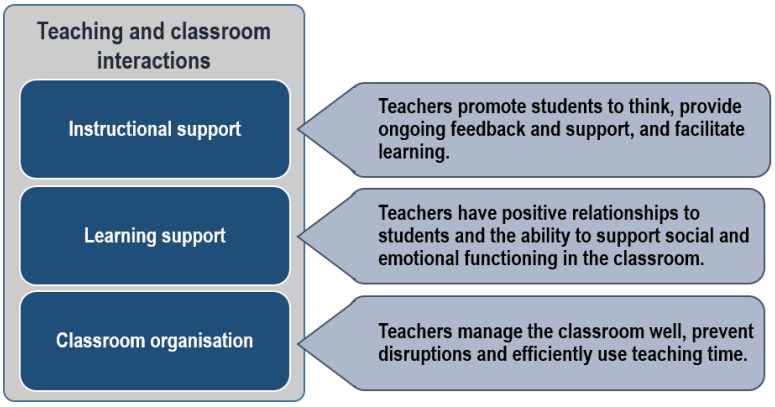
RQ1: Is general pedagogical knowledge a prerequisite and resource for high-quality teaching?

What students learn and experience in the classroom is heavily influenced by teachers' behaviour. That is why teaching is one of the core processes in effectiveness research (Scheerens and Blömeke, 2016[38]) and researchers have invested huge efforts to identify the aspects of teaching that matter most for student outcomes (Seidel and Shavelson, 2007[29]) (see section 1.2.1).

The scientific opinions converge more and more towards a model of teaching quality with three dimensions (Praetorius et al., 2014[62]; Creemers and Kyriakides, 2008[63]; Hamre and Pianta, 2013[64]; Kunter and Voss, 2013[65]): Teachers should provide instructional support, learning support and organise the classroom (Hamre and Pianta, 2013[64]). Rather than the surface-level of teaching (teaching methods, social forms, the teaching materials used etc.), the dimensions describe the deep structure of teaching (Praetorius et al., 2014[62]), which are further explained in Figure 1.2. Similar to general pedagogical knowledge, the three dimensions capture a wide array of classroom interactions across different subjects. Several studies have demonstrated the associations of the quality dimensions to student outcomes (Baumert et al., 2017[66]; Klieme, Schümer and Knoll, 2001[67]; Reyes et al., 2012[68]; Klieme, Pauli and Reusser, 2009[69]; Kane and Staiger, 2012[39]).

Figure 1.2. Zooming in on teaching

Summarising the evidence for the associations of general pedagogical knowledge to the three main dimensions of teaching quality



Source: The dimensions form part of the Teaching through Interaction Framework (Hamre and Pianta, 2013[64]).

In models of teacher professionalism, teachers' knowledge is understood as an important prerequisite and resource for high-quality teaching (Scheerens and Blömeke, 2016[38]; Voss et al., 2015[24]; Guerriero, 2017[9]). Effectiveness researchers similarly recognise teacher knowledge as a likely prerequisite of effective teaching but do not include it in their investigations (Scheerens and Blömeke, 2016[38]; Creemers and Kyriakides, 2008[63]). Evaluating the available evidence for this assumption is a necessary step in studying the relevance of general pedagogical knowledge for teaching success and closing a gap in effectiveness research. A question arising in this context is whether the evidence spans across all three dimensions of teaching quality or is limited to one or two dimensions. Another question is whether the evidence suggests the relevance of general pedagogical knowledge in all phases of teaching, i.e. do teachers draw on general pedagogical

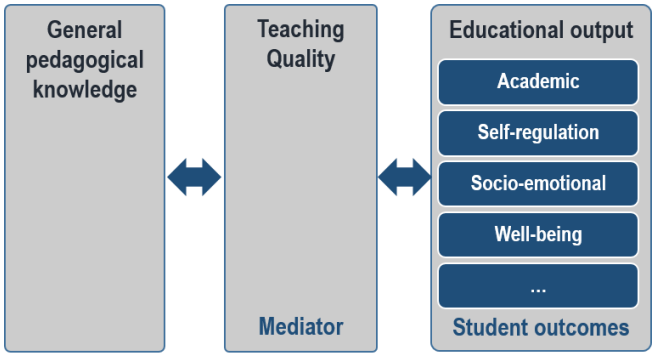
knowledge while planning and teaching lessons and reflecting and evaluating taught lessons?

RQ2: Is general pedagogical knowledge a key ingredient for the "educational output" of systems?

Considering that maximising the positive impact of education is a policy priority in most OECD countries (OECD, 2018[1]), the main purpose of this review is to compile the evidence for the relationship between teachers' general pedagogical knowledge and student outcome. Because of its cross-curricular nature, teachers' general pedagogical knowledge potentially relates to a broad range of student outcomes – such as academic achievements in different subjects, socio-emotional skills, self-regulation, well-being etc., as illustrated in Figure 1.3. This paper will, therefore, additionally evaluate whether there is sufficient evidence to confirm this.

Figure 1.3. Understanding the "educational output" of systems

Summarising the evidence for the associations of general pedagogical knowledge to a broad range of student outcomes and for the mediator effect of teaching quality

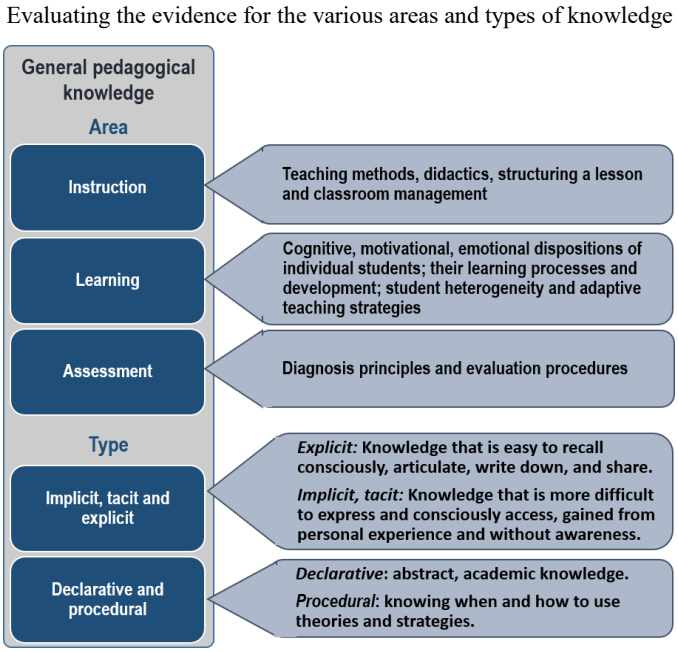


General pedagogical knowledge is thought to unfold its impact on students' learning and development through its effects on teaching and classroom interactions (Scheerens and Blömeke, 2016[38]; Voss et al., 2015[24]; Guerriero, 2017[9]). This suggests that *teaching is a mediator* of the effect of general pedagogical knowledge on student outcomes. Without results for this mediation effect, the evidence base on the practical relevance of general pedagogical knowledge remains incomplete.

RQ3: Which areas and types of knowledge are important for successful teaching?

Teaching is a complex endeavour and, thus, requires teachers to meld knowledge in various areas. In his review of existing approaches to measure teachers' general pedagogical knowledge, König (2014[23]) concluded that comprehensive approaches cover knowledge related to teaching in following areas: instructional process, student learning and assessment. Figure 1.4 zooms in on general pedagogical knowledge and explains the content covered by the three knowledge areas.

Figure 1.4. Distinguishing areas and types of teachers' general pedagogical knowledge



Note: Based on knowledge areas identified through a review of instrument for measuring teachers' general pedagogical knowledge by König (2014[23]).

Apart from content, a distinction is often made between the different types of knowledge (Guerriero, 2017[9]; König, 2014[23]): declarative vs. procedural knowledge. Declarative knowledge summarises the abstract, academic knowledge of teachers (e.g. theories of learning and of teaching-learning processes or facts about instruction and classroom management). Teachers need to know how to apply such knowledge to contexts. This requires a certain degree of professional judgement and experiential or practice-based learning (e.g. knowing when and how to use a particular instructional strategy). This forms part of teachers' procedural knowledge base.

Teachers are assumed to use more knowledge in the classroom than they are aware of, which poses huge challenges for measurement and teacher training. Parts of teacher knowledge, especially experiential and practical knowledge, are tacit, implicit and, thus, only insufficiently accessible through conscious reflection. Implicit knowledge is largely nurtured by teaching experience (Guerriero, 2017[9]; Vogelsang and Reinhold, 2013[70]).

In conclusion, this review requires a nuanced perspective on the available evidence. One that critically appraises if findings suggest the practical relevance of the different knowledge areas and types displayed in Figure 1.4.

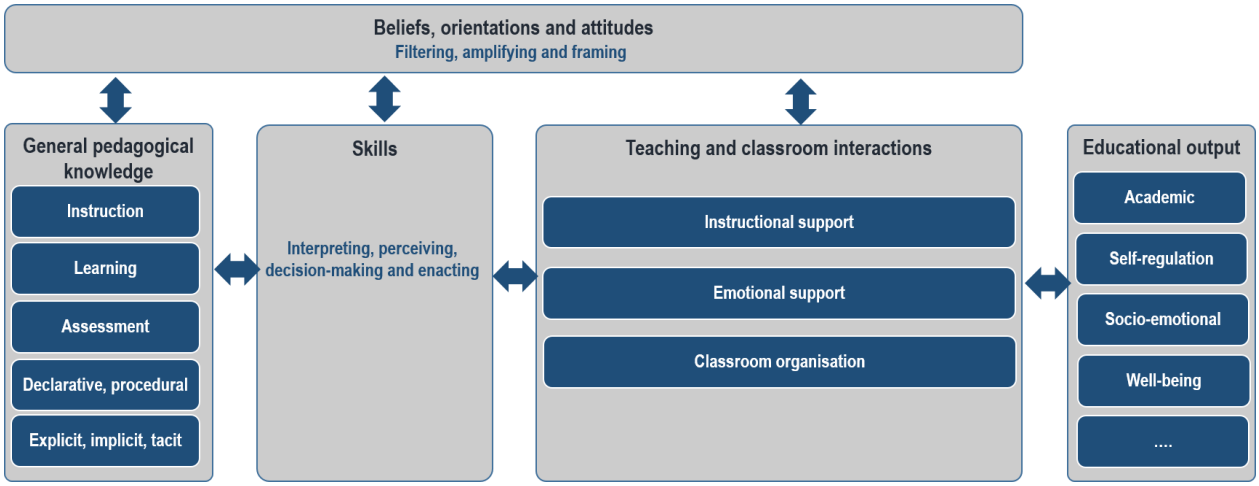
RQ4: How is general pedagogical knowledge transformed into practice?

There is clearly more to excellent teaching than knowledge, because the knowledge relevant for the specific situation in the classroom needs to be activated and transformed into practice. For this, teachers need to notice, interpret and react to important classroom features (Meschede et al., 2017[71]; Stürmer and Seidel, 2015[72]; König, 2015[73]; Blömeke and Kaiser, 2017[74]). For instance, during a lesson a teacher might notice that students are explaining ideas to one another, and helping each other grasping challenging concepts. Teachers can build on this information to decide how the lesson should proceed

(van Es and Sherin Gamoran, 2002[75]). In an attempt to better understand this transformation, researchers began to investigate various skills and cognitive process as intermediating factors between knowledge and teaching practice (Baumert and Kunter, 2006[8]; Voss et al., 2015[24]; Blömeke and Kaiser, 2017[74]), as illustrated in Figure 1.5. Shedding lights on such factors seems also crucial for understanding the context-specific application of knowledge in the classroom.

Figure 1.5 also puts an emphasis on exploring beliefs, attitudes and orientations - ones which are closely related to knowledge (such as teachers' value of pedagogical knowledge or teachers' perception of their own knowledge) (Baier et al., 2018[76]; Blömeke et al., 2015[77]; Lauermann and König, 2016[78]). Beliefs serve functions distinct from teacher knowledge: as filters for interpretation of classroom situations, frames for defining pedagogical problems, and guides or standards for action (Fives and Buehl, 2012[79]; Pajares, 1992[80]). In this regard teachers' beliefs exert influence on teachers' application of knowledge in specific classroom situations as they amplify or filter which knowledge teachers regard as important (Fernandez, 2014[81]; Morine-Dershimer and Kent, 1999[25]; Blömeke et al., 2014[82]; Gess-Newsome, 2015[83]).

Figure 1.5. Investigating knowledge-related skills and beliefs to understand knowledge transmission



RQ5: How can teachers be supported in using general pedagogical knowledge effectively in the classroom?

It is a shared assumption that general pedagogical knowledge can be acquired (see section 1.1). A sizable number of studies have shown that teacher education and professional development can be effective in enhancing teachers' general pedagogical knowledge and knowledge-related skills (Stürmer, Könings and Seidel, 2013[84]; Scheerens and Blömeke, 2016[38]) – a stream of research labelled "teacher education effectiveness research" by Scheerens and Blömeke (2016[38]).

Unless clear evidence exists that the knowledge and skills measured in such evaluation studies are relevant for teaching success, their results are not entirely convincing. It is important to bear in mind that teacher education has been frequently criticised for failing to provide teachers with the knowledge they need in the classroom. Despite scarcity of evidence, some supposed that the knowledge provided is too theoretical and abstract to be

of great use for teaching (Stürmer, Könings and Seidel, 2013[84]; Kennedy, Ahn and Choi, 2008[85]).

It seems therefore important to challenge this criticism by examining the evidence. This review thus summarises research that not only evaluates changes in knowledge and skills of teachers participating in teacher training but additionally assesses subsequent changes in teacher quality and student outcomes. Figure 1.6 integrates this question into the review roadmap.

RQ6: What role does the teaching context play in applying general pedagogical knowledge in the classroom?

Models of teacher professionalism and educational effectiveness alike highlight that the teaching context plays a crucial role for the knowledge teachers apply and the teaching approach they choose (Voss et al., 2015[24]; Scheerens and Blömeke, 2016[38]; Seidel, 2014[86]; Rey et al., 2018[87]). Figure 1.6 extents the developed graphical display to embed teachers use of knowledge into the wider context of learning in schools and institutions (Scheerens and Blömeke, 2016[38]).

For example, teachers draw on general pedagogical knowledge that is useful for achieving the goals of the lesson or teaching unit (Herppich et al., 2018[88]). Moreover, teachers have to consider the size of the class, as well as materials and equipment available in the classroom for evaluating which principles and theories of learning and teaching apply for their class.

Teachers' instructional choices and their success in promoting learning and creating a positive and nurturing learning atmosphere in the classroom further depends on the students in the classroom. Students are no tabula rasa when they enter the classroom and their motivation, prior knowledge and experiences shape teaching practice and the outcomes of teaching.

In addition, teachers' use of knowledge and its consequences needs to be interpreted against the background of the institutional and national context. The type of school leadership and organisation, educational policies and further contextual factors influence what is happening in classrooms, even if the influence is not direct as teachers are usually relatively autonomous in their teaching.

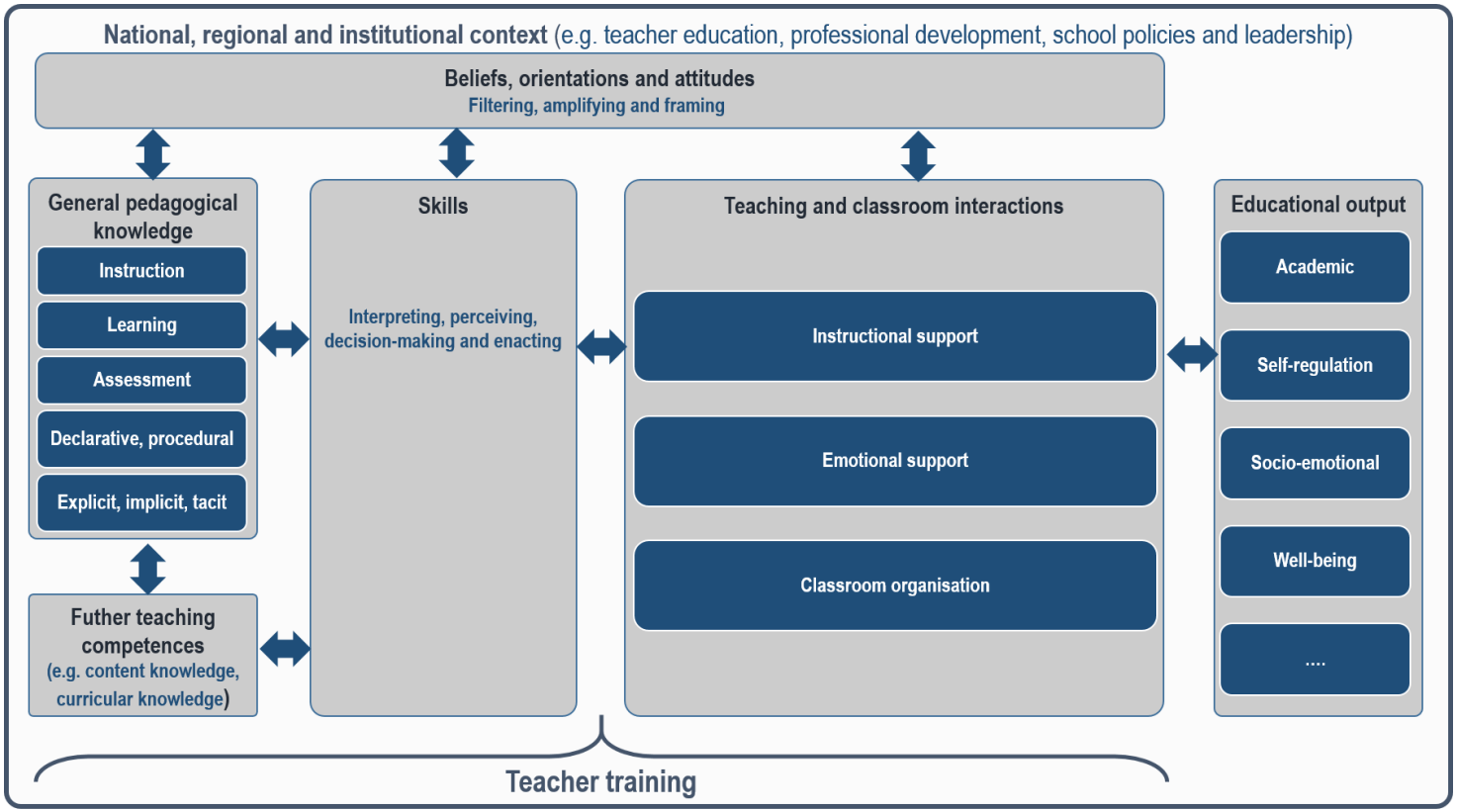
RQ7: What role do other teaching competences play for teachers' use of general pedagogical knowledge?

Undoubtedly, there is more to effective teaching than general pedagogical knowledge (Baumert and Kunter, 2006[8]; Blömeke and Kaiser, 2017[74]; Guerriero, 2017[9]). As the section 1.1 explained it is assumed that effective teaching evolves from a dynamic interplay of generic beliefs, skills and knowledge and subject-specific competences (Baumert and Kunter, 2006[8]; Tatto, 2013[20]; Blömeke et al., 2014[19]). Thus, a comprehensive overview of the empirical knowledge requires reviewing the existing research for evidence on how general pedagogical knowledge works together with other teaching competences to shape teachers' action in the classroom.

Including this last step into the model, as done in Figure 1.6, completes the roadmap that guides the synthesis of this review (Scheerens and Blömeke, 2016[38]; Voss et al., 2015[24]; Hamre and Pianta, 2013[64]; Blömeke and Kaiser, 2017[74]; Stürmer and Seidel, 2015[72]; Rey et al., 2018[87]; Gess-Newsome, 2015[83]).

Figure 1.6. Final roadmap for the review

The roadmap highlights the topic that should be addressed by research to provide a comprehensive picture of the practical relevance of general pedagogical knowledge.



Note: The map should not be interpreted as a conceptual model of teacher professionalism because it sets a specific focus on the review questions regarding general pedagogical knowledge, and, thereby, deliberately leaves out important details and further professional competences of teachers.

2. The review

2.1. Review questions

Although it is widely acknowledged that general pedagogical knowledge is a crucial prerequisite for effective teaching and thus should be a targeted by efforts to ensure and increase teacher quality across countries, this claim is seldom positioned on solid empirical grounds and previous reviews only provide limited information on the topic, as discussed in section 1.2.2.

This review sets out to close this gap by summarising systematically what the empirical research has to say regarding the practical relevance of teachers' general pedagogical knowledge. Drawing on the discussion in section 1.3 and the review roadmap displayed in Figure 1.6, the following seven review questions (RQ) will be addressed in section 3. :

- **RQ1:** Is general pedagogical knowledge a prerequisite and resource for high-quality teaching?
- **RQ2:** Is general pedagogical knowledge a key ingredient for the "educational output" of systems?
- **RQ3:** Which areas (instructional process, student learning and assessment) and types (implicit, tacit and explicit knowledge; declarative and procedural knowledge) of general pedagogical knowledge are important for successful teaching?
- **RQ4:** How is general pedagogical knowledge transformed into practice?
- **RQ5:** How can teachers be supported in using general pedagogical knowledge in the classroom?
- **RQ6:** What role does the teaching context play in applying general pedagogical knowledge in the classroom?
- **RQ7:** What role do other teaching competences play for teachers' use of general pedagogical knowledge?

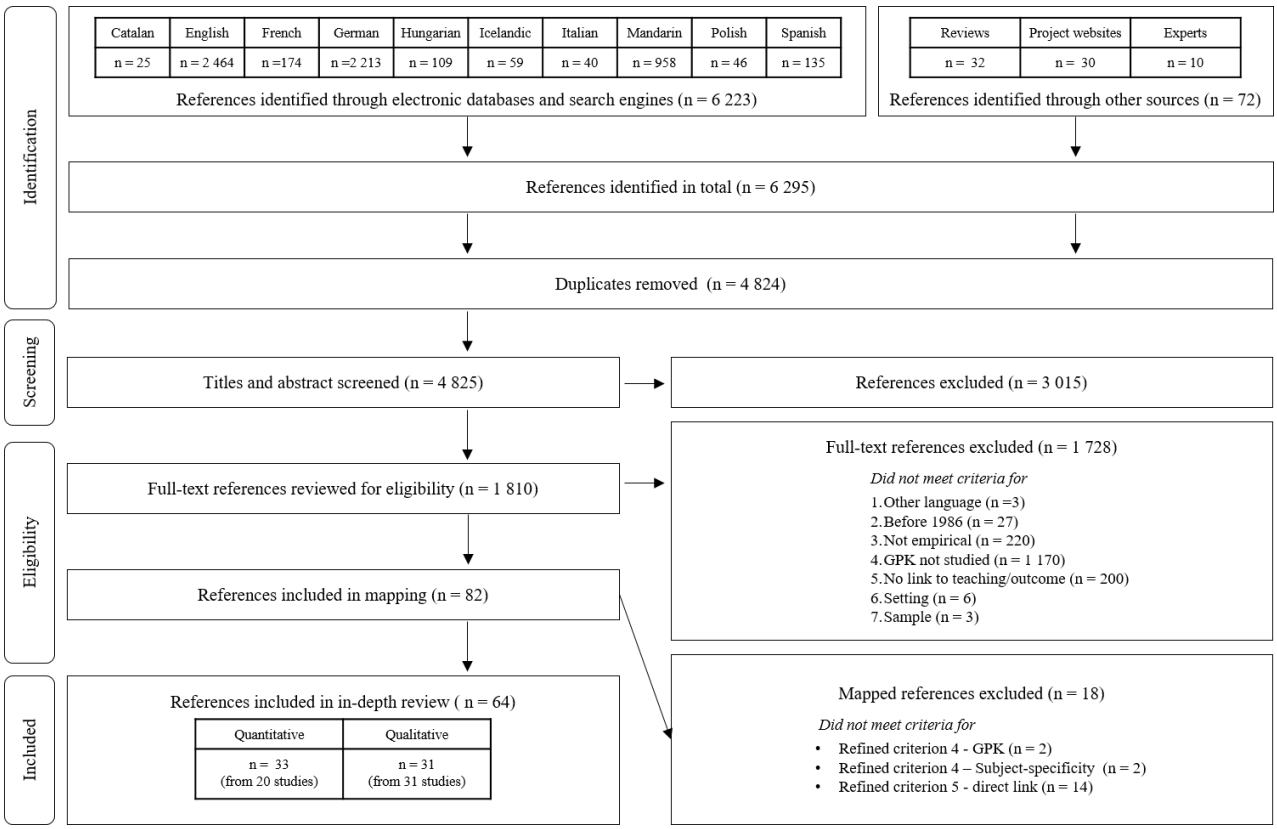
After reviewing the findings, sections 4. and 5. *evaluate the available evidence* in light of the following two evaluation questions (EQ):

- **EQ 1:** How generalisable are the findings (e.g. to different subjects, countries and teaching settings)?
- **EQ2:** How can the research methodology improve (e.g. evaluation of the instruments used to measure knowledge and teaching)?

2.2. Review approach and overview

In an attempt to deliver a more comprehensive synthesis than previous work, the review addresses these questions by reviewing the international evidence published between 1992 and 2018 in ten languages (Catalan, English, French, German, Hungarian, Icelandic, Italian, Mandarin, Polish and Spanish). This review is based on an intensive and systematic search and selection process, illustrated in Figure 2.1, which resulted in an in-depth review of 64 publications reporting findings from 51 studies (see Annex A). Reviewed research also covers beliefs and attitudes as well as skills related to knowledge and consists of qualitative, quantitative and mixed-method studies. Further details on review methodology (including search terms and engines, selection criteria and details on the synthesis of evidence) are available in Annex B and a more exhaustive overview on included publications and studies is provided in Annex C.

Figure 2.1. Flow Diagram of the search and selection process



Note: Details on the search, selection and mapping for the review (including selection criteria and refinements after mapping) are available in Annex B.

The synthesis of both (mainly) quantitative and (mainly) qualitative studies contributed to the answers of all seven review questions and the two evaluation questions, though analysed separately.

2.2.1. Synthesis of quantitative studies

Findings from 20 *quantitative studies* for the relationship of teachers| general pedagogical knowledge to aspects of teaching and student outcomes were coded and, if necessary, transformed or computed to represent effect sizes (ES) of the correlation family (Fernández-Castilla et al., 2019[89]). Three-level meta-analytic models aggregated the effect sizes into overall effects for teacher knowledge (Assink and Wibbelink, 2016[90]): an overall effect for teaching and an overall effect for student outcomes. Additionally, mixed-effects models studied if different moderators modulated the size of effects (Viechtbauer, 2010[91]).

As effect sizes for some specific questions are rarely reported (e.g. the indirect effects of teacher knowledge on student outcomes through aspects of teaching), they were not compiled into overall effects. Instead, they are narratively summarised. Further, various additional analysis tested the robustness of results (see Annex D). Table 2.1 lists how the quantitative evidence is synthesised for each question of the review. Section 3. describes the findings of the moderator analysis (results are presented in Box 3.1).

Table 2.1. Overview on the synthesis approach for each review and evaluation question

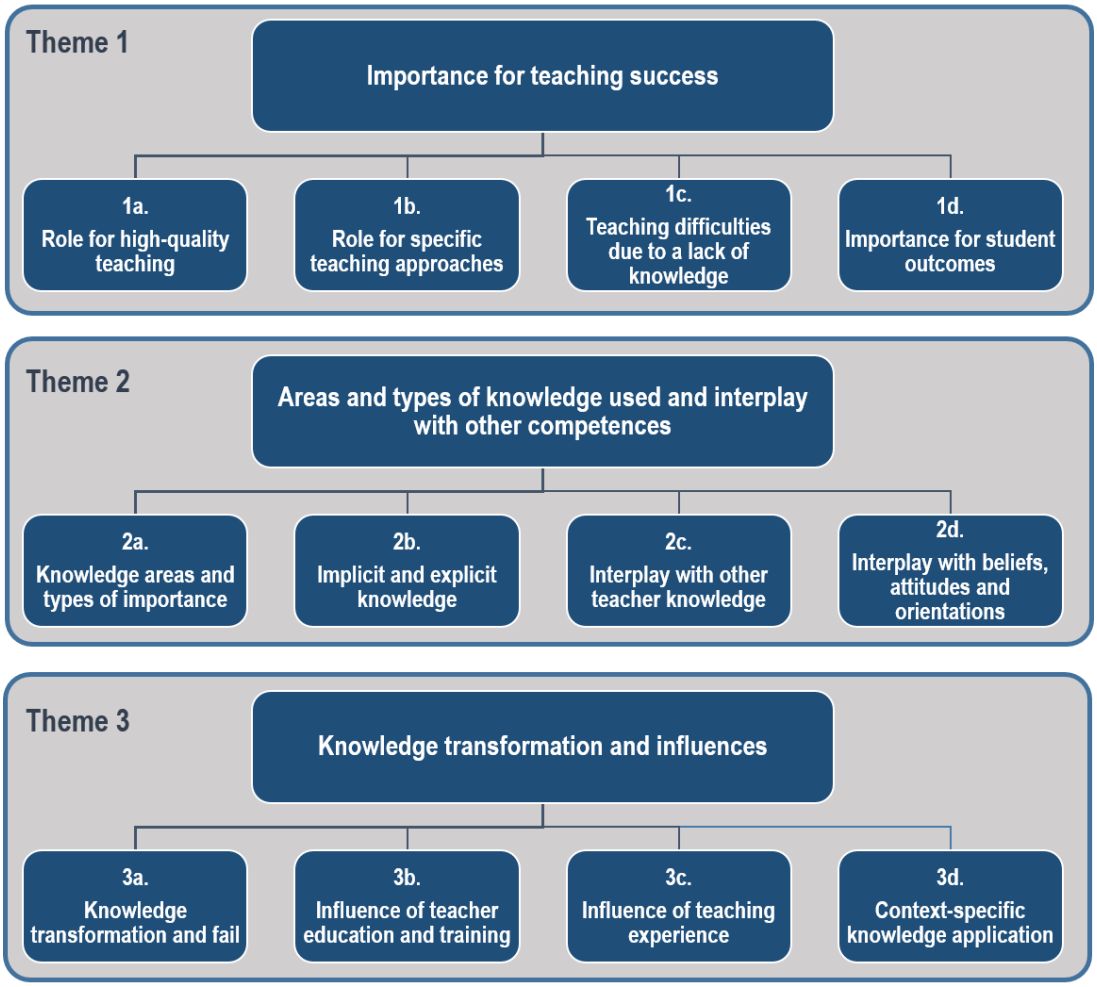
Question	Synthesis of quantitative studies	Synthesis of qualitative studies
RQ1: Pedagogical knowledge as a prerequisite and resource for high-quality teaching	• **Overall effect** of teachers' general pedagogical knowledge on teaching • **Moderator analysis for quality dimensions:** Comparison of effect sizes obtained for indicators of overall teaching quality, instructional support, learning support and organisational support to test if general pedagogical knowledge is relevant for different aspects of teaching quality.	Themes 1a, 1b, 1c
RQ2: Teacher knowledge as a key ingredient for educational output	• **Overall effect** of teachers' general pedagogical knowledge on student outcomes • **Moderator analysis for outcome type**: Comparison of effect sizes obtained for student achievement versus other outcomes to test if general pedagogical knowledge is relevant for different outcome types. • **Narrative summary** of findings for the mediator effect (i.e. the indirect effect of knowledge on student outcomes through teaching quality)	Theme 1d
RQ3: Knowledge areas and types of importance for teaching	• **Narrative summary** of findings for the three knowledge areas (instructional process, learning process, assessment) and types of knowledge (declarative and procedural knowledge)	Themes 2a, 2b
RQ4: Transforming general pedagogical knowledge into practice	• **Moderator analysis for skills versus knowledge**: Comparison of effect sizes obtained for measures of teachers' general pedagogical knowledge versus knowledge-related skills to test the relevance of both for successful teaching	Theme 3a
RQ5: Shaping teachers' use of general pedagogical knowledge	• **Narrative summary** of findings for interventions aimed at increasing teacher's general pedagogical knowledge to enhance the quality of teaching and student outcomes	Theme 3b, 3c
RQ6: The context matters for teachers' knowledge use	• **Narrative summary** of findings for the influence of contextual factors (e.g. class size, class composition) on the effect of general pedagogical knowledge on teaching and student outcomes	Theme 3d
RQ7: General pedagogical knowledge as one ingredient among others	• **Narrative summary** of findings for how general pedagogical knowledge works together with further professional competences to shape teachers' practice in the classroom	Theme 2d
EQ1: Evaluating the evidence: How generalisable are the findings?	• **Descriptive overview** on the regional coverage of the available evidence as well as the teaching settings, teaching professionals, subjects and students studied	
EQ2: Evaluating the evidence: How can research methodology improve?	• **Descriptive overview** on the weight of evidence and study designs as well as the approaches to measure knowledge, teaching and student outcomes • **Moderator analysis for teacher questionnaires versus assessments:** Comparison of effect sizes obtained with teacher questionnaires as measures of knowledge versus teacher assessments (e.g. tests, rated portfolios) • **Moderator analysis for contextualised measures**: Comparison effect sizes obtained with contextualised measures of teacher knowledge (vignettes, scenarios or situational judgement items) versus other measures. • **Moderator analysis for perspectives on teaching quality**: Comparison of effect sizes obtained for teacher questionnaires about the quality of teaching, student questionnaires or external ratings.	-
Evaluating potential bias in the quantitative synthesis (Annex D)	• **Moderator analysis for publication bias:** Comparison of effect sizes obtained from peer- versus non-peer-reviewed studies • **Moderator analysis for study quality:** Comparison of effect sizes obtained for studies varying in quality • **Moderator analysis for analytical approach:** Comparison of effect sizes obtained with bivariate approaches (e.g. Pearson or Kendall correlation) versus multivariate approaches (e.g. multiple regression, structural equation modelling) • **Funnel plot analysis:** Visual inspection of funnel plots for the overall effects for teaching and student outcomes as well as a statistical testing of potential asymmetries • **File drawer analysis:** Testing the robustness of effects against potentially missing null findings	-

Note: RQ = Review question. EQ = Question for the evaluation of study design.

2.2.2. Synthesis of qualitative studies

The synthesis of *qualitative studies* involved a search for common themes across studies that characterise teachers' use of knowledge in the classroom (Braun and Clarke, 2006[92]). The evidence of the emerging topic clusters is presented narratively to address each of the review questions and complement the evidence from the quantitative review. Three broad themes comprising four topics each were developed as part of the qualitative synthesis. Figure 2.2 provides an overview of the themes and Table 2.1 lists for each question of the review the corresponding theme and analysis.

Figure 2.2. Themes developed during the synthesis of qualitative studies



3. Synthesis of the evidence: What does research tell us about the practical relevance of general pedagogical knowledge?

RQ1: Pedagogical knowledge as a prerequisite and resource for high-quality teaching

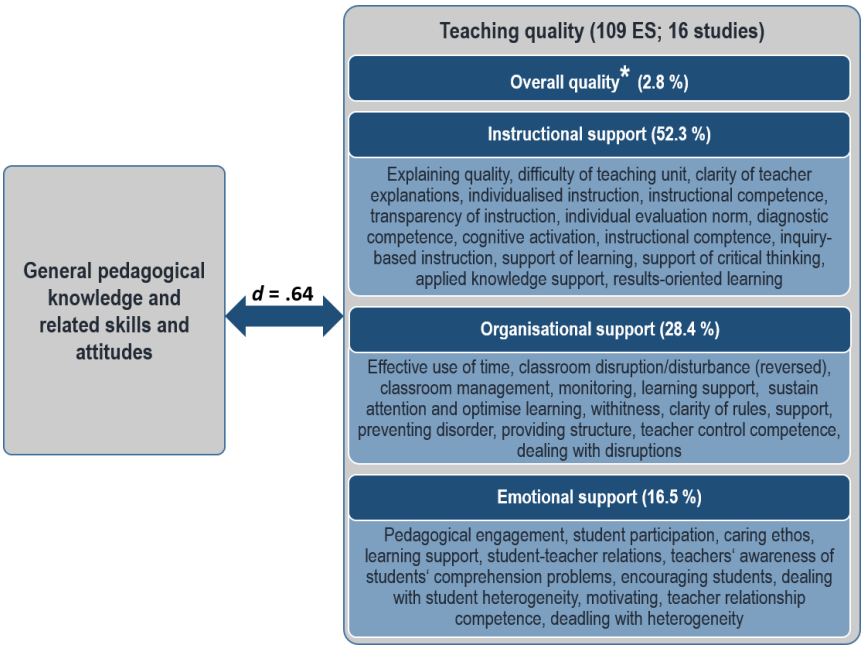
Overall, the available research indicates that teachers draw on general pedagogical knowledge for high-quality teaching and creating beneficial learning environments in the classroom. Understanding the way this knowledge supports teachers' action in the classroom, however, requires looking at the results more closely.

Synthesis of quantitative studies for RQ1: Relevance of general pedagogical knowledge for teaching

Figure 3.1 shows that the synthesis of 109 effect sizes from 16 *quantitative studies* resulted in a moderate overall effect of general pedagogical knowledge on teaching: d = .64 (Cohen, 1988[93]). Effect sizes, however, varied as visually displayed in the forest plot of the effect (see Figure A G.1 of Annex G). Box 3.1 provides details on the overall effects and results of the moderator analysis. Notably, no finding indicated that teachers' general pedagogical knowledge was detrimental to the quality of teaching and classroom interactions. All studies were at least partly affirmative, meaning that significant results were at least observed for some of the relationships studied.

Figure 3.1. Overall effect for the relationship between general pedagogical knowledge and teaching quality

The overall effect of d = .64 did not differ for the different aspects of teaching quality studied.



The overall effect is comprised of indicators across all three dimensions of teaching quality (instructional support: 52.3%, organisational support: 28.4% and emotional support:

16.5%), though more than half of the effect sizes included qualify as indicators of teachers' "instructional support" (see Figure 3.1). Almost three percent of effect sizes used an overall indicator of teaching quality comprised of indicators from all three dimensions. Testing the dimension of teaching as a moderator showed that the effects did not differ significantly (see Box 3.1). This means that whether effects referred to overall teaching quality or one of the tree dimensions did not explain the observed variation in effect size.

Taken together, the results suggest that general pedagogical knowledge supports teachers in delivering lessons of high-quality in all three dimensions: More knowledgeable teachers are better able to promote students to think and learn, support a healthy social and emotional climate during lessons and to manage the classroom efficiently.

Box 3.1. Details on the meta-analytic results for the quantitative studies reviewed

Effect on teaching

The 109 effect sizes from 16 studies built a significant effect of general pedagogical knowledge on teaching ($ES = .31$, $se = 0.05$, $p < .001$, $CI_{95\%}$ [.22, .41]). Transforming the results into Cohen's d yielded a medium effect of $d = .64$ (Cohen, 1988[93]).. Effect sizes varied both within ($\delta_{within} = .017$) and between studies ($\delta_{studies} = .026$). The weighted least squares extension of Cochran's Q-test (Higgins et al., 2019[94]) was significant, indicating that observed variations were larger than expected based on sampling variability alone (Viechtbauer, 2010[91]): $Q_{ES}(108) = 649.71$, $p < .001$.

Effect on student outcomes

Similarly, the 34 effect sizes for the effect on student outcomes from 8 studies were aggregated into a significant effect ($ES = .13$, $se = .04$, $p < .01$, $CI_{95\%}$ [.06, .20]). The effect is small: $d = .26$ (Cohen, 1988[93]). Effect sizes varied between but not within studies ($\delta_{studies} = .01$ and $\delta_{within} = .00$). Again the variation was significant: $Q_{ES}(35) = 67.61$, $p < .001$.

Table 3.1 shows the results for the moderator analysis. The moderator tests (Q_M) indicated only a marginal significant effect for teacher questionnaires. For all moderators significant variations in effects remained after inclusion (Q_E). The table also provides the effect sizes (ES), number of effect sizes (k_{ES}) and studies (k_{Study}), the standard errors (se), and confidence interval ($CI_{95\%}$) for each subgroup (e.g. knowledge measured with questionnaires versus other measures).

Table 3.1. Results of the moderator analysis

Moderators	Test of moderator		Residual variance		Sample		Effect size of subgroups		
	Q_M	df_M	Q_E	df_E	k_{ES}	k_{Study}	ES	*se*	$CI_{95\%}$
For the effect on teaching									
RQ1: Quality dimension	0.31	3	610.85***	105	109	16			
Overall quality					3	1	.34***	.13	.18, .45
Instructional support					57	8	.29***	.06	.19, .41
Organisational support					31	7	.31***	.06	.20, .44
Emotional support					18	5	.34*	.07	.06, .65
RQ4: Skills vs knowledge	1.42	1	548.08***	107	109	16			
Knowledge					76	12	.28***	.05	.19, .39
Skills					33	6	.35***	.06	.24, .49
Evaluation: Questionnaire on knowledge	3.83#	1	411.70***	107	109	16			
Knowledge questionnaire					4	1	.54***	.16	.30, .91
Other knowledge instruments					105	15	.28***	.05	.20, .38
Evaluation: Contextualised knowledge instruments	0.48	1	595.78***	106	109	16			
Contextualised instruments					93	12	.29***	.06	.18, .41
Other instruments					15	4	.36***	.10	.17, .58
Evaluation: Perspective on teaching	.39	2	634.26***	106	109	16			
Teachers					19	3	.29**	.10	.09, .50
Raters					31	8	.35***	.08	.21, .53
Students					59	5	.26**	.08	.11, .43
For the effect on student outcome									
RQ2: Outcome type	2.01	1	62.06**	32	34	8			
Academic achievement					23	7	.10**	.03	.04, .15
Self-regulation skills					11	3	.19**	.06	.07, .31
RQ4: Skills vs knowledge	0.91	1	57.69**	32	34	8			
Knowledge					12	4	.18**	.06	.05, .31
Skills					22	4	.10#	.05	-.01, .21
Evaluation: Contextualised knowledge instruments	1.65	1	63.16**	32	34	8			
Contextualised instruments					33	7	.11**	.03	.05, .18
Other instruments					1	1	.30*	.15	.01, .61

Note: No study reporting student outcomes used questionnaires to measure teacher knowledge. Significance levels are indicated as # p< .10, *p< .05, **p< .01, ***p< .001.

Synthesis of qualitative studies for RQ1: Relevance of general pedagogical knowledge for teaching

Table 3.2 provides details on the themes and subthemes as well as weight of evidence for the qualitative studies reviewed (see section 5. for an in - depth discussion on the weight of evidence). Similar to quantitative studies, the qualitative studies contributing to the *first theme* highlighted how general pedagogical knowledge contributed to teaching success. A profound and broad knowledge about general pedagogy allowed for successful teaching-learning events (Atjonen, Korkeakoski and Mehtalainen, 2011[95]), for a greater efficacy in teaching (Hativa, Barak and Simhi, 2001[96]), and the successful management of multicultural classrooms (Tartwijk et al., 2009[97]) *theme 1a*). Knowing about pedagogy helped teachers and instructors to be flexible in their teaching so that they could change

their didactical approaches to meet student needs during lessons (Cui, 2017[98]; Gao, 2015[99]; Dögg Proppé, 2014[100]; McAlpine et al., 1999[101]). In addition, general pedagogical knowledge was a driver for applying particular teaching approaches (*theme 1b*) such as:

- implementing the Sport Education (SE) model, a specific curriculum model of sport education based on play education theory (Stran and Curtner-Smith, 2010[102])
- using concrete questions and a combination of instructor-centred and student-centred teaching methods (Boz and Boz, 2008[103])
- facilitating meta-cognitive reflections among students (Stankovic and Delafontaine, 2016[104]).

According to some authors (*theme 1c*), a lack of general pedagogical knowledge, on the other hand, caused teaching difficulties in the classroom (Hativa, 2000[105]; Li, 2012[106]; Walsh, 2017[107]; Yao, 2014[108]).

Table 3.2. Evidence from qualitative studies – Themes, subthemes and quality

Study	Themes and subthemes			Study WoE[a]
	1	2	3	
Atjonen (2011)	1a	2a	3d	good
Boz & Boz (2007)	1b	2d		satisfactory
Cocard & Krähenbühl (2015)		2b	3a	satisfactory
Cui (2017)	1a	2a	3c	satisfactory
Dögg Proppé (2014)	1a, 1d	2d		satisfactory
Friedrichsen et al. (2007)			3c	satisfactory
Gao (2015)	1a			satisfactory
Gholami & Husu (2010)		2b	3d	satisfactory
Hativa (2000)	1c	2d	3b	good
Hativa et al. (2001)	1a	2b	3a	good
Hunger (2013)			3a	satisfactory
Jiang & Hao (2010)		2a, 2d	3c	satisfactory
Jiang & Hao (2011)			3c	satisfactory
Jiang (2006)		2a		satisfactory
Kawecki (2009)			3b, 3c	satisfactory
Lehrer & Franke (1992)		2d, 2d		good
Li (2012)	1c	2d	3a	satisfactory
Magnoler et al. (2008)		2b, 2d	3b, 3c	satisfactory
McAlpine et al. (1999)	1a	2b, 2d	3a, 3b, 3c	good
Roux-Paties (2014)			3c,3d	satisfactory
Salata (2016)			3c	satisfactory
Sanders et al. (1993)		2d	3b	satisfactory
Sothayapetch et al. (2013)		2d	3d	satisfactory
Stankovic & Delafontaine (2016)	1b, 1d	2d	3b	satisfactory
Stran & Curtner-Smith (2010)	1b			good
Syarief (2017)		2d		satisfactory
Tran & Lawson (2007)		2a	3d	satisfactory
van Tartwijk et al. (2009)	1a	2a		satisfactory
Walsh (2017)	1c			satisfactory
Wu (2013; qualitative study)		2b, 2d		excellent
Yao (2014)	1c			satisfactory
Topic WoE[a]: Studies rated as				
excellent		**1**		**1**
good	**5**	**5**	**4**	**6**
satisfactory	**9**	**15**	**16**	**24**

Note: a.) WoE = Weight of Evidence.
Themes are 1 = Importance for teaching success, 2 = Areas and types of knowledge used and interplay with other competences, 3 = Knowledge transformation and influences. Subthemes are 1a. = Role for high-quality teaching, 1b = Role for specific teaching approaches, 1c = Teaching difficulties due to a lack of knowledge, 1d = Importance for student outcomes, 2a = Knowledge areas and types of importance, 2b = Implicit and explicit knowledge, 2c = Interplay with other teacher knowledge, 2d = Interplay with beliefs, attitudes and orientations, 3a = Knowledge transformation and fail, 3b = Influence of teacher education and training, 3c = Influence of teaching experience, 3d = Context-specific knowledge application (see Figure 2.2).

RQ2: Teacher knowledge as a key ingredient for educational output

Taken together, the evidence reviewed supported the notion of teachers' general pedagogical knowledge as an ingredient for the output of educational institutions. Similar

to the link observed for teaching, however, a more differentiated view is necessary and evidence in general is scarce.

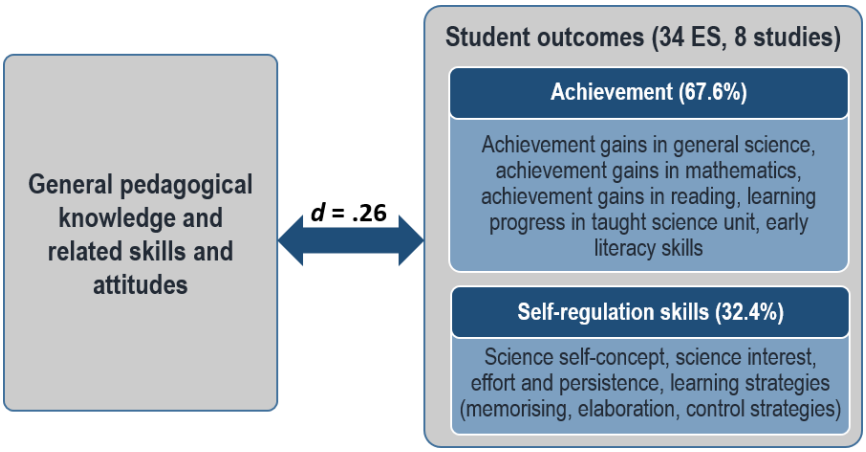
Synthesis of quantitative studies for RQ2: Relevance of general pedagogical knowledge for student outcomes

Figure 3.2 illustrates that synthesising the 34 effect sizes from 8 quantitative studies yielded a significant positive effect (d = .26), which according to Cohen is small (Cohen, 1988[93]). The results imply that students of teachers with stronger general pedagogical knowledge had better achievement in reading, mathematics and science, applied more learning strategies and showed greater interest and a better self-concept in the subject taught. According to the Education Endowment Foundation (2018[109]) results imply that more knowledgeable teachers achieve a three-month additional progress for students. Importantly, no study reported negative consequences of a higher knowledge of teachers and all studies were at least partly affirmative (i.e. reporting significant results for some of the relationships studied). Figure A G.2 of Annex G shows the forest plot for this effect.

The student outcomes studied were restricted to outcomes which strongly related to academic learning (see Figure 3.2): Over two thirds of effect sizes related to student achievement (67.6%) and only one third referred to students' self-regulation skills including students' self-concept, interest, effort and persistence as well as variouslearning strategies (32.4%). Other outcome types such as socio-emotional skills or well-being are completely missing from research. Effects for the two outcome types were similar in size, as the moderator analysis indicated (see Box 3.1).

Figure 3.2. Overall effect for the relationship between general pedagogical knowledge and educational output

The overall effect of d = .26 did not differ for the two types of educational output studied.



Only two studies, both in science, reported on teaching quality as a *mediator of this effect* (see Table 3.3). Brühwiler (2011[110]) found that the effect of teachers' adaptive teaching competence on students learning gains in a taught unit was mediated by teaching quality. Lenske and colleagues (2016[111]; Lenske, Wirth and Leutner, 2017[112]) observed that the effects of teachers' pedagogical-psychological knowledge on student interest and achievement in taught unit was mediated by their classroom management (Lenske et al., 2016[111]; Lenske, Wirth and Leutner, 2017[112]). Further studies that investigated how teachers' general pedagogical knowledge related to teaching and student outcomes did not report effect sizes for indirect effects.

Table 3.3. Narrative summary of results for the quantitative studies reviewed for RQ2 and RQ3

Review question	Study	Sample	Summary	ES, Cohen's d
RQ2: Teacher knowledge as a key ingredient for educational output	ATC (Brühwiler, 2011[110])	47 Swiss teachers of science teaching 832 primary and lower secondary students	The effect of teachers' adaptive teaching competence on student's learning gains in taught unit was *mediated by a better educational quality* (i.e. higher student engagement, quality of instruction and appeal of the lesson, as well as greater orientation towards rules and less pressure as reported by students).	• Indirect effect: *ES* = .15, *d* = 30 • Total effect: *ES* = .34, *d* = .72
	PROWIN II (Lenske et al., 2016[111]; Lenske, Wirth and Leutner, 2017[112]).	34 German teachers of physics teaching 973 lower secondary students	Effects of pedagogical-psychological knowledge on student interest and achievement in taught unit was mediated by their classroom management.	• Indirect effect for interest: *ES* = .26, *d* = .54 • Indirect effect for achievement: *ES* = .27, *d* = .56
RQ3: Knowledge areas of importance for teaching quality	BilWiss (Lohse-Bossenz et al., 2015[113])	268 German teachers in induction at primary and secondary schools	Mixed findings emerged for teachers' educational knowledge in the area of *learning*: the learning subscale was related to positive shifts over the course of a year for all studied aspects whereas development subscale showed no significant relationships. Knowledge in *assessment* was only related to a single quality indicator.	• Learning: *ns*, *.ES* = .21 – .51, *d* = .43 – 1.19 • Assessment: *ns*, *.ES* = .35, *d* = 75
	Laflotte (2015[114])	8 Swiss primary and middle school teachers	No significant relationships emerged between teachers' knowledge in the areas of *instruction* and *assessment* (i.e. knowledge about classroom management, teaching methods and evaluation) to their instructional and organisational support.	• Instruction: *ns*, *ES* = .66, *d* = 1.76 • Assessment: *ns*
	SioS-L (Biermann and Kaub, 2014[115])	89 German teacher candidates in practicum	Teacher candidates' knowledge in the areas of *learning* and *instruction* (i.e. knowledge about heterogeneity, teaching and learning and lesson structure) related marginally to instructional and organisational support.	• Instruction: *ES* = .20, *d* = .41 • Learning: *ES* = .18, *d* = 37
RQ3: Knowledge areas of importance for educational output	ATC (Beck et al., 2008[116])	47 Swiss teachers of science teaching 832 primary and lower secondary students	Teachers' adaptive competences in *instruction* (didactic competences and classroom management) were associated with students' learning progress in taught unit as well as their self-concept and interest in science. No relationship emerged to learning strategies (except for the strategy of elaboration) or general science achievement. Similarly, teachers' adaptive competences in *assessment* (diagnostic competences) related only to student progress unit taught, interest and self-concept in science.	• Instruction: *ns*, *ES* = .20 – .27, *d* = .41 – 56 • Assessment: *ns*, *ES* = .22 – .43, *d* = .45 – .95
	ProTeach (Cowan and Goldhaber, 2014[117])	1 992 primary and lower secondary teachers of mathematics and English teaching 730 877 students	Neither teachers' knowledge and skills in *instruction* (e.g. classroom management, instructional practices) and *learning* (e.g. cultural sensitivity) nor their *assessment* strategies showed significant relationships with student achievement in reading and mathematics, when studied separately.	• Instruction: *ns* • Assessment: *ns* • Learning: *ns*
	Salinger (2014[118])	97 primary teachers of English teaching 1 396 students	No significant associations between teacher knowledge in the student domain and student literacy skills were observed. When comparing percentage of students at or above the benchmark cut-points, students with teachers who scored above the mean scored higher on all outcome measures except for third graders' reading comprehension but none of the comparisons was statistically significant.	• Learning: *ns*
RQ3 b: Knowledge types of importance for teaching	PROWIN II (Lenske et al., 2016[111])	34 German teachers of physics teaching 973 lower secondary students	Teachers' *declarative* and *conditional-procedural* knowledge related significantly to students' progress in taught science unit, when considered separately. Yet, if studied simultaneously, only *conditional-procedural* knowledge remained a significant predictor.	• Declarative knowledge (studied separately and simultaneously): *ES* = .28, *d* = .58 and *ns* • Conditional-procedural knowledge (studied separately and simultaneously): *ES* = .38, *d* = .82 and *ES* = .38, *d* = .82

Synthesis of qualitative studies for RQ2: Relevance of general pedagogical knowledge for student outcomes

The *theme 1d* developed in the synthesis of *qualitative studies* identified only two studies that investigated the way general pedagogical knowledge influenced students' learning and growth in the classroom (see Box 3.1). Dögg Proppé (2014[100]) highlighted that teachers' general pedagogical knowledge was crucial to elicit students' interest in the Icelandic language. The study by Stankovic and Delafontaine (2016[104]) observed that general pedagogical knowledge allowed teachers to promote meta-cognitive skills and deeper learning of students. In both cases, the positive impact on students was seen as a result of good teaching (i.e. the teachers' capability to adjust teaching to student needs, as well as to provoke meta-cognitive reflections and deeper learning among students).

RQ3: Knowledge areas and types of importance for teaching

Synthesis of quantitative studies for RQ3: Relevance of areas and types of knowledge

In general, findings suggest the practical relevance of the different knowledge areas and types. The *quantitative studies* reviewed usually investigated teachers' knowledge in all three areas proposed by König (2014[23]) without reporting results for each of them separately (probably because single areas alone did not contribute sufficiently to observed relationships). This could be an indication that it is an immensely complex task to create teaching and learning environments that are of high quality and beneficial for students' development. Hence, mastering this complex challenge probably requires an elaborated knowledge base in all of these areas.

Only three studies included findings for teaching separated by area (Biermann and Kaub, 2014[115]; Laflotte, 2015[114]; Lohse-Bossenz et al., 2015[113]) and only three studies did so for student outcomes (Beck et al., 2008[116]; Salinger, 2014[118]; Cowan and Goldhaber, 2014[117]). Considering the extremely small numbers of studies that report results for areas separately and the mixed findings no strong inferences can be drawn from these results (see Table 3.3).

Apart from various areas, many quantitative studies research declarative and procedural knowledge but usually without reporting separate results (Voss et al., 2015[24]; König, 2014[23]; Guerriero, 2017[9]), potentially indicating the relevance of both parts of teacher knowledge for their teaching and the educational output achieved. However, Lenske and colleagues (2016[111]) studied declarative and procedural knowledge of science teachers separately (see Table 3.3). They found that both related significantly to students' science learning when considered separately. Yet, if studied simultaneously, only procedural knowledge related to students' science learning.

Synthesis of qualitative studies for RQ3: Relevance of areas and types of knowledge

Qualitative studies were, in general, less clear about the knowledge areas under investigation. When listed, the areas tackled in qualitative research showed strong resemblance to the areas studied in quantitative studies, and, identically, procedural and declarative knowledge were often investigated. Some researchers have focused solely on certain areas, such as knowledge about classroom management (Tartwijk et al., 2009[97]) or knowledge about instructional strategies (Boz and Boz, 2008[103]). In contrast to

quantitative studies, stronger weight is placed on researching implicit and tacit knowledge, mainly because it is hardly accessible with quantitative approaches (Vogelsang and Reinhold, 2013[70]; Wu, 2013[119]; Hativa, Barak and Simhi, 2001[96]).

The *themes 2 a and b* of the qualitative synthesis revealed that teachers and teacher educators draw on knowledge and reason about issues in several areas including classroom management and instructional methods, student assessment as well as student learning and maintaining and establishing positive relationships to students (Cui, 2017[98]; Jiang and Hao, 2010[120]; Jiang, 2006[121]; Tran and Lawson, 2007[122]; Tartwijk et al., 2009[97]; Atjonen, Korkeakoski and Mehtalainen, 2011[95]). Pre-service and in-service teachers used knowledge that was normative and moral and was composed of declarative and procedural knowledge (Cocard and Krähenbühl, 2013[123]; Gholami and Husu, 2010[124]; Magnoler, Rossi and Giannandrea, 2008[125]). Several studies pointed to the fact that teachers and instructors may not always be aware of the knowledge they use because part of it is implicit and tacit, and, thus may not be accessible through conscious inspection (Hativa, Barak and Simhi, 2001[96]; McAlpine et al., 1999[101]; Wu, 2013[119]).

RQ4: Transforming general pedagogical knowledge into practice

If and how the knowledge of teachers gets transformed into practice is key to the question of the practical relevance of general pedagogical knowledge (Guerriero, 2017[9]). Thus, research has looked into knowledge transformation and influential factors.

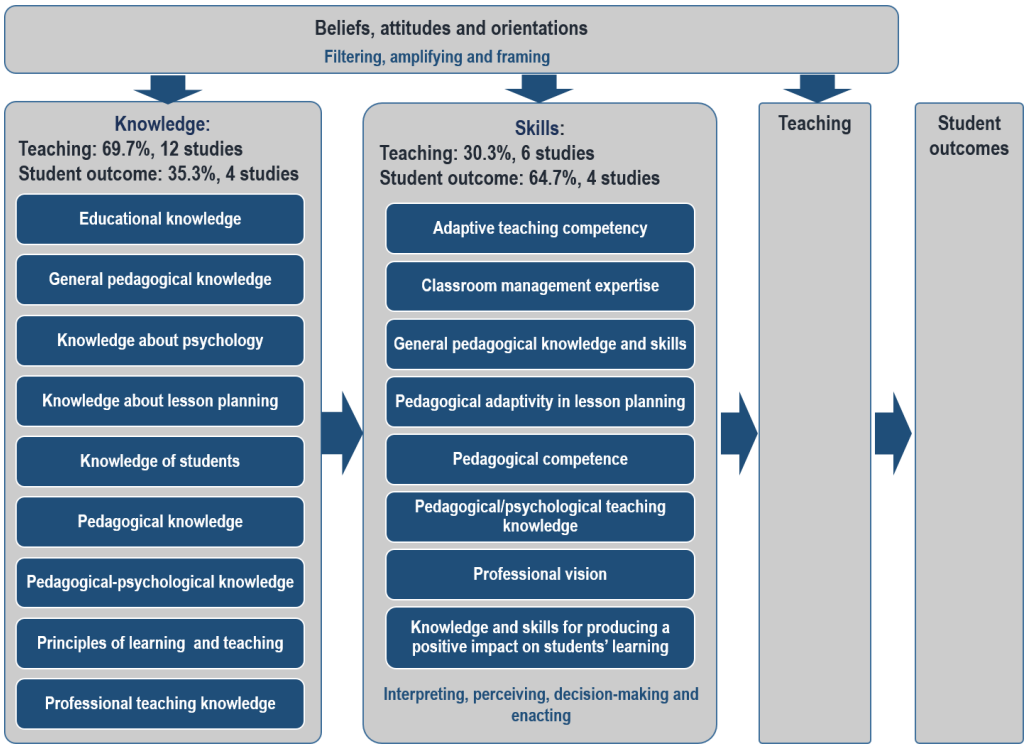
Synthesis of quantitative studies for RQ4: Knowledge transformation

Some studies included in the *quantitative review* explored skills conceptualised as mediating factors, thereby indirectly addressing the question of knowledge transformation: 6 studies and 30.3% of the effect sizes for teaching quality and 4 studies and 64.7% of the effect sizes for student outcomes. Figure 3.3 lists all knowledge concepts and skill concepts researched in quantitative studies. Reviewed research generated findings for a wide range of knowledge concepts but knowledge referred to as general pedagogical knowledge or pedagogical knowledge was clearly in the scientific focus. Results of the moderator analysis indicated no differences between knowledge and skills in effects: Similar to knowledge, the skills included in studies such as classroom management expertise and adaptive teaching competence related to aspects of teaching. There was also no significant difference observed between knowledge and skills regarding the effects for student outcomes.

Studies showed that these skills relate to general pedagogical knowledge (König and Kramer, 2016[126]; Blömeke et al., 2016[127]); but see (Brühwiler et al., 2017[27]), and, thus, potentially serve important functions for the way knowledge gets transformed into practice (see section 1.3). Direct quantitative evidence for this intermediating role effect, however, is still missing. Moreover, quantitative evidence for the role of knowledge-related beliefs, attitudes and orientations was entirely missing.

Figure 3.3. Knowledge and skills included in the overall effects for teaching and student outcomes

The overall effects for teaching and student outcomes did not differ between knowledge and skills.



Synthesis of qualitative studies for RQ4: Knowledge transformation

Qualitative studies answering the question of knowledge transformation fell into the *theme 3a.* More specifically, McAlpine and colleagues (1999[101]) explored the cognitive processes involved in the transformation of knowledge: University professors drew heavily on general pedagogical knowledge to evaluate cues in the classroom, which helped them to monitor the impact of their teaching and to decide whether to adapt it. They then used pedagogical knowledge for the adaptation. The study by Cocard and Krähenbühl (2013[123]) observed that pre-service teachers differed in the type of knowledge activated (more procedural and declarative knowledge or normative knowledge), which was tied to the different purposes the knowledge served: as guiding principles for reducing uncertainties in complex teaching situations, as impulse for reflecting on pedagogical actions or as an argumentative and normative foundation for defining their teaching roles. It is particularly troubling that three studies indicate that pre-service and in-service teachers did not or were unable to use the knowledge they possessed (Hativa, Barak and Simhi, 2001[96]; Hunger, 2013[128]; Li, 2012[106]).

RQ5: Shaping teachers' use of general pedagogical knowledge

It seems vital to understand how teachers' application of knowledge can be enhanced and shaped through teacher training, which only two studies addressed in the *quantitative review* with mixed results.

Synthesis of quantitative studies for RQ5: Shaping knowledge use

Vogt and Rogalla (2009[129]) demonstrated that for a small sample of science teachers, adaptive *planning* competence could be enhanced through coaching compared to a control group of teachers (see Table 3.4). The coaching did, however, not boost their adaptive *implementation* competence. A higher adaptive teaching competence of teachers had in turn a positive impact on students' learning gains in the topic taught after the intervention. No significant effect on their general science achievement was observed.

Gess-Newsome and colleagues (2017[130]) similarly found that skills relating to general pedagogical knowledge could be enhanced for science teachers with an impact on teaching quality. In this particular study, however, general pedagogical knowledge was not related to student achievement.

Synthesis of qualitative studies for RQ5: Shaping knowledge use

Twelve *qualitative studies* contributed to the scientific knowledge about opportunities to shape teachers' use of knowledge (*theme 3b* and *theme 3c*), but only one study evaluated an intervention. The study by Hativa (2000[105]) demonstrated that an intensive intervention can bring about lasting improvements of the instructional effectiveness for instructors who lack pedagogical knowledge.

Further studies highlighted that teachers acquire the knowledge they apply in the classroom in teacher training (Kawecki, 2009[131]; Stankovic and Delafontaine, 2016[104]; McAlpine et al., 1999[101]). It was also found that pedagogical training shapes the type of knowledge that teachers mostly apply: Without pedagogical training, university professors relied more on tacit and experiential knowledge (McAlpine et al., 1999[101]). Similarly, science teachers when teaching outside of their area of certification drew more heavily on general pedagogical knowledge and less on subject-specific knowledge (Sanders, Borko and Lockard, 1993[132]).

Other studies underlined that the knowledge that teachers and instructors use in teaching evolves from experience (Kawecki, 2009[131]; Magnoler, Rossi and Giannandrea, 2008[125]; McAlpine et al., 1999[101]). In addition, teaching experience leads to a stronger, more interconnected knowledge base and promotes a knowledge that is more frequently used and better fits to the context (Cui, 2017[98]; Jiang and Hao, 2010[120]; Jiang and Hao, 2011[133]; Roux-Paties, 2014[134]; Friedrichsen et al., 2009[135]). Salata (2016[136]) emphasises that practical experiences needs to be accompanied by a substantive, methodical preparation: This combination was found to provide teachers with opportunities to work on the transformation of professional knowledge into appropriate practice, and, to inspire new teaching practices.

Table 3.4. Narrative summary of results for the quantitative studies reviewed for RQ5-RQ7

Review question	Study	Sample	Summary	ES, Cohen's d
RQ5: Shaping teachers' use of general pedagogical knowledge	ATC (Vogt and Rogalla, 2009[129])	50 Swiss teachers of science teaching (intervention: 32; control:18) 832 primary and lower secondary students	The adaptive planning competence of science teachers could be enhanced through coaching. The coaching did, however, not boost their adaptive implementation competence. A higher adaptive teaching competence of teachers had in turn a positive impact on students' learning gains in the topic taught after the intervention. No significant effect on their general science achievement was observed.	• Pre-post test comparison of adaptive *planning* competences : *ES* = .20, *d* = .40 • Pre-post test comparison of adaptive *implementation* competences : *ns* • Teachers' adaptive teaching competence and students' learning progress: *ES* = .34, *d* = .68 • Teachers' adaptive teaching competence and general science achievement: *ns*.
	PRIME (Gess-Newsome et al., 2017[130])	50 US high school teachers teaching biology to 4 718 students	Teachers' skills relating to general pedagogical knowledge could be enhanced through a professional development programme focused on the implementation of a specific science curriculum. Teachers' pedagogical skills were related to teaching quality but not students' science achievement.	• Pre-post test comparison of pedagogical skills: *ES* = .44, *d* = .98 • Relationship of pedagogical skills to teaching quality: *ES* = .37, *d* = .80 • Relationship of pedagogical skills and teaching quality to students' science achievement: *ns*
RQ6: The context matters for teachers' knowledge use	ATC (Brühwiler, 2011[110]; Brühwiler and Blatchford, 2011[137])	47 Swiss teachers of science teaching 832 primary and lower secondary students	Compared to less adaptive colleagues, teachers with a high adaptive teaching competence were better able to promote science learning in classrooms with a higher share of foreign language students (students spoke mostly not German at home) and students with low prior achievements. The effect was, however, independent of class size.	• Interaction with share of foreign language students: *ES* = -.15, *d* = -.30 • Interaction with share of students with low achievements: *ES* = .14, *d* = .29 • Interaction with class size: *ns*
	NTES 2004-2011 (Carrasco, 2014[138])	3 310 middle and high school teachers of mathematics teaching 102 919 students	Compared to less knowledgeable colleagues, teachers with a higher pedagogical knowledge were not more able to foster achievements in classes with more socio-economic disadvantaged students.	• Interaction with share of students with low socio-economic background in middle schools: *ns* • Interaction with share of students with low socio-economic background in high schools: *ns*
RQ7: General pedagogical knowledge as one ingredient among others	COACTIV-R (Seiz, Voss and Kunter, 2015[139])	209 secondary teachers of mathematics in induction teaching 7 968 students	Only teachers with high levels of knowledge and low levels of exhaustion showed better monitoring and prevention of disturbances in the classroom.	• PPK X emotional exhaustion to classroom disturbances: δ^a = .16 • PPK X emotional exhaustion to monitoring: δ^a = -.29

Note: a.) Effect size δ can be interpreted similarly to Cohen's d (Reyes et al., 2012[68]).

RQ6: The context matters for teachers' knowledge use

Research also tried to unravel the role of the context in explaining differences in the use of knowledge.

Synthesis of quantitative studies for RQ6: Context influence on knowledge use

Only two studies in the *quantitative review* addressed this question (see Table 3.4). Brühwiler (2011[110]) found that teachers with a high adaptive teaching competence promoted science learning better than less adaptive colleagues in classrooms with a higher share of foreign-language students and students with low achievements. The effect of adaptive teaching competence was, however, independent of class size (Brühwiler and Blatchford, 2011[137]). Similarly, Carrasco (2014[138]) did not find that knowledgeable teachers were more able to foster achievements in classes with more socio-economic disadvantaged students.

Synthesis of qualitative studies for RQ6: Context influence on knowledge use

Five *qualitative studies* pointed to the importance of the context as part of the *theme 3d*: The decision to follow scientific recommendations, for example, depends on the pedagogical situations and everyday realities in the classroom (Roux-Paties, 2014[134]; Gholami and Husu, 2010[124]; Atjonen, Korkeakoski and Mehtalainen, 2011[95]). Teachers perceived various obstacles to following pedagogical principles such as time and curricular pressures, heterogeneous learning groups, and students' behavioural or motivational problems (Atjonen, Korkeakoski and Mehtalainen, 2011[95]). Pre-service teachers' reports on applied knowledge was shown to depend on eliciting prompts (Tran and Lawson, 2007[122]). Observed differences in Finnish and Thai teachers' use of knowledge was explained with the varying degree of autonomy in the classroom (Sothayapetch, Lavonen and Juuti, 2013[140]).

RQ7: General pedagogical knowledge as one ingredient among others

Undoubtedly, there is more to effective teaching than general pedagogical knowledge (Baumert and Kunter, 2006[8]; Blömeke and Kaiser, 2017[74]; Guerriero, 2017[9]).

Synthesis of quantitative studies for RQ7: Interplay with other competences

Apart from comparing the results obtained for the different parts of teacher knowledge and reporting their interrelations, studies in the *quantitative review* did not investigate how general pedagogical knowledge worked together with other knowledge to shape teachers' action in the classroom. Though not about knowledge, the study by Seiz and colleagues (2015[139]) is an exception showing that teachers need general pedagogical knowledge paired with emotional resources to successfully monitor and manage the classroom (see Table 3.4).

Synthesis of qualitative studies for RQ7: Interplay with other competences

One key finding of the *themes 2c and d* in the qualitative review was that teaching depends on the integration of different knowledge into a coherent source of information (Friedrichsen et al., 2009[135]) and that during lessons teachers and teacher educators draw on pedagogical knowledge in combination with pedagogical content knowledge (Jiang and Hao, 2010[120]; Dögg Proppé, 2014[100]; Lehrer and Franke, 1992[141]; Magnoler, Rossi and

Giannandrea, 2008[125]; McAlpine et al., 1999[101]; Sanders, Borko and Lockard, 1993[132]; Sothayapetch, Lavonen and Juuti, 2013[140]; Syarief, 2017[142]; Wu, 2013[119]), content knowledge (Magnoler, Rossi and Giannandrea, 2008[125]; McAlpine et al., 1999[101]; Sanders, Borko and Lockard, 1993[132]; Stankovic and Delafontaine, 2016[104]; Wu, 2013[119]; Boz and Boz, 2008[103]), and curriculum knowledge (Syarief, 2017[142]; Wu, 2013[119]) as well as beliefs, orientations and attitudes (Hativa, 2000[105]; Friedrichsen et al., 2009[135]; Li, 2012[106]).

Conclusion

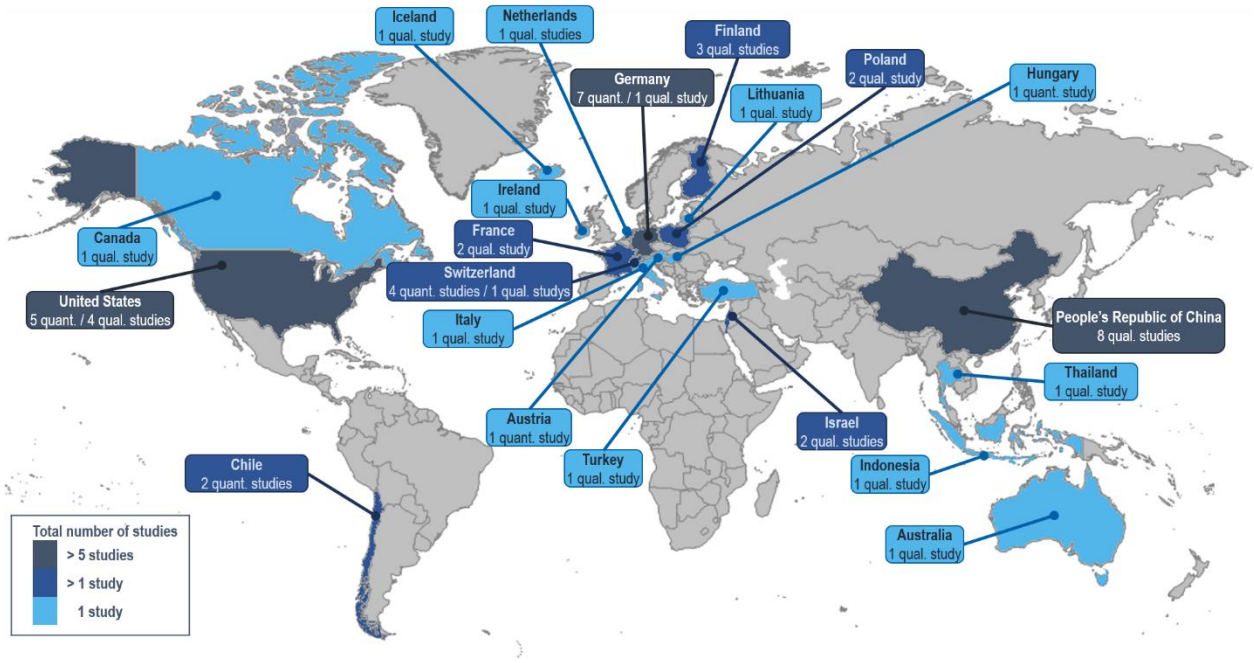
The synthesis of 20 quantitative studies and 31 qualitative studies indicated that teachers' general pedagogical knowledge is a prerequisite and resource for high quality teaching and a key ingredient for the educational output of schools and educational systems. There is some indication that teaching quality serves as a mediator of the effect on student outcomes. To be successful, teachers need knowledge of different types (normative, declarative and procedural) and in various areas (covering the areas of instruction, learning and assessment), as well as knowledge-related skills. The knowledge that teachers use can be shaped through teacher training and experience and there is some indication that it varies depending on the context. The review also showed that more research is needed to further understand some of the review questions (e.g. mediating effect of teaching quality, role of knowledge-related skills and beliefs).

4. EQ1: Evaluating the evidence: How generalisable are the findings?

Regional coverage and teaching settings investigated

As displayed in Figure 4.1, the 51 studies provided evidence from 21 countries. Some countries are overrepresented. For example, 80% percent of the 20 *quantitative studies* were from either Germany, the United States or Switzerland. The 31 *qualitative studies* had various origins but most research was conducted either in the People's Republic of China or the United States (almost 40%).

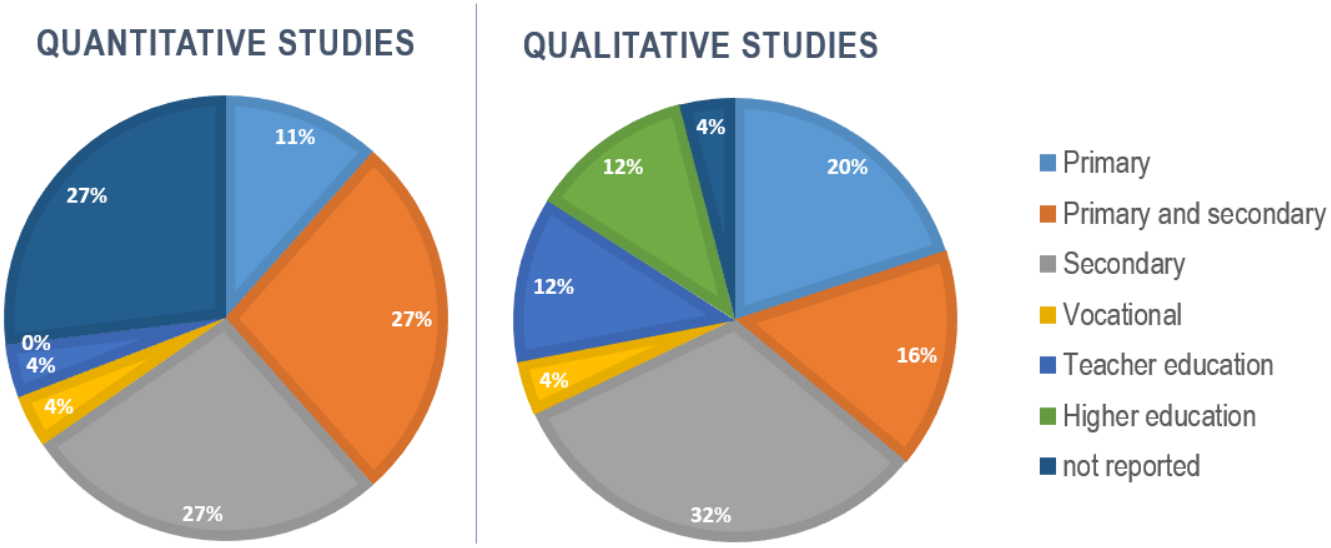
Figure 4.1. Countries where studies were conducted



Note: Two qualitative studies were conducted in more than one country: the study by Kawecki (2009[131]) and by Sothayapetch and colleagues (2013[140]).

A look at the teaching settings studied reveals that by far the greatest share of research has been conducted at school level (85% of the quantitative studies and 54.8% of the qualitative studies): either at primary, secondary or primary and secondary level (see Figure 4.2). Evidence beyond school is still scarce: only one quantitative study and three qualitative studies for teacher education, three quantitative studies for higher education, and a qualitative and a quantitative study each for vocational training.

Figure 4.2. Teaching settings of studies

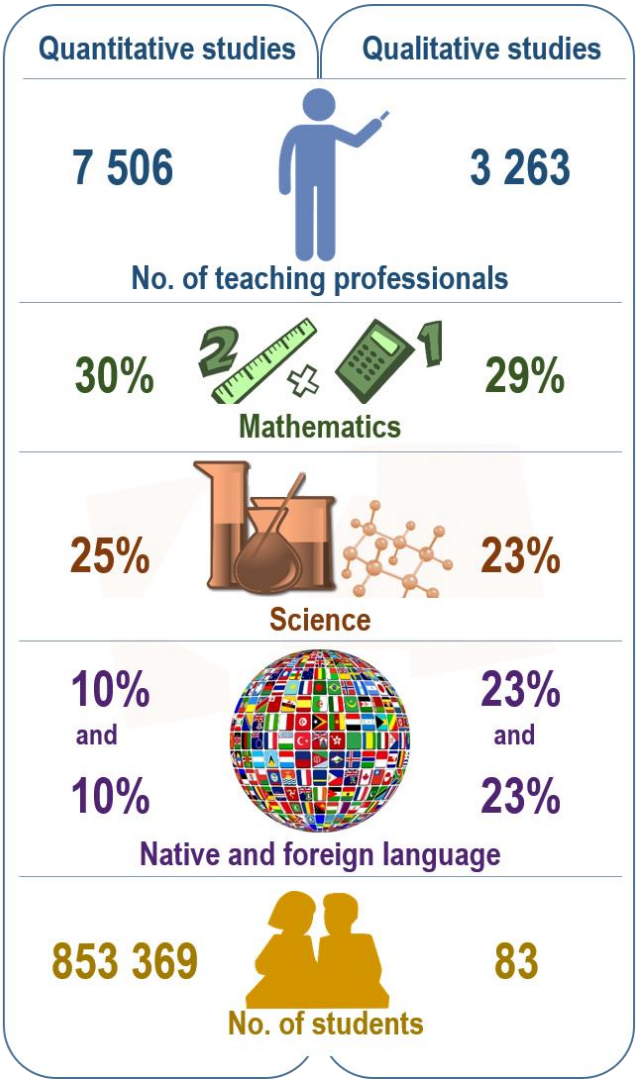


Note: Information on the school level was not available for 8 studies; mostly studies sampling pre-service teachers.

Teaching professionals and the subject studied

A total of 10 769 teaching professionals participated in reviewed studies but sample size varied considerably: from 8 to 3 310 teaching professionals *in quantitative studies* and from 1 to 2 351 teaching professional(s) in *qualitative studies*. Half of the sample sizes were within the range of 46 to 252 and 4 to 15 teaching professionals, respectively. In accordance with its cross-curricular nature, research explored the use of general pedagogical knowledge across various subjects. Evidence on mathematics, science and mother tongue and foreign language is predominant (see Figure 4.3). Ten studies studied teachers from more than one subject area.

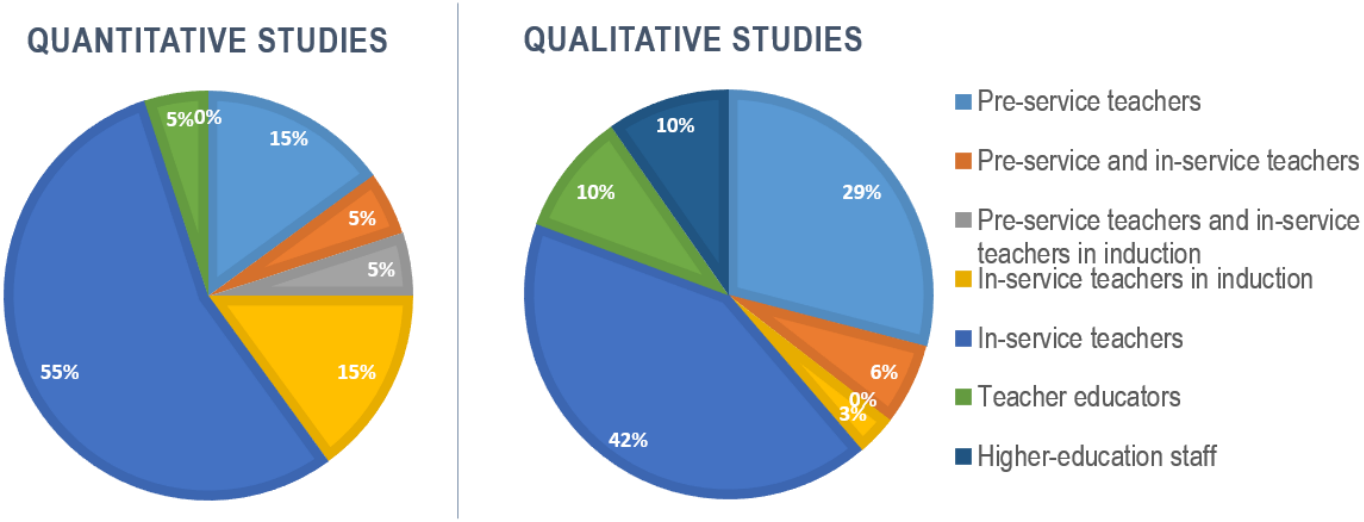
Figure 4.3. Samples and subjects taught



Note: Information about subject taught was not reported for 13 studies. Information about sample size of students was not available for three studies.

Over 60% of all studies looked at in-service teachers and a few of these looked specifically at teachers in induction (see Figure 4.4). Still, almost one third of the evidence related to pre-service teachers, even if mainly qualitative in nature. The rest of the evidence related to teacher educators as well as tutors, professors or instructors.

Figure 4.4. Phase professionals studied are in



Students as informants of teaching quality and educational output

Students provided information on teaching quality or outcomes for some studies; typically quantitative studies (65% of the quantitative studies and only 19.4% of the quantitative studies). All in all, the scientific knowledge about the practical implications of teachers' general pedagogical knowledge is based on information from at least 853 452 students. Sample sizes ranged substantially; from 164 to 730 877 students in *quantitative studies* and from 6 to 40 students in the three *qualitative studies*. Sample sizes *in quantitative studies* fell mostly within a range of 949 to 5 531 students.

Conclusion

All taken together, the evidence covers teaching professionals in different phases and subjects and includes various settings and countries but clearly the scientific knowledge horizon needs to expand to further countries and more evidence is needed for some teaching professionals and subjects. Sample sizes for teachers varied substantially but most studies used rather small samples (e.g. below 300 for quantitative studies) and only half of the quantitative studies and a few qualitative studies sampled students.

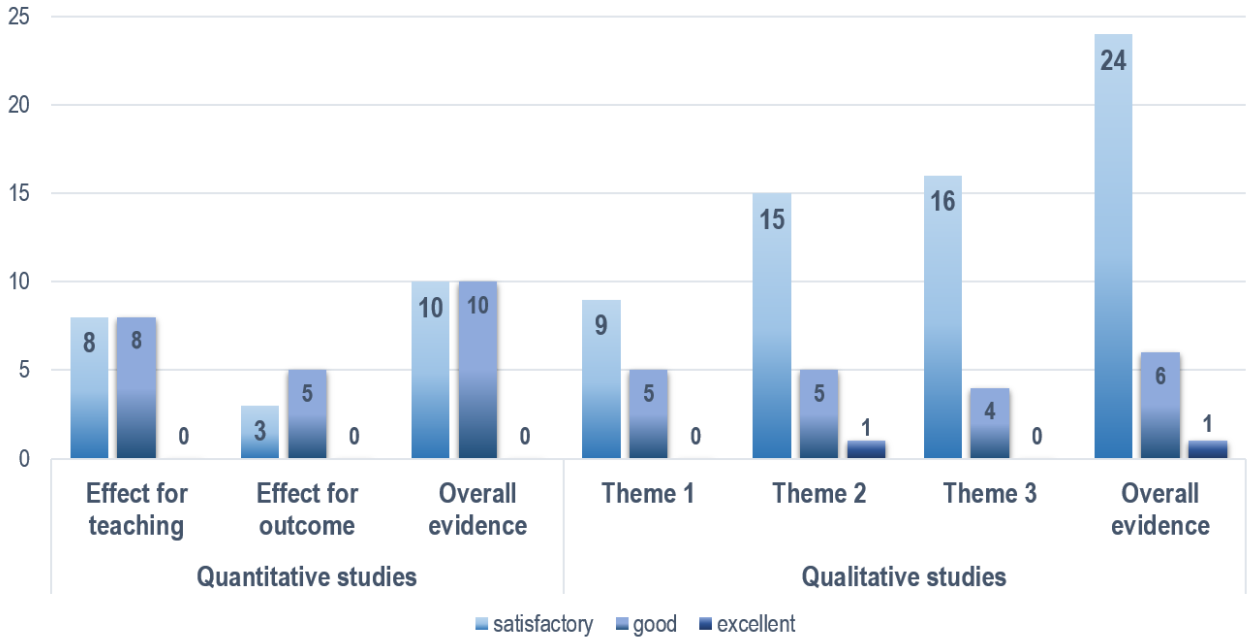
5. EQ2: Evaluating the evidence: How can research methodology improve?

Despite contributing substantially to an understanding of the role of general pedagogical knowledge for teaching, the available research leaves important questions unanswered or at least insufficiently answered, and partly lacks conceptual clarity. A closer look at the methodological approaches reveals areas for improvements regarding study design and measurement of teacher knowledge.

Appraising the weight of evidence

Researchers can further improve study design. This was a result from an appraisal of the weight of evidence regarding three criteria: the methodological quality and relevance of the study as well as the relevance of the study topic for answering the review question (see Box 5.1 for more detail). The quality of evidence was ''good'' or ''satisfactory'' for almost all studies and slightly higher for quantitative studies compared to qualitative studies. A balanced mix of "satisfactory" and "good" findings contributed to the overall results in the *quantitative synthesis*. No theme developed in the *qualitative synthesis* was generated solely by "satisfactory" findings (see Figure 5.1).

Figure 5.1. Weight of Evidence (WoE) of quantitative and qualitative studies reviewed



Note: For quantitative studies the average across the different publications was used as WoE.

Even though some studies were evaluated as inadequate on one of the three criteria used during the quality appraisal (methodological quality, methodological relevance and topic relevance), none received an overall inadequate rating. On the other hand, only one study in the qualitative and quantitative review received excellent overall ratings. Taken together, the quality appraisal indicates room for improvement of the research in the field regarding several aspects such as the design of studies or the way teacher knowledge is measured.

Box 5.1. Appraising the Weight of Evidence (WoE) of the available research

In line with the weighting system by the EPPI-Centre, (Gough, 2007[143]), the weight of evidence from each publication was evaluated to assess its contribution in addressing the review questions on four levels as either "*inadequate", "satisfactory", "good" or "excellent"*. Table 5.1 explains the three judgements involved in the quality appraisal. The judgements considered whether findings of a publication could be considered trustworthy within its own terms (*WoE A: Methodological quality*) and took account of the appropriateness of the study design (*WoE B: Methodological relevance*) as well as the relevance of the topic focus for answering the review questions (*WoE C: Topic relevance*). The weights were finally combined into an *overall weight* (*WoE*).

Table 5.1. Criteria for judging the Weight of Evidence (WoE)

Level/criterion	**WoE A:** Methodological quality	**WoE B:** Methodological relevance	**WoE C:** Topic relevance
Excellent	Research design justifying all decisions taken: e.g. sample, instruments, analysis. Clear evidence of measures taken to maximise validity and reliability.	Research questions clearly stated. Methodology is highly relevant to RQs and answers them in detail.	Study is very closely aligned to one of the key review questions and provides very strong evidence upon which to base future policy/action.
Good	Research design clearly stated with evidence of sensible decisions taken to provide valid and reliable findings.	Research questions are explicit or can be deduced from text. Findings address RQs.	Study is broadly in line with one of the key review questions and provides useful evidence.
Satisfactory	Research design may be implicit but appears sensible and likely to yield useful data.	RQs implicit but appear to be broadly matched by research design and findings.	At least part of the study findings is relevant to one of the key review questions.
Inadequate	Research design not stated and contains flaws.	RQs not stated or not matched by design.	Study does not address key questions.

Note: WoE D: The overall weight of evidence resulted from a combination of the weights for WoE A, B, C.
Source: (Davies et al., 2013[13]) (after (Gough, 2007[143]).

Quantitative and qualitative approaches and the benefits of mixing approaches

Understanding the use of knowledge in the classroom is a challenging scientific endeavour, which clearly requires research of various designs. Expectedly, research from quantitative designs (11 studies), from qualitative designs (24 studies) and a considerable share of mixed-method studies contributed to the reviewed evidence (17 studies). It is rather disappointing that almost all mixed-method studies used embedded designs (Creswell and Plano Clark, 2011[144]): either with a traditional quantitative design with a qualitative strand added (9 studies) or a traditional qualitative design with a quantitative strand added (7 studies). For the former, qualitative approaches often complemented quantitative approaches for measuring knowledge or teaching. For the latter, quantitative scales served to assess aspect of teaching or qualitatively collected data was analysed with chi-square tests, path analysis or other quantitative methods.

Box 5.2. Typology of mixed-method designs

Various typologies of mixed-methods designs exist. Creswell and Plano Clark (2011[144]) distinguished **six major mixed-method designs**:

1. *Embedded design:* in a traditional qualitative or quantitative design, a strand of the other type is added to enhance the overall design.
2. *Multiphase design:* more than two phases or both sequential and concurrent strands are combined over a period of time within a programme of study addressing an overall programme objective.
3. *Explanatory sequential design:* a first phase of quantitative data collection and analysis is followed by the collection of qualitative data, which are used to explain the initial quantitative results.
4. *Exploratory sequential design:* a first phase of qualitative data collection and analysis is followed by the collection of quantitative data to test or generalise the initial qualitative results.
5. *Convergent parallel design:* the quantitative and qualitative parts of the research are performed independently, and their results are brought together in an overall conclusion.
6. *Transformative design:* a transformative theoretical framework, e. g. feminism or critical race theory, shapes the interaction, priority, timing and mixing of the qualitative and quantitative strand.

Explanatory sequential designs promise particular benefits for research on teachers' use of general pedagogical knowledge, where a first phase of quantitative data collection and analysis is followed by the collection of qualitative data, which are used to explain the initial quantitative results. Only two mixed-method studies used an exploratory sequential design. In both cases, teacher interviews were conducted and analysed using content analysis in order to explain the results obtained in a preceding survey. However, only the results from the qualitative studies were relevant in both cases (Zhang, 2012[145]) (Wu, 2013[119]).

The study designs used by Hativa (2000[105]) and Hativa and colleagues (2001[96]) do not strictly qualify as sequential designs as they simply used available quantitative data from teacher evaluations. Nonetheless, the studies provide good examples for illustrating the merits of sequential designs: The quantitative results from the teacher evaluation were used for purposefully sampling excellent teachers (Hativa, Barak and Simhi, 2001[96]) and struggling teachers (Hativa, 2000[105]) for in-depth analysis of the pedagogical knowledge they had or lacked.

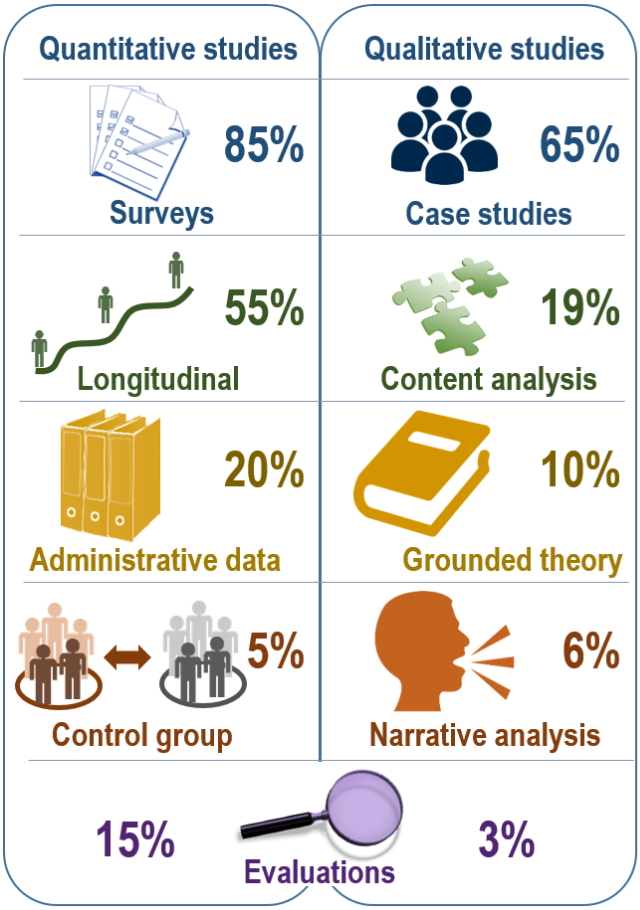
In general, studies with (predominantly) quantitative and qualitative designs seem to cover different topics. On both sides, efforts to build on the available research of the other strand have a great potential for furthering the scientific insights into teachers' use of knowledge. Some fictional examples can illustrate this potential: Qualitative studies showed teachers differing in teaching experience or qualification used knowledge differently and provided some indication for the fact that teachers draw simultaneously on different parts of their knowledge base during teaching.

Quantitative studies could test the generalisability of such findings by using, for example, multi-group or moderator analysis to compare the association between knowledge and teaching for teachers varying in teaching experience and qualification or for pre-service and in-service teachers. If at all, quantitative studies thus far report differences in means for different teacher populations as a way to validate instruments and draw conclusions about teacher education and practical experiences (König et al., 2011[146]; König and Kramer, 2016[126]; Voss, Kunter and Baumert, 2011[147]; Beck et al., 2008[116]). Qualitative studies, on the other hand, could do more pioneer work in the area of mediating and moderating factors to reveal barriers and facilitators of knowledge application.

Discussing study designs and options for improvement

A closer look at the study designs of available research reveals that besides three quasi-experimental studies, most quantitative studies were surveys (see Figure 5.2). Following the taxonomy of qualitative approaches by Korstjens and Moser (2017[148]) studies investigating the topic qualitatively could be categorised into either pure case studies or studies using content analysis, grounded theory or narrative analysis.

Figure 5.2. Study designs



Over half of the quantitative studies were longitudinal. Researchers of longitudinal surveys, however, seldom exploited the potential of the designs: Most studies exclusively analysed longitudinal data for student outcomes and only one study, by Lohse-Bossenz and

colleagues (2015[113]), used longitudinal data for teachers: They reported how teachers with higher general pedagogical knowledge displayed greater gains in teaching quality over time. Other studies, for example the Study on Teacher Candidates' Acquisition of Professional Competence During Teaching Practice (COAKTIV) which apparently assessed teachers more than once, did not study change in teachers' knowledge or teaching quality (Baier et al., 2018[76]; Gindele and Voss, 2017[149]; Seiz, Voss and Kunter, 2015[139]; Voss et al., 2014[26]; Voss, Kunter and Baumert, 2011[147]). Understanding how teachers acquire and refine knowledge and teaching skills over time and identifying influential factors would potentially help improving the professional support of professionals in practicum, induction and beyond. Moreover, the longitudinal perspective of studies was mostly rather short-term (around one year): Only two studies followed students' development with more extended time frames (from two to four years; (Cowan and Goldhaber, 2014[117]; Carrasco, 2014[138]).

Though three quantitative studies and a qualitative study evaluated an intervention or a professional development programme, all using some sort of a pre-post-design, none was a randomised-control trail (RCT) and only the Adaptive Teaching Competence (ATC) study used a control group (Vogt and Rogalla, 2009[129]; Beck et al., 2008[116]; Brühwiler and Blatchford, 2011[137]; Brühwiler, 2006[150]; Brühwiler, 2011[110]). Taken together, the correlational nature of the evidence does not allow for causal interpretations, especially since selection effects in education present rather the norm than an exception (Sykes, Schneider and Plank, 2009[151]).

A couple of studies used administrative data or merged administrative data with data on collected as part of research projects. In light of current initiatives that encourage researcher to exploit the full potential of existing data, this seems still insufficient (e.g. (IES, 2019[152]; NSF, 2015[153]; ESRC, 2019[154]; Douglas N. Harris, 2016[155]; Higgins, Dettmer and Albro, 2019[156]; Vincent-Lancrin and Levine, 2019[157]).

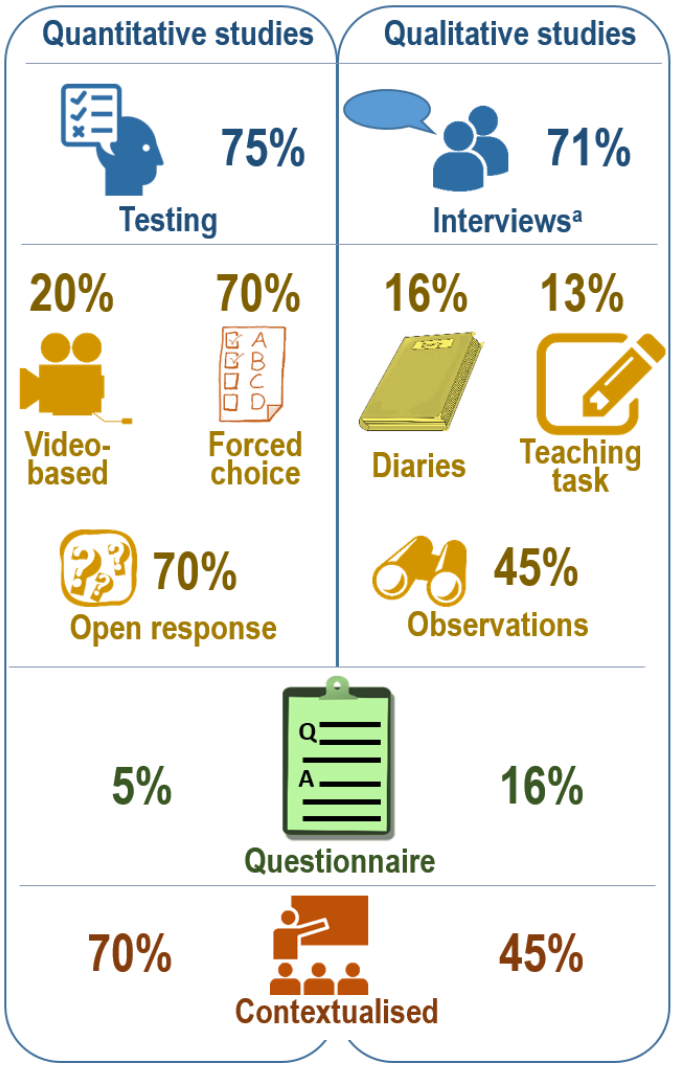
Reviewing the approach to measure knowledge and proposing refinements

The 51 studies included used 52 different instruments and approaches for measuring teachers' general pedagogical knowledge. The *qualitative approaches* for measuring knowledge were all unique in a way, but two instruments were administered in more than one *quantitative study*: five studies used the instrument from the Teacher Education and Development Study in Mathematics (TEDS-M) study and two studies the test from the ATC study. Despite a seeming heterogeneity, a closer investigation of the in measurement approaches revealed great similarities across studies.

Measurement of knowledge in quantitative studies

Quantitative studies mostly relied on some sort of testing, though portfolios and interviews were also used to rate teacher's knowledge (see Figure 5.3 for an overview and Table A E.1 in Annex E for details). Single studies relied on other modes of data collection such as teacher questionnaires, observations and lesson plans.

Figure 5.3. Approaches to measure general pedagogical knowledge



Note: a = 29% of qualitative studies used stimulated-recall interviews.

The review did not find much quantitative evidence linking teaching quality or student outcomes to self-rated teacher knowledge. Only one study used teacher questionnaires to study the link of self-rated knowledge to different teaching aspects (Kálmán, 2016[158]). Comparing the results to the overall effect for other measures did indicate a marginal stronger effect for teacher questionnaires. Yet, as the results stem from a single study no strong inferences can be drawn (see Table 3.1 in section 3.).

Generally, there are quite a few studies that use questionnaires or interviews to research teacher knowledge (Merk et al., 2017[59]; Merk et al., 2017[159]; König, Kaiser and Felbrich, 2012[160]; Choy, Wong and Lim, 2013[161]). Self-reports may seem like a better choice for monitorings of educational systems and teacher evaluations as they are seen as less intrusive and harmful to teachers' self-worth when compared to tests. In conclusion, more research effort is needed to show whether self-reported knowledge and use of knowledge are valid measures of teacher knowledge. In the study by König and colleagues (2012[160]), self-rated competence and knowledge correlated significantly but low and not for all

studied groups. The qualitative studies that discussed the high share of implicit knowledge also raise some doubts about the validity of self-reports (see section 3.). Self-awareness about own competences may be a competence in itself but should not be taken as a given - the accuracy of such judgements may depend on the experience and expertise of the teachers.

Many studies combined different item and response types in their instruments: apart from written tasks teachers had to solve *video-based tasks* respond to *multiple- or single-choice items* or provide *open responses*. This reflects the complex nature of the knowledge base (Stürmer and Seidel, 2015[72]; Herppich et al., 2018[88]) and, thus, seems like the right step forward.

Noteworthy, in many quantitative studies vignettes, scenarios or situational judgement items, where teachers had to respond to typical classrooms situations, served as *contextualised measures* of teacher knowledge. This approach roots in the assumption that teachers draw particularly on knowledge that is contextualised and situated (Guerriero, 2017[9]; Stürmer and Seidel, 2015[72]). Though, of course, other factors also play a role. The moderator analysis comparing effects for contextualised versus other measures for the quantitative studies did not confirm this claim empirically: No significant differences were observed (see Table 3.1 in section 3.). However, for student outcomes the comparison was based on a single study.

Measurement of knowledge in qualitative studies

Qualitative studies showed a greater variety in measurement approach. Some studies used *teacher questionnaires* to collect information about teacher knowledge (see Figure 5.3 for an overview and Table A E.2 in Annex E for details). More frequently, studies consisted of a combination of *interviews* with other approaches. Researchers, for example, additionally *observed* teachers in the classrooms or asked teachers to keep teaching *diaries* or write a *lesson plan*. Often the videotaped lesson and written material were used for *stimulated-recall* interviews, in which teachers reflected on and elaborated on the reasoning behind taught or designed lessons. Finally, the information gathered with the interviews, observations and written material was combined to deduce teachers' reasoning behind taught or designed lessons. This kind of triangulation of information from different approaches seems important, especially for complementing self-reports on knowledge and knowledge application in the classroom, as discussed earlier. Similar to quantitative studies, two qualitative studies used vignette measures showing that they can provide interesting insights into the way teachers deploy knowledge in the classroom.

Evaluating the measurement of teaching and outcomes and suggesting future directions

Three points related to the measurement of teaching and student outcomes are worth discussing:

- considering other-reports and observations to study student outcomes
- the drawbacks of integrating knowledge and knowledge application into a single measure
- the criticism regarding teacher information on teaching quality.

Firstly, student outcomes were measured with achievement tests or self-reports on self-regulations skills. Future research, especially for other types of outcomes, should

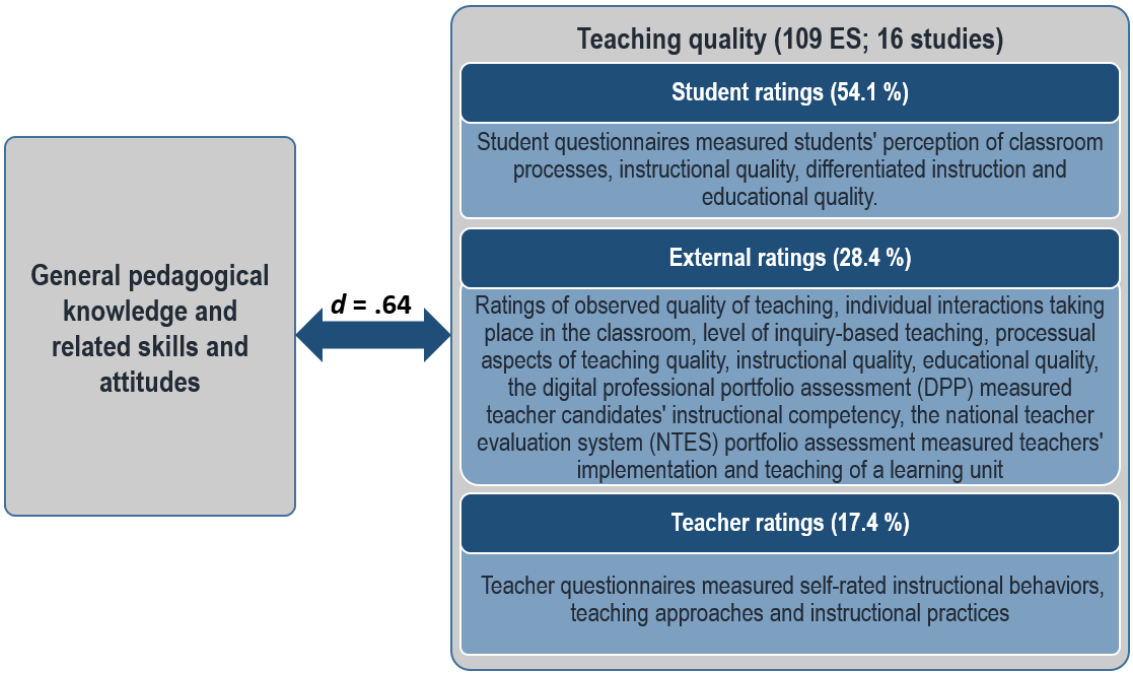
consider further measurement approaches such as other reports or observations. For instance, the social integration of students in the class could be judged by the students and their peers as well as through observations (Cambra and Silvestre, 2003[162]; Gest et al., 2003[163]). Likewise, students themselves as well as parents and teachers may provide vital insights into the way teachers' knowledge relates to students' emotional competences (Smith et al., 2019[164]).

Secondly, a large share of *qualitative studies* (22 studies) integrated, or at least partly integrated, the measurement of knowledge and its application in the classroom into a single measure (Vogelsang and Reinhold, 2013[165]). That means that evidence on teacher knowledge and its use in teaching and lesson design is derived from the same data sources including portfolios, classroom observations or lesson plans. The use of integrated measurements as a sole indication of knowledge-in-action is not really feasible in quantitative research (Voss et al., 2015[24]; Vogelsang and Reinhold, 2013[165]). If not combined with qualitative data or further quantitative data, such measures merely produce descriptive results of little value for the question about links between knowledge and teaching (see Annex B for two excluded examples). Consequently, most quantitative studies included in the review used separate measures for teacher knowledge and teaching (all but 2 studies).

Thirdly, as Figure 5.4 shows, some of the *quantitative researchers* asked teachers to report about their teaching. Critique regarding this is common, however Helmke and Schrader (2008[166]) argued (based on a review of evidence on teaching quality) that teachers provide unique information about what is happing in the classroom and, in fact, all student ratings and observations have their own drawbacks (Praetorius et al., 2014[62]; OFSTED, 2019[167]; Mashburn, Meyer and Allen, 2014[168]; Spooren, Brockx and Mortelmans, 2013[169]). The moderator analysis did not indicate a significant difference in size of effects for the different perspectives (see Table 3.1). Researchers and policy-makers need to reflect carefully about the optimal choice for studies and monitorings and, if possible, a combination of the perspectives from teachers, students and external experts seems the best option. As emphasised by Helmke and Schrader (2008[166]), all parties contribute with unique information to provide a comprehensive picture about classroom processes.

Figure 5.4. Capturing classroom processes - the "information triangle"

The overall effect of *d* = .64 did not differ for the different perspectives on teaching quality and classroom processes: students, external raters or teachers.



Conclusion

An evaluation of the research methodology revealed areas for improving and innovating the study design such as using "real" mixed-method designs and longitudinal designs that also analyse the development of general pedagogical knowledge and subsequent changes in teachers' practices in the classrooms. Research further needs to probe if teacher questionnaires measure general pedagogical knowledge of teachers that is relevant for successful teaching. Teacher knowledge was found to be relevant for teaching success, no matter if knowledge was measured with contextualised instruments and if teachers, students or external raters reported on the quality of teaching in the classroom. Not only the type of student outcomes studied needs to be broadened but also the also the measurement approach (e.g. using observations and other reports on student outcomes).

6. Conclusions and implications

With due consideration to existing limitations of the review (see Annex E), this final section provides some concrete suggestions for teacher policies and future research based on the main conclusions of the review summarised in Table 6.1.

Table 6.1. Main findings of the synthesis of quantitative and qualitative studies

Question	Synthesis of quantitative studies	Synthesis of qualitative studies
RQ1: Pedagogical knowledge as a prerequisite and resource for high-quality teaching	• moderate effect of teachers' general pedagogical knowledge on teaching quality • relevance for overall teaching quality as well as the instructional support of teachers, their learning support and organisational support	• general pedagogical knowledge as key resource for delivering lessons of high-quality and the application of specific teaching approaches • lack of general pedagogical knowledge as an explanation for teaching difficulties
RQ2: Teacher knowledge as a key ingredient for educational output	• moderate effect of teachers' general pedagogical knowledge on student outcomes, including achievement and self-regulation skills • Some indication that the effect of knowledge on student outcomes is mediated via teaching quality	• general pedagogical knowledge helped eliciting student learning (interest, meta-cognitive skills, deep learning) through better teaching
RQ3: Knowledge areas and types of importance for teaching	• Successful teaching requires declarative and especially procedural knowledge, which spans various topics related to the areas of instruction, learning and assessment	• teachers used normative, declarative and procedural knowledge, which contained implicit, and tacit knowledge and topics in areas related to instruction, learning, positive relationships in the classroom and assessment
RQ4: Transforming general pedagogical knowledge into practice	• knowledge-related skills of teachers contributed to the overall effects of on teaching and student outcomes; equally as teachers' knowledge; and potentially serve important function for transforming knowledge into practice	• use of general pedagogical knowledge during several cognitive processes (e.g. evaluate cues, monitoring the impact of teaching) • how knowledge is used depends on the individual purpose for its activation • observed failure of knowledge transformation (i.e. to apply available knowledge in the classroom)
RQ5: Shaping teachers' use of general pedagogical knowledge	• weak indication that teachers knowledge could be enhanced with positive impact on teaching quality and mixed findings for student outcomes	• teacher training and teaching experience (with adequately preparation) equipped (future) teachers with the knowledge they used in the classroom • intensive interventions can produce lasting improvements for teachers lacking sufficient knowledge
RQ6: The context matters for teachers' knowledge use	• overall scarce and mixed findings regarding the role of the context for teachers' use of knowledge	• Use of knowledge depends on the national context as well as pedagogical situation and classroom context (e.g. available time, curriculum, teachers' degree of autonomy, group of learner)
RQ7: General pedagogical knowledge as one ingredient among others	• lack of quantitative evidence except for a single study showing that a combination of knowledge and emotional resources is needed for quality teaching (Seiz, Voss and Kunter, 2015[139])	• teaching depends on an integration and combined use of different knowledge (such as general pedagogical knowledge, content and curricular knowledge, pedagogical content knowledge) as well as beliefs, orientations and attitudes
EQ1: Evaluating the evidence: How generalisable are the findings?	• the evidence covers teaching professionals in different phases and subjects and includes various settings and countries but particular groups of teaching professionals as well as certain subjects and regions are underrepresented • sample sizes for teachers varied substantially but most studies used rather small samples (e.g. below 300 for quantitative studies) and only sometimes include students	
EQ2: Evaluating the evidence: How can research methodology improve?	• good to satisfactory quality of studies • mixing with qualitative methods limited to the measurement of knowledge or teaching aspects • only student outcomes but (almost) never knowledge and teaching were explored longitudinally and time frames were rather short • almost exclusively used assessments of teacher knowledge (mostly tests) and only a single study used teacher questionnaires resulting in a marginally stronger effect on teaching quality • Use of achievement tests or self-reports to measure student outcomes	• mainly satisfactory quality of studies • mixing with quantitative methods limited to quantitative teaching scales or analysing parts of the data quantitatively • greater variety in how knowledge is measured but frequent used stimulated recall methods and triangulation of information from different material • frequent use of integrated measures where evidence on teacher knowledge and its use is derived from one data source
Annex D: Evaluating potential bias in the quantitative synthesis	• marginal publication bias for the effect on student outcomes • effect sizes were equal for studies of "good" and "satisfactory" quality • funnel plots showed some asymmetries for the effects but the Egger test only indicated significant asymmetry for the effect on student outcomes • file drawer analysis suggests that findings are robust against potential missing null findings	

Note: Results for the evaluation of potential bias of the quantitative synthesis are listed in Annex D.

Implications for educational policy and practice

This systematic review highlighted the importance of teachers' general pedagogical knowledge as an ingredient for high quality and effective teaching. Knowledge about general pedagogy helps teachers to design and teach lessons, irrespective of the taught subject. Findings beyond school were sparse but point in the same direction. Thus, a profound knowledge about pedagogy is an indicator of teaching expertise that is shared among professionals from different disciplines and different teaching settings (Guerriero, 2017[9]; Baumert and Kunter, 2006[8]; Voss et al., 2015[24]).

Though only one ingredient among many, greater attention should be paid to the development and constant update of this currently overlooked knowledge. Options for ensuring and supporting the teaching profession in the development of this knowledge are manifold – some of which will be discussed below. Generally, it seems advisable to strive towards increased professionalisation through a well-orchestrated mix of various measures.

1. ***Setting pedagogical knowledge as a common standard for teaching:*** Standards could be introduced or revised to reflect the presented evidence that a profound knowledge in important areas of general pedagogy is key to professional teaching (Révai, 2018[170]; Santelices and Taut, 2011[171]). Even though standards exist in many countries for teachers, it is concerning that this is sometimes missing for teaching staff in other settings such as teacher education and higher education. Such teaching settings could equally benefit from a shared statement about the importance of pedagogical knowledge for teaching.
2. ***Providing opportunities to learn about pedagogy in teacher education and professional development:*** Teacher education and professional development need to offer teachers sufficient opportunities to acquire and update their general pedagogical knowledge. A review of the structure and syllabi of existing and new programmes should ensure that courses cover important pedagogical topics (Tatto and Hordern, 2017[172]). The review does not address the question of how pedagogical knowledge is best taught and, depending on the system, different approaches are possible, for example, offering specific courses on general pedagogy or embedding general pedagogical content in subject-specific courses. Research discusses some determinants of successful pedagogical courses and trainings in pedagogical issues. As there is probably no one-size-fits-all approach to successful pedagogical training, countries need to carefully evaluate the best choice for their contexts and continuously evaluate its success.
3. ***Promoting teachers with the ability to make use of their knowledge:*** Ensuring that teachers are able to use acquired knowledge deserves special attention, because research implies that there is more to pedagogical excellence than knowledge: certain skills, belief and cognitions are vital for harvesting the benefits of a strong knowledge base. The reviewed literature highlights practical experience as crucial for the transfer of knowledge to practice and development of an efficient pedagogical mind-set (Tatto, 2013[20]).
4. ***Enhancing the amount of guided teaching experience:*** Teachers need hands-on practical experiences where they have to put their knowledge into practice and learn about the context adequate application of knowledge. Though learning by doing in some contexts still drives the first practical experiences of teachers, countries more and more carefully structure and enrich it with professional guidance to boost its beneficial effects and prevent the "reality shock" for new teachers (Paniagua,

Sánchez-Martín and A., 2018[173]; OECD, 2019[174]; OECD, 2018[34]). Guided practical experience and reflection can be provided in practicum, courses with practical components (Cocard and Krähenbühl, 2013[123]) or well-structured teacher induction (Scheerens and Blömeke, 2016[38]). Stimulated reflection on teaching through video or other material, as used for researching teachers' use of knowledge in the classroom in qualitative studies, can also be an effective tool for improving pedagogical skills of teachers (Kleinknecht and Gröschner, 2016[175]; Gamoran Sherin and Es, 2009[176]; Es and Sherin, 2010[177]; Evens, Elen and Depaepe, 2015[53]). In addition, video- and computer-based trainings represent "lighter" ways to begin with the practical training of knowledge application (Piwowar et al., 2017[178]; Barth et al., 2019[179]).

5. ***Creating coherence in the pedagogical input provided inside and outside of formal training:*** Facilitating the transformation and consolidation of knowledge and skills acquired in teacher education and professional development courses surely is not a simple question of offering pedagogical input from theory and practice, but also of aligning them and creating coherence. Hence, a good coordination and cooperation between schools and institutes offering initial pedagogical training and continuous pedagogical training seems indispensable.

6. ***Increasing the quality of pedagogical training and support:*** The quality of pedagogical courses and professional support is key to its effectiveness. This is also a mounting concern in some OECD countries (OECD, 2018[34]; OECD, 2019[174]).The European Commission (2013[180]), for example, raises the question whether teacher educators at universities, teacher education institutes or other providers themselves are adequately equipped. This has been questioned especially for instructors teaching subject content such as mathematics, arts or science. The research-teaching dilemma at research institutes that offer pedagogical courses may also be detrimental to the quality offered: instructors are expected to teach and publish research, and the former often promises little merit. In addition to safeguarding the pedagogical preparedness of instructors, mentors should be selected based on pedagogical expertise and not simply career length (Totterdell and Woodroffe, 2008[181]).

7. ***Leveraging the potential of the work environment for pedagogical learning:*** Probably not just teacher educators and school-based mentors but also expert colleagues can have a positive impact on the consolidation and refinement of knowledge from new colleagues. New colleagues potentially bring recent knowledge and innovative pedagogies to the field. Leveraging this potential requires structures that support the mutual exchange between new and experienced colleagues, such as regular discussions about pedagogical topics and experiences during in-house workshops or reflective meetings. Similarly, the participation in professional development courses, whether online or face-to-face, could be an occasion for a meeting and discussion of new ideas and input from colleagues (Laurillard, D. and Kennedy, 2019[182]).

8. ***Safeguarding the pedagogical knowledge of teachers from alternative routes:*** Alternative certification programmes and possibilities for lateral entries are increasing in many countries in order to tackle teacher shortage (OECD, 2018[34]). A particular effort is required to ensure the pedagogical preparedness of teachers entering into the profession through such pathways (Boyd et al., 2007[183]). It is, for example, debatable if it is a good step forward to allow individuals without

preparation in pedagogy or teaching experience to enter the profession, as done through programs such as "Ensena por México" (Teach for Mexico) or "Learning One-to-one" in Mexico (Tatto and Parra-Gaete, 2019[184]).

9. ***Laying the foundation for a good entry level and a career-long updating of pedagogical knowledge:*** Teacher evaluations are increasingly used not just for licensing teachers but also as a measure to ensure that in-service teachers meet recent requirements for the jobs (Santelices and Taut, 2011[171]; Tuytens and Devos, 2011[185]). Given the rapid changes in the classroom (including increasing diversity and multiculturalism, curricular reforms, new technologies, research and approaches), it seems necessary for teachers to continuously update their professional knowledge. Without doubt, accountability measures can be used as a governance tool to ensure not only a sufficient entry level but also a regular update of pedagogical knowledge. Two things seem important when considering accountability measures that include tests of pedagogical knowledge. Firstly, accountability systems should be motivating, empowering and leave teachers the agency to take charge of their knowledge rather than impose stress and pressure on teachers (Fahey and Köster, 2019[186]; Pearlman and Tannenbaum, 2003[187]). Secondly, the choice of test should ensure the validity and reliability of the instruments.
10. ***Selecting valid instruments for licensing and programme evaluations:*** It is astonishing that for a long time the choice of instruments used for teacher licensing or monitoring the effectiveness of teacher education programmes has largely relied on reliability reports and documentation of content and construct validity alone (Carter and Lochte, 2017[188]; Cochran-Smith et al., 2016[189]; Cochran-Smith, 2003[12]). For instance, experts judged whether the content of a test covers pedagogical topics relevant for teaching, factor analysis confirmed the structure of the measured knowledge or the sensitivity of the instrument to mean differences between pre- and in-service teachers was tested. For a while now, requests for evidence on the criterion validity of tests became more dominant, and as discussed in the Measures of Effective Teaching project (2012[39]), testing the link to high-quality teaching and even more so to student outcomes is a 'central' test of validity and, thus, should be a leading criteria for the choice of instrument. This is also true for selecting instruments for monitoring.
11. ***Raising awareness for the complexity of teaching:*** Last but not least, the results of the current review can also serve to raise the public awareness for the complexity of teachers' everyday job in the classroom. The Teaching and Learning International Survey (TALIS) showed that less than a third of all teachers felt that they are valued by society (OECD, 2014[190]). This review shows that irrespective of the subject being taught, teaching requires pedagogical expertise in various areas; and this represents just a slice of the required competence portfolio.

Implications for research on teacher knowledge

This paper discussed research gaps and the methodological soundness of the available research. In spite of the promising findings and general satisfactory to good quality of the studies, several research gaps and methodological issues became apparent in section 4. and section 5. that future research has to address:

1. ***Intensifying the research efforts in general and regarding educational output in particular:*** The research available thus far covers a wide range of teaching aspects and various student outcomes. In general, research on the topic, however, is still scarce, particularly for the relationship between general pedagogical knowledge and student outcomes. Given its high priority in most countries, more research effort is needed to discover the various ingredients to high-quality teaching and the educational outputs of systems, including teacher knowledge. This is also important as a foundation for research on the effectiveness of teacher education. Research should first confirm that the measures of knowledge are relevant for teachers' job success before using them as outcome measures in evaluation studies in order to substantiate obtained results (Scheerens & Blömeke, 2016).
2. ***Researching educational output with a broader and longer perspective:*** All considered student outcomes relate closely to academic achievements of students. The studied aspects of teaching, however, imply broader implications of teachers' general pedagogical knowledge. Research has shown, for example, that the quality dimensions are beneficial for students' well-being and socio-emotional outcomes (Hamre and Pianta, 2005[191]; Suldo, Shaffer-Hudkins and Riley, 2008[192]; Ruzek et al., 2016[193]). Another important point is the scarcity of mid-term and the absence of long-term findings. All in all, future research should aim for longitudinal studies with an extended time frame and a broader perspective on the educational output.
3. ***Moving towards a more fine-grained analysis of teacher knowledge:*** There is a positive tendency in research towards a more fine-grained and specific exploration of the different knowledge components. For instance, evaluations of teacher certifications moved away from a crude comparisons of certified versus uncertified teachers to a reporting of the results for the different parts of the certification procedure: e.g. separate reporting for tests on pedagogical knowledge and content knowledge (Carrasco, 2014[138]; Santelices and Taut, 2011[171]; ABC, 2007[194]). The review showed that decomposing general pedagogical knowledge into different knowledge areas and types is hardly ever done, but potentially allows for important conclusions on how to improve instruments and teacher training. Researchers should, thus, report results for different parts of teachers' knowledge, if reliable and valid subscales are available.
4. ***Continuous updating of the research to represent better emerging teaching challenges:*** Classrooms (whether in schools, colleges or universities) are increasing in diversity and multiculturalism, and educational settings are striving towards greater inclusiveness (Schleicher, A., 2016[4]). More than ever, teachers need to know how to meet diverse needs and manage multicultural classrooms (Ben-Peretz, 2011[195]; Gorski, 2009[196]; Burns and Shadoian-Gersing, 2010[6]). Thus far the topic seems to have been only lightly touched (e.g. in research on adaptive teaching competence or in instruments with scales on teachers' knowledge about heterogeneity in the classroom). It is up for debate whether this allows for sufficient measuring of the knowledge needed to master multicultural classrooms. While specific instruments on teachers' knowledge about multiculturalism exists, findings regarding the practical relevance of this knowledge are still missing (Ambrosio, 2001[197]; Wasonga, 2005[198]; Valanidou and Jones, 2012[199])..
   Moreover, technology is now interwoven into the everyday reality of teaching jobs and, to a certain extent, teaching no matter which subject requires knowledge on how to use technology in education. Seemingly, research on this topic emerged -

though with reference to Shulman - as a separate line of research (Harris et al., 2017[200]). If this dissociation is serving any scientific purpose or is rather artificial is open for discussion.

5. ***Discovering with greater detail and more rigour the transformation of knowledge into practice:*** Even though more research is dedicated to knowledge-related skills, quantitative studies did not yet directly test their assumed role as mediators and moderators for the transformation of knowledge into practice (Baumert and Kunter, 2006[8]; Voss et al., 2015[24]; Blömeke and Kaiser, 2017[74]). The hypothesised role of knowledge-related beliefs is barely empirically researched at all.

6. ***Understanding better how teachers' knowledge use and impact can be shaped:*** Naturally, the reviewed correlational evidence does not allow for causal interpretations. None of the studies was a randomised control trail. Furthermore, quasi-experimental studies and longitudinal quantitative surveys often made restricted use of their designs. This is disappointing as understanding how knowledge can be changed with tangible results for teaching quality and students' learning would be extremely valuable for improving the professional support of teachers. More longitudinal data and more rigorous experimental designs are needed that collect and analyse not only the changes in student outcomes but also in teacher knowledge and teaching quality. Additionally, quantitative research can learn from qualitative studies, which showed that teachers differing in teaching experience or qualification used knowledge differently with important insights into potentially ways of promoting teachers 'professional development. Admittedly, not as powerful as longitudinal or experimental data, comparing in-service and pre-service teachers or teachers with varying teaching experience (e.g. by using multi-group or moderator analysis) can yield first quantitative insight into effective teacher support. So far, quantitative studies exclusively reported mean differences in general pedagogical knowledge for different teacher groups but did not investigate differences in the way knowledge is associated with high-quality teaching and student outcomes (Gold, Holodynski and M., 2015[201]; Voss, Kunter and Baumert, 2011[147]; Baer et al., 2011[202]). It can be assumed, for example, that the association gets stronger with increased teaching experience, because teachers and instructors grow in their ability to put knowledge into practice (Kawecki, 2009[131]; Magnoler, Rossi and Giannandrea, 2008[125]; McAlpine et al., 1999[101]).

7. ***Investigating the way general pedagogical knowledge works in combination with other teaching competences:*** Similarly, inspired by insights from qualitative studies indicating that good teaching is a result of a simultaneous activation of general pedagogical knowledge, content and pedagogical content knowledge, quantitative studies should change their approaches for analysing general pedagogical knowledge jointly with further teaching competences: Instead of investigating them separately or comparing their predictiveness, more quantitative studies should investigate their interplay as done by Seiz and colleagues (2015[139]) or by studying the impact of certain competence profiles (cf. Blömeke (2015[77]).

8. ***Unravelling the role of the context for application of knowledge in the classroom:*** The inconclusive quantitative findings regarding classroom composition, such as the share of educationally disadvantaged students in the classroom (Carrasco, 2014[138]; Brühwiler, 2011[110]; Beck et al., 2008[116]), can be understood as a call for more research on the topic. In light of findings from other studies, further questions arise regarding contextual influence of teacher's use of knowledge in the classroom.

For example, what role do time pressure (OECD, 2019[174]) and intended goals of the lesson play (Herppich et al., 2018[88])? Answering such questions allows for addressing two important policy issues: how to equip teachers with the knowledge required for specific teaching contexts and how to structure classrooms to facilitate the application of acquired knowledge.

9. ***Expanding the knowledge horizon to further regions:*** Teaching in deprived areas and developing countries, for example, is not represented and deserves research that targets issues pertinent to such contexts, such as a lack of teacher training, larger class sizes and a lack of educational resources. The questions of the knowledge teachers use to tackle such challenge and how teacher training can prepare for this is of great importance. Only one qualitative study studied differences of teachers from different countries (Sothayapetch, Lavonen and Juuti, 2013[140]): Finland and Thailand. Further, cross-country comparative results are needed for carving out differences in educational systems and cultures and their implications for the way teachers use general pedagogical knowledge in the classroom.
10. ***Expanding the knowledge horizon to further educational settings and professionals:*** More work needs to be done beyond primary and secondary education, as the professional background of teaching staff and desired outcomes of teaching in higher education and vocational training are unique. It is particularly disappointing that research still provides few answers to the question regarding the pedagogical knowledge needed to successfully prepare future teachers, notwithstanding the recent increase in scientific interest in the so-called "hidden profession" (European Commission, 2013[180]). Existing instruments for assessing teacher knowledge quantitatively, however, would need some adjustments, because teacher educators need to be able to deploy knowledge on two levels: First-order knowledge concerns schooling and teaching which teacher educators convey to pre-service teachers. Second-order knowledge comprises the knowledge of how teachers learn and how they become competent teachers (European Commission, 2013[180]).
11. ***Further improving the methodological quality of studies:*** The appraisal of the design and methodology of the existing research highlighted further aspects that could be improved that have not been mentioned so far. First of all, sample sizes varied considerably for quantitative studies and was rather small in some cases. As illustrated, research would also benefit from implementing more mixed-method studies that are not predominantly quantitative or qualitative in nature.

Final conclusion

All in all, the review provided evidence that general pedagogical knowledge is a prerequisite of high-quality and efficient teaching. Thus, a profound knowledge about pedagogy is an indicator of teaching expertise that is shared among professionals from different disciplines and different teaching settings. Intensified scientific efforts are needed to understand better how this knowledge develops and gets transformed into practice as well as educational outcomes. Furthermore, sufficient attention should be paid to this teaching prerequisite and resource in policy-making, as well as teacher education and further professional support of teaching staff.

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Annex B. Details of the review approach

The review is based on an intensive and systematic search, selection and coding process (as was illustrated in Figure 2.1).

Search strategy

With the aim of identifying as much of the relevant literature as possible, a search for published and unpublished research literature in different sources was conducted. The search took place from April 2018 to May 2019 and was not limited to references in English, but also included references in Catalan, French, German, Hungarian, Icelandic, Italian, Mandarin, Polish and Spanish. Additionally, we reached out to the international research community. This broad and intensive strategy was chosen to reduce the influence of possible language and publication bias, i.e. including only findings that have not (yet) been translated into English or published in peer-reviewed articles.

Search engines and data bases

The following international electronic search engines and databases were searched[1]: Google Scholar, EBSCOhost, ERIC, OECD iLibrary, PMC, Scopus, and ScienceDirect. The databases were browsed using a search term related to general pedagogical knowledge (e.g. "general pedagogical knowledge", "general pedagogical and psychological knowledge", "declarative knowledge about teaching"). If the search term produced too many hits (more than 100), the search was narrowed down by combining the term using the logical operator "AND" with other terms. Firstly, terms were added that referred to either teaching practice (e.g. "teaching practice", "teaching quality", "classroom management", "instruction", "instructional quality") or student outcomes (e.g. "outcomes", "achievement", "development"). Secondly, the search was refined by including terms aimed at identifying empirical research (e.g. "study", "sample").

To identify references in other languages, the same databases were searched with equivalent search terms and their combinations in the aforementioned languages. Additionally, national databases were consulted such as Fachportal Pädagogik for German publications (specialist portal on pedagogy) and Országos Pedagógiai Könyvtár és Múzeum for Hungarian publications (National Pedagogical Library and Museum).

Other sources: Hand, web site, and bibliographic searches

The search further involved a cross-check of the resulting database of studies with the reference lists of related reviews (König, 2014[23]; Voss et al., 2015[24]; D'Agostino and Powers, 2009[60]; Klassen and Kim, 2019[61]) and further key publications (Baumert & Kunter, 2006; Guerriero, Sonia, 2017; Südkamp & Praetorius, 2017). In addition, the websites of research projects on general pedagogical knowledge were checked such as the website of the COAKTIV-R study (A Study on Teacher Candidates' Acquisition of Professional Competence During Teaching Practice) or the TEDS-M study (Teacher Education and Development Study in Mathematics).

[1] [1] The authors can provide search records for the review on request.

Selection process and criteria

A mapping exercise preceded the in-depth reviews (see Box A B.1) to allow for a systematic description of research and for refining the inclusion and exclusion criteria for the in-depth reviews (Gough, 2004[14]). The final selection of publications was done in two steps: First, the titles and abstracts of documents were screened and, then, full text articles were reviewed to determine eligibility. It was based on the following inclusion and exclusion criteria:

1. **Language:** The study had to be in a language spoken by the researchers involved in the review. This included Catalan, English, French, German, Hungarian, Icelandic, Italian, Mandarin, Polish and Spanish.
2. **Study begin:** Only studies conducted after 1986 – the publication date of Shulman's typology (Shulman, 1986[22]; Shulman, 1987[21]) – were considered to ensure a common conceptual understanding of teacher knowledge among included studies.
3. **Empirical study:** Due to the limited number of expected relevant studies, no restrictions were made with regard to the study design, as long as studies were empirical. Thus, quantitative, qualitative and mixed-method studies of varying designs were eligible (including cross-sectional and longitudinal studies, evaluation and intervention studies or case studies).
4. **Measurement of general pedagogical knowledge or related beliefs and skills:** Studies were only included if they measured teachers' general pedagogical knowledge or related beliefs and skills or at least meaningful segments of these knowledge concepts. The latter refers to isolated findings for certain areas of teachers' knowledge (e.g. knowledge about teaching in diverse classrooms, knowledge about classroom management). As long as the knowledge area was related to the teaching task, such evidence was reviewed. Studies were excluded if they exclusively explored knowledge for non-teaching related tasks (e.g. knowledge about school improvement, professional development or leadership). Moreover, the review did not consider skills and beliefs that were not explicitly associated with general pedagogical knowledge (e.g. teaching efficacy). Content-specific teacher knowledge such as content knowledge, pedagogical content knowledge or technological pedagogical content knowledge were also excluded.
5. **Link to practice or student outcomes:** To be included, studies had to report findings on the association between knowledge and teaching practice, student outcomes or both. Yet, studies were not eligible if they only explored the relationship between knowledge and other professional competences or further characteristics of teachers (work experience, teacher identity, beliefs, content knowledge etc.).
6. **Educational level and context:** The review included studies conducted in various educational contexts. Studies ranged across different educational levels from primary to tertiary education. Evidence from the pre-primary level was discarded (e.g. preschools, kindergarten), because the applied educational approaches, learning goals and pedagogical theories in these settings are somewhat distinct (Sylva, Ereky-Stevens and Aricescu, 2015[203]; OECD, 2012[204]). Moreover, studies on one-to-one tutoring, as well as individual mentoring or coaching were

not accepted, as included studies had to explore teaching in group or classroom contexts (e.g. classroom, courses or lectures).

7. **Samples:** Studies sampling in-service and pre-service teachers, professors or people in other teaching positons were acceptable, as long as participants had actual teaching experience through work, courses, practicum or as part of an induction phase.

Box A B.1. Mapping of studies

A mapping exercise preceded the in-depth reviews to allow for a systematic description of research and for refining the inclusion and exclusion criteria for the in-depth reviews (Gough, 2004[14]). The mapping exercise followed a technique proposed by the Evidence for Policy and Practice Information and Coordinating (EPPI) Centre (EPPI-Centre, 2006[205]): Analysis of codes such as language of the publication and country of study origin, topic, population focus, study design and setting. The EPPI-Centre Core Keywording Strategy was complemented by a set of review specific keywords focused on the topic of general pedagogical knowledge. The mapping was conducted in two rounds.

First round of mapping

A first round of mapping was conducted for publications in English and German. The map contained few studies - all of which seemed highly relevant for the review and of acceptable methodological quality. As a result, the original criteria for the inclusion of studies were broadened. Before the mapping, only quantitative studies were eligible. After mapping, qualitative and mixed-method studies were also included, as outlined in the previous section. After mapping, studies measuring beliefs and skills related to general pedagogical knowledge were included, instead of exclusively focusing on studies about knowledge. This broadening of criteria aimed for providing a more comprehensive picture about the relevance of teacher's general pedagogical knowledge for successful teaching.

Second round of mapping

A *second round of mapping* helped narrow the developed criteria to identify studies that would be better able to address the review questions (see section 2.1).

First, the *criterion 4 (measurement of general pedagogical knowledge or related beliefs and skills)* was adjusted. It was specified that the review did not consider skills and beliefs that do not explicitly refer to teaching knowledge, for example measures of cognitive ability or meta-cognition without clear reference of these skills to general pedagogical knowledge. All except two of the publications were included in the mapping.

Second, the *criterion 4* was further refined to consider studies that included to a certain extent *content-specific knowledge* of teachers. As previously done in the review by Voss (2015[24]), it was decided to include the studies and be transparent about the mixed-nature of the knowledge but only if general pedagogical knowledge was sufficiently represented. The mixture of general and content specific facets was carefully coded. In this case, whenever possible, the coding focused on the generic knowledge parts, for example by coding the findings for the generic parts only, if available. This led to the exclusion of two further publications.

Third, the *criterion 5 (link to practice or student outcomes)* was refined so that studies had to provide clear and concrete evidence on the relationship between general pedagogical knowledge and teaching, student outcomes or both. "Direct and concrete evidence on the link" was stipulated in this case because merely investigating knowledge and teaching or student outcomes without analysing their relationships – whether quantitatively or qualitatively – does not address the review questions. As could be seen in Figure 2.1, 14 of the publications in the review map did not meet this criterion.

As a result of the mapping and refinement of the criteria, 18 studies were excluded from the in-depth reviews.

Mapping of studies

A mapping exercise preceded the in-depth reviews to allow for a systematic description of research and for refining the inclusion and exclusion criteria for the in-depth reviews (Gough, 2004[14]). The mapping exercise followed a technique proposed by the Evidence for Policy and Practice Information and Coordinating (EPPI) Centre (EPPI-Centre, 2006[205]): Analysis of codes such as language of the publication and country of study origin, topic, population focus, study design and setting. The EPPI-Centre Core Keywording Strategy was complemented by a set of review specific keywords focused on the topic of general pedagogical knowledge.

Coding of studies for the in-depth review

Five researchers searched for and coded studies. All reviewers had PhDs or were PhD students in education or psychology, and possessed advanced knowledge about teachers' professional competences and international educational research. Reviewers only coded studies in languages that were either their native languages or languages in which they had excellent reading skills.

The coding followed a structured coding scheme in excel. It was developed based on EPPI-Centre Review Guidelines (EPPI-Centre, 2006[205]) and included the codes of the mapping exercises. The scheme was amended for review-specific codes.[2]

The coding scheme for quantitative and qualitative studies was similar and only diverged slightly (for coding study findings) and included the following information on the publication and study characteristics:

- aims and foci of the studies
- sample(s) and educational setting
- definition of knowledge, study design and measurement of knowledge
- teaching and student outcome
- analytical approach and findings
- the weight of evidence (WoE; further explained in Box 5.1).

Synthesis of quantitative and qualitative studies

The quantitative and qualitative studies included in the in-depth review differed fundamentally in important characteristics (e.g. sample sizes and analytical approach) and provided different types of evidence. Hence, they were not directly comparable and were analysed separately in this review. As most mixed-method studies could clearly be divided into mainly quantitative or qualitative designs (see section 5.), they are presented as part of the quantitative and qualitative review. For the mixed-method studies by (Wu, 2013[119]) and (Zhang, 2012[145]), only the qualitative studies yield review-relevant findings and were therefore included as qualitative studies.

[2] [2] [2] The authors can provide details on the coding scheme of the review on request.

Synthesis of quantitative studies

Researchers of quantitative studies analysed the review questions with various analytical approaches (see Annex D for details). All findings were extracted and, if necessary and possible, transformed or computed (Lenske et al., 2016[111]; Lenske, Wirth and Leutner, 2017[112]; Nieminen et al., 2013[206]; Lorah, 2018[207]) to represent effect sizes of the correlation family (Fernández-Castilla et al., 2019[89]). Where theory suggested reversed effects, for example, for the relationship of knowledge to classroom disturbance (Seiz, Voss and Kunter, 2015[139]), the effects was post hoc inverted.

To address the review questions (RQ) in section 3. , three-level meta-analytic models aggregated the effect sizes into two overall effects for teacher knowledge (Assink and Wibbelink, 2016[90]): an overall effect for teaching (RQ1) and an overall effect for student outcomes (RQ2). A multilevel meta-analysis takes into account the dependency of effect sizes, as several publications reported effect sizes from the same studies.

Additionally, mixed-effects models studied if different moderators modulated the size of effects to answer the review and evaluation questions (Viechtbauer, 2010[91]). As recommended by Cooper (2009[208]), each moderator was tested separately to avoid a severe loss of statistical power and multicollinearity. As the findings for the other review questions are rarely reported, they are summarised. In a last step, the results were evaluated for possible bias using different tests (see Annex D). Table 2.1 in section 2. lists the analysis for each of the review question as well as each of the evaluation question.

Synthesis of qualitative studies

For the qualitative review, studies were read and re-read to identify themes and knowledge concepts inductively. The analysis began with generating initial codes, naming interesting segments of data that characterise teachers' use of knowledge in the classroom. Reciprocal translation of studies occurred by identifying common themes which were applied across studies. The analysis continued by searching for overarching themes that represented coherent patterns in the reviewed evidence (Braun and Clarke, 2006[92]).

The synthesis of the 31 qualitative studies revealed three themes and 12 subthemes illustrating teachers' experiences with applying knowledge in teaching and lesson design. For each of the seven review questions in section 3. , the results are presented narratively after the quantitative findings to complement them.

Annex C. Coded publications and studies

Overview of publications included

A total number of 64 publications was included in the in-depth review. Most (40 publications) of these publications were peer-reviewed journal articles. The rest were project reports (3 publications), theses (15), mainly doctoral theses, book chapters or books (5 publications), conference proceedings or conference abstracts (1 publication).

Coded publications were mostly in English (31 publications), German (17 publications) or Mandarin (8 publications). The review also includes 3 publications in French, a publication in Hungarian, Icelandic and Italian as well as 2 publications in Polish. Of the 64 publications, 34 publications related to quantitative studies and 31 publications to qualitative studies. Moreover, 14 publications, all reporting quantitative results, came from the same large-scale studies. Authors from two additional publications (Jiang and Hao, 2010[120]; Jiang and Hao, 2011[133]) probably used data from the same qualitative study. As this was not entirely clear, they were treated as separate studies.

Overview of studies included

The review analysed 20 quantitative studies and 31 qualitative studies. The vast majority of the included studies were research projects. Only three administrative datasets on teacher knowledge were used. In two cases, teacher data was merged with administrative data on students and in one case, teachers' administrative teacher data was validated through collecting additional data on teacher knowledge.

Of the 19 studies with available information on funding, 10 were funded by research grants and 7 studies received funding from ministries. One study received funding from a board responsible for teacher certification and another one from an independent government organisation.

Annex D. Evaluating potential bias in the quantitative synthesis

Description of the methodological approach

Despite a thorough review of the literature, the final sample may not include all relevant studies. Different analysis were conducted to test the possibility and consequences of missing findings and further bias (Card, 2012[209]; Cooper, 2009[208]; Higgins et al., 2019[94]):

- **Moderator analysis for peer- versus non-peer-reviewed studies:** A moderator analysis tested if effects from peer-reviewed articles differed in size of effects from non-peer-reviewed publications.
- **Moderator analysis for study quality:** Effect sizes obtained from satisfactory vs. good quality studies were compared with an additional moderator analysis.
- **Moderator analysis for analytical approach:** Another moderator analysis analysed the type of analytical approach (comparing effect sizes obtained from bivariate vs multivariate approaches; Box A D.1 explains the rational of this robustness check).
- **Visual funnel plot inspection:** Funnel plots of the overall effects were visually inspected for asymmetries.
- **Testing for funnel plot asymmetry:** The random-effects version of the Egger test was additionally computed to test for funnel plot asymmetry**.**
- **File drawer analysis:** A file drawer analysis determined if overall effects were robust against potentially missing null findings.

Box A D.1. Testing the robustness of effects obtained from heterogeneous analytical approaches

Researchers of quantitative studies analysed the review questions with various analytical approaches, producing a range of coefficients (such as product-moment-correlations, tau correlations, standardised and unstandardised coefficients from multiple regressions, path analysis and structural equation models). Sometimes they used multilevel approaches and considered various covariates.

Scepticism exists as to whether multivariate effect sizes are comparable because considered covariates likely vary (Cooper, 2009[208]; Becker and Wu, 2007[210]). Thus, combining such effect size metrics can be misleading regarding overall effects and heterogeneity of effects (Aloe and Thompson, 2013[211]). At the same time, compiling only bivariate correlations would not do justice to the complexity of the topic and, hence, probably not lead to accurate estimations either (Bowman, 2012[212]; Card, 2012[209]). In addition, sorting out multivariate effect size metrics, which are probably from peer-reviewed studies of higher quality, would reduce the effect sizes considered, which could bias population parameters (Aloe and Thompson, 2013[211]).

Following suggestions by Peterson and Brown (2005[213]) and Bowman (2012[212]), and in order to maximise the number of studies considered, it was decided to include all results convertible into effect sizes of the correlation family. Similar to investigating design characteristics as moderators (Card, 2012[209]; Cooper, 2009[208]; Higgins et al., 2019[94]) the influence of differences in applied analytical approach was tested as a moderator of the overall effects (Ulferts, Wolf and Anders, 2019[214]; Nores and Barnett, 2010[215]).

Results of the bias analysis

The *moderator analysis comparing peer- versus non-peer-reviewed effect sizes* indicated a a marginal publication bias for the effect on student outcomes only: Effect sizes obtained from peer-reviewed publications were slightly stronger than those from non-peer-reviewed publications (see Table A D.1). The quality of studies was not a significant moderator of effects (i.e. effect sizes from "satisfactory" and "good" studies did not differ). *Analysing type of analytical approach* adopted in studies revealed no differences between effect sizes resulting from multivariate approaches.

Table A D.1. Results of the moderator analysis

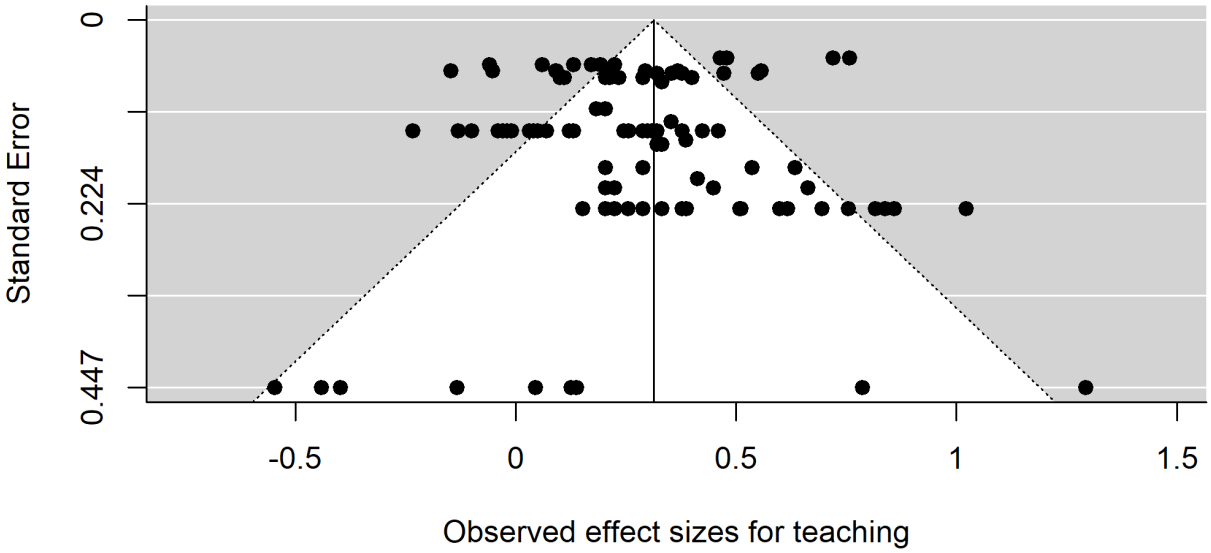
Moderators	Test of moderator		Residual variance		Sample		Effect size of subgroups		
	Q_M	df_M	Q_E	df_E	k_{ES}	k_{Study}	ES	*se*	$CI_{95\%}$
Effect on teaching									
Peer-review	1.67	1	418.67***	107	109	16			
Not reviewed					29	6	.37***	.08	.24, .55
Reviewed					80	12	.27***	.05	.18, .38
Study quality	0.25	1	646.81***	107	109	16			
Satisfactory					38	8	.33***	.07	.20, .48
Good					71	8	.28***	.07	.16, .42
Analytical approach	1.18	1	440.63***	107	109	16			
Bivariate					42	11	.28***	.06	.18, .40
Multivariate					67	9	.32***	.06	.23, .45
Effect on student outcome									
Peer-review	3.89#	1	57.86**	32	34	8			
Not reviewed					25	6	.09**	.03	.04, .15
Reviewed					9	4	.23**	.07	.10, .37
Study quality	0.44	1	65.41***	32	34	8			
Satisfactory					13	3	.17*	.07	.03, .32
Good					21	5	.12*	.05	.01, .22
Analytical approach	0.05	1	62.67'*	32	34	8			
Bivariate					16	4	.14*	.05	.03, .25
Multivariate					18	5	.13*	.05	.02, .23

Note: No study reporting on student outcomes used questionnaires to measure teacher knowledge. Significance levels are indicated as # p< .10, * p < .05, ** p < .01, *** p < .001.

The *visual inspection of the funnel plots* showed some asymmetries (see Figure A D.1 and Figure A G.2). As can be seen, the included effect sizes scattered slightly unevenly to the sides of the lines. A few effect sizes are outside the 95% pseudo confidence interval region of the effects (area of ± 1.96 standard error around the estimated effects).

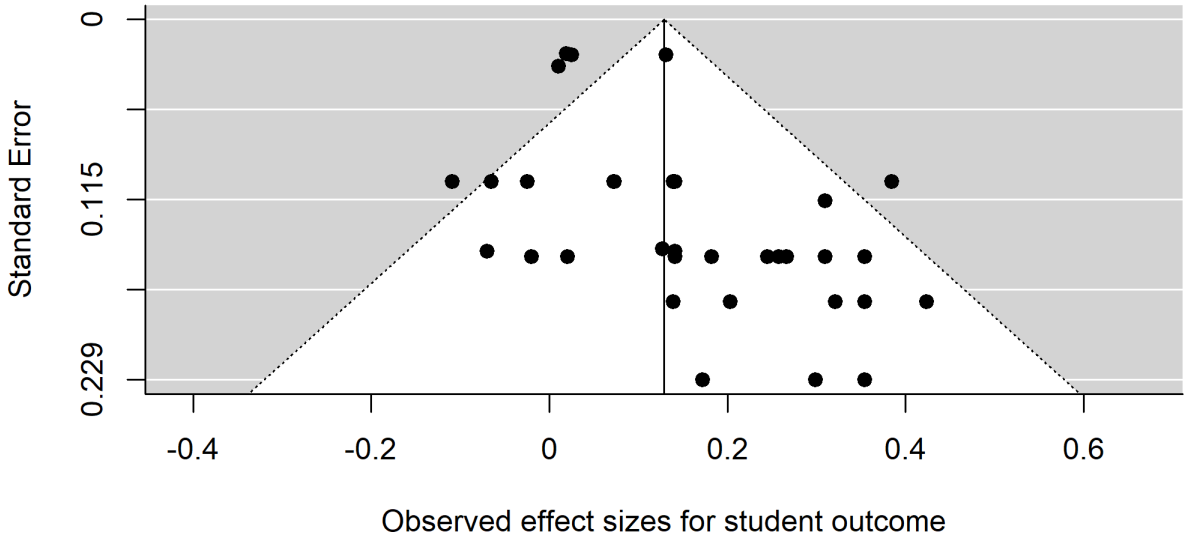
Figure A D.1. Funnel plot for teaching

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Note: The scatter plot displays the effect sizes on the x-axis against their corresponding standard errors on the y-axis (Higgins et al., 2019[94]). The vertical line show the estimated effects.

Figure A D.2. Funnel plot for student outcomes



Note: The scatter plot displays the effect sizes on the x-axis against their corresponding standard errors on the y-axis (Higgins et al., 2019[94]). The vertical line show the estimated effects.

The random-effects version of the *Egger test for funnel plot asymmetry* indicated asymmetries for the effect on student outcomes only ($z = 3.25$, $p < .01$). This implies a significant correlation between effect estimates and sampling variances. Results of the *file drawer analysis,* however, demonstrated that the meta-analytical results are robust. It would take 25 958 and 647 null findings to outreach a significance level of $p < .05$ for the overall effects on teaching and student outcomes.

Annex E. Details on approaches to measure knowledge

Table A E.1. Instruments for measuring knowledge in quantitative studies

			Measurement mode					Item types					Knowledge Areas		
Study	What is measured	Instrument	Test	Questionnaires	Interviews	Observations	Portfolios/Plan	Contextualised	Forced choice	Oen	Likert scale	Ratinn volved?	Learning	Assessment	Instruction
ATC	Adaptive teaching competence	ATC	✓					✓v		✓		✓	✓	✓	✓
BilWiss	Psychological knowledge	BilWiss	✓						✓				✓	✓	
COACTIV–R	Pedagogical-psychological knowledge	COACTIV	✓					✓v	✓	✓		✓	✓	✓	✓
Derham & Diperna (2007)	Teaching knowledge	Praxis II - PLT	✓						✓	✓		✓	✓	✓	✓
IBH / SNF	Adaptive teaching competence	ATC (vignette)	✓					✓		✓		✓	✓	✓	✓
Kálmán (2016)	Self-perceived pedagogical competences			✓							✓		?	?	?
Laflotte (2015)	General psycho-pedagogical knowledge				✓			✓				✓		✓	✓
LEK-R	Classroom management expertise	CME	✓					✓v	✓	✓		✓			✓
	General pedagogical knowledge	TEDS-M	✓					✓	✓	✓		✓	✓	✓	✓
	Pedagogical adaptivity in lesson design						✓						✓	✓	✓
Mathematics Certification Study in Tennessee	Professional teaching knowledge	PTK test	✓						✓	✓		✓		✓	✓
NTES 2004-2011	Pedagogical knowledge	NTES portfolio					✓					✓		✓	✓
NTES 2005/06	Pedagogical knowledge	Prueba CDP	✓							✓		✓		✓	✓
PRIME	General pedagogical knowledge	Part of RTOP				✓						✓			✓
ProTeach	Knowledge and skills for a positive impact on learning	ProTeach					✓					✓	✓	✓	✓
ProwiN II	Pedagogical-psychological knowledge	ProwiN	✓					✓	✓		✓	✓A	✓	✓	✓
Salinger (2014)	Teacher knowledge of student content engagement	TKSCE	✓						✓	✓			✓	✓	✓
SioS-L[a]	Knowledge of teaching and learning	SioS-L	✓					?	?	?	?	?	?	?	?
	General pedagogical knowledge	TEDS-M	✓					✓	✓	✓		✓	✓	✓	✓
SKiLL	General pedagogical knowledge	TEDS-M	✓					✓	✓	✓		✓	✓	✓	✓
Validierung…	Educational knowledge	BWW	✓					✓	✓	✓		✓	✓	✓	✓
WiL	General pedagogical knowledge	TEDS-M	✓					✓	✓	✓			✓	✓	✓
	Professional vision	Observer	✓					✓v			✓	✓A			✓
	Pedagogical teaching knowledge	PPHW	✓					✓	✓		✓		✓		✓
ZuS	General pedagogical knowledge	TEDS-M	✓					✓	✓	✓			✓	✓	✓

Note: V = Video-based scenarios, A = Scoring through comparison with test solution of experts. ? = No information available.

a.) Information on the SIOS-L study was limited as there was only an abstract of a conference presentation available.

Table A E.2. Instruments for measuring knowledge in qualitative studies

Study	Questionnaires	Teaching task	Interviews	Review of docs	Observations	Diaries / blogs	Focus groups	Integrated	What is measured?
Atjonen et al. (2011)	✓							✓	teachers' key pedagogical principles for teaching
Boz & Boz (2007)		✓	✓S					✓	teaching knowledge used to introduce a science topic
Cocard & Krähenbühl (2015)				✓				✓	pedagogical knowledge in classroom management concepts
Cui (2017)			✓S		✓			✓	use of knowledge for lesson design and decision-making
Dögg Proppé (2014)			✓					(✓)	General pedagogical knowledge and lesson organisation
Friedrichsen et al. (2007)		✓	✓S					✓	prior knowledge for teaching
Gao (2015)	✓								perceptions of knowledge constructs
Gholami & Husu (2010)			✓S		✓			✓	practical knowledge about general pedagogy and knowledge-in-use
Hativa (2000)	✓		✓						pedagogical knowledge underlying problems in classroom behaviour
Hativa et al. (2001)			✓		✓			(✓)	general pedagogical knowledge
Hunger (2013)			✓S					✓	didactical knowledge used in lesson planning and teaching reflections
Jiang & Hao (2010)			✓S		✓			✓	pedagogical thoughts during teaching
Jiang & Hao (2011)			✓S		✓			✓	practical knowledge used during teaching
Jiang (2006)	✓							✓	knowledge for implementing affective instruction
Kawecki (2009)			✓		✓			✓	theoretical knowledge used in teaching
Lehrer & Franke (1992)			✓						teacher knowledge
Li (2012)			✓S		✓			✓	practical knowledge during teaching
Magnoler et al. (2008)						✓		✓	knowledge used for project planning and reflection
McAlpine et al. (1999)			✓S		✓			✓	knowledge used for reflections on course planning, instruction and learner evaluation
Roux-Paties (2014)			✓		✓			✓	and teachers' scientific knowledge
Salata (2016)	✓			✓				✓	acquired competences during practicum
Sanders et al. (1993)			✓	✓	✓	✓		✓	knowledge base including pedagogical knowledge
Sothayapetch et al. (2013)			✓					✓	general pedagogical knowledge used in teaching
Stankovic & Delafontaine (2016)					✓			✓	knowledge including knowledge for teaching
Stran & Curtner-Smith (2010)		✓	✓	✓	✓	✓		✓	Knowledge used for delivering the Sport Education (SE) model
Syarief (2017)						✓	✓	✓	general pedagogical knowledge used for teaching
Tran & Lawson (2007)		✓	✓					✓	student pedagogical knowledge (SPK) in simulated teaching situations
van Tartwijk et al. (2009)			✓		✓			(✓)	practical knowledge of classroom management strategies in multicultural classrooms
Walsh (2017)			✓		✓			✓	use of general pedagogical knowledge in teaching
Wu (2013; qualitative study)			✓					✓	teachers' key pedagogical principles for teaching
Yao (2014)						✓		✓	teaching knowledge used to introduce a science topic

Note: S = stimulated recall interview. *(✓)* = Teaching is only partly assessed with the same instrument.

Annex F. Strengths and limitations of this review and conclusions

Strengths of this review

The present review makes several noteworthy contributions to the knowledge about the relevance of general pedagogical knowledge for teachers' job success and disclosed foci and gaps of the available research. More specifically, the particular strength are the following:

- **Specific focus on general pedagogical knowledge:** Early effectiveness reviews and reviews of licensing and teacher programs swamped research in the 1990 and subsumed evidence for very different indicators of teachers' effectiveness into overall effects. Compared to them, this and other more recent reviews provide more guidance in how to restructure teacher education and licensing to ensure and increase the quality of education (see section 1.2).
- **The search in several languages:** A particular strength of this review is that the review searched and mapped studies published in 10 different languages. As the results showed, this clearly contributed to the comprehensiveness of the review: studies in languages were included in the mapping and evidence published in 9 languages was included in the in-depth review.
- **Including qualitative studies and knowledge-related skills and beliefs:** Comparing the evidence from qualitative and quantitative studies and working out knowledge gaps and methodological strengths and weaknesses clearly allowed for some important conclusions for educational policy and research. Including knowledge-related beliefs, skills and cognitions clearly has the potential of a deep understanding of how knowledge is put into practice. Through the review it became evident, however, that more and more thorough research is needed to realise this potential. These points, nonetheless, make it different from the review on German quantitative studies by Voss and colleagues (2015[24]) and the meta-analysis on teacher assessment (D'Agostino and Powers, 2009[60]; Klassen and Kim, 2019[61]).
- **Limiting the time frame for studies:** Limiting the time frame to studies published after 1987 seemed to have been a good choice considering that the review by D'Agostino and Powers (2009[60]) showed that effect sizes published later in the 20th century were lower in size than those published earlier.

Limitations of this review

This review also faces some important limitations:

- **Potential bias:** Firstly, only around half of the reviewed publications were peer-reviewed. Discarding non-peer-reviewed evidence on the other hand would not only have reduced the sample size of included studies it would have also reduced the number of included countries and the number of studies. Instead of discarding the evidence, whether a study was peer-reviewed or not was considered in the quality ratings and was tested as a moderator. There was some indication of bias in the quantitative syntheses. The effects, however,

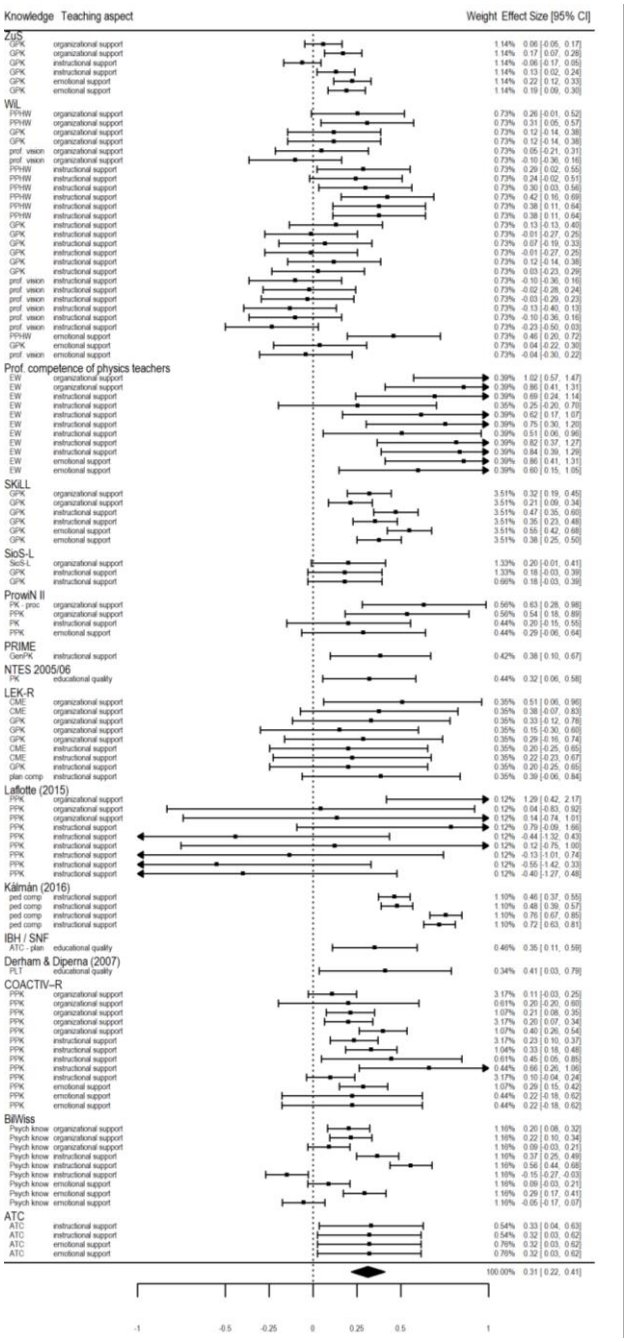
were robust against potential null findings (Card, 2012[209]; Cooper, 2009[208]; Higgins et al., 2019[94]).

- **Missing information on the validity and reliability of instruments:** The review did not provide in-depth analysis of the reliability and validity of included instruments. Naturally, using valid and reliable measures is key to providing sound evidence. Hence, this information is included in the quality ratings without an in-depth discussion. Other reviews have already discussed this issue in great detail (Voss et al., 2015[24]; König, 2014[23]).
- **Missing meta-analytic results for some of the review questions:** This review does not include meta-analytic findings for some questions, as evidence was too scarce (e.g. mediator effects of teaching quality and knowledge-related skills, shaping teachers' use of knowledge, role of the context and beliefs related to general pedagogical knowledge). Future secondary studies may be able to address this issue.
- **The exclusion of mentoring:** Mentoring of teachers was excluded as a topic from the review. Since the review was limited to findings for classroom settings and group contexts, such intensive one-to-one support was not included in the review. However, it seems that dynamics and competences for supporting teachers in a one-to-one setting differs from group settings. Some specific reviews about mentoring are available (Hobson et al., 2009[216]; Aspfors and Fransson, 2015[217]).
- **The exclusion of knowledge that goes beyond the teaching task:** Last but not least, this review does not provide a comprehensive review of evidence on knowledge areas that go beyond the teaching task. Such knowledge areas were only included in this review if they formed part of an instrument that measured knowledge relevant for teaching. Admittedly, such knowledge gains in importance for teachers' job success (e.g. knowledge about parent-teacher-collaboration and schools as an organisation (Cowan and Goldhaber, 2014[117]; Valanidou and Jones, 2012[199]; Wasonga, 2005[198]) or knowledge regarding child neglect and abuse (Falkiner et al., 2017[218]; Walsh et al., 2013[219]). It was argued, however, that for planning and teaching lessons the knowledge areas studied in this review are of greater relevance as they are more closely directed towards the teaching task (Baumert and Kunter, 2006[8]). The mode of effect for other areas of knowledge is likely to differ. For instance, knowledge about parent-teacher collaboration is likely to exert influence on students' learning through an enhanced parental support of out-of-school learning (Borgonovi and Montt, 2012[220]; Bull, Brooking and Campbell, 2008[221]). Furthermore, knowledge about the school as an organisation and professional learning may boost teachers' professional identity, their wellbeing and interest in professional development. The review does not provide information as to whether these assumptions are empirically justified (but see (Voss et al., 2015[24]). Future reviews should summarise the evidence for this specific question.

Annex G. Forest plots for the overall effects

Figure A G.1. Forest plot for the effect of knowledge on teaching

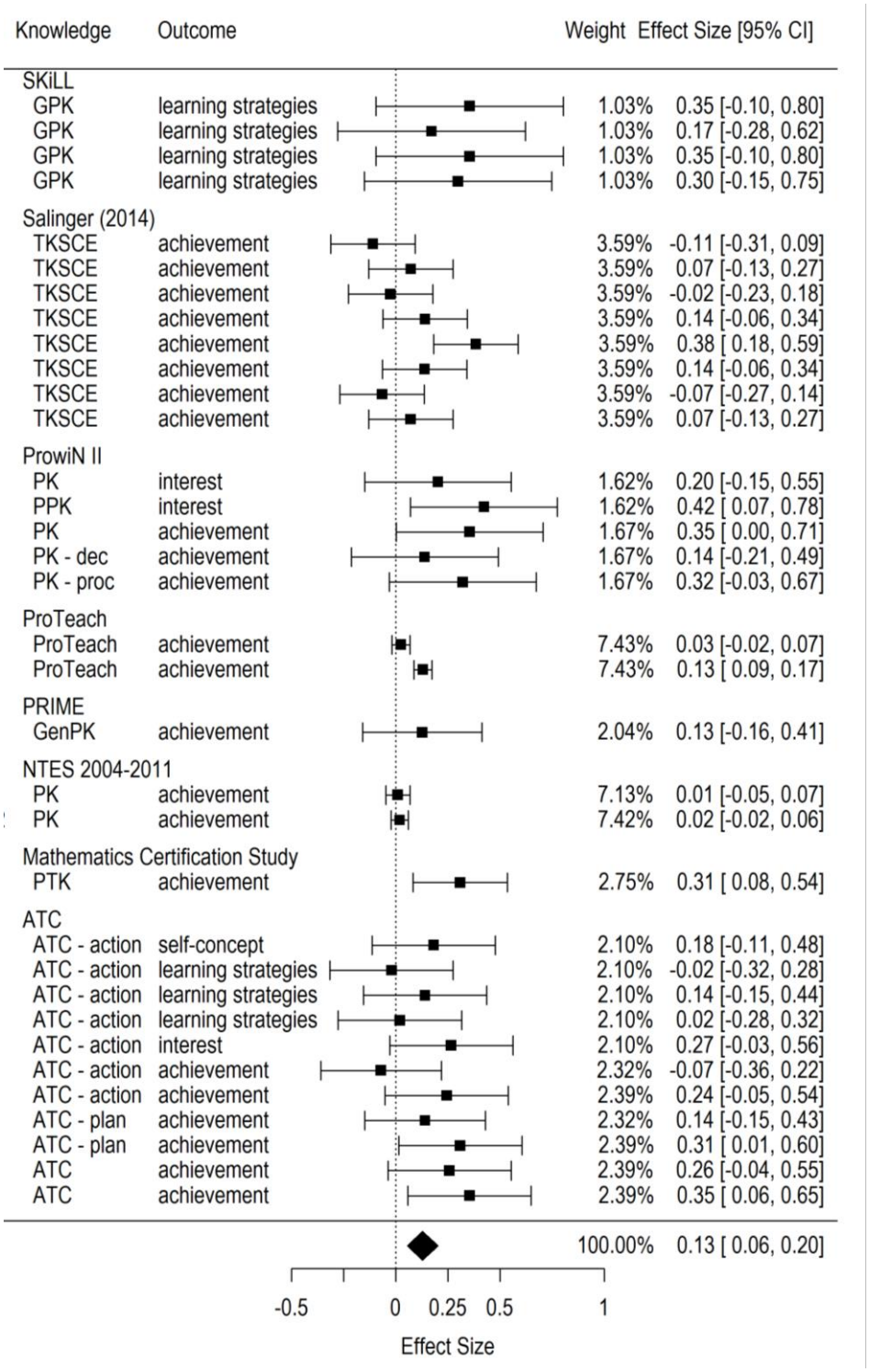
The synthesis of 109 effect sizes from 16 studies results in an overall effect of ES = .31 (p < 001).



Note: Forest plot for the relationship between teachers' general pedagogical knowledge and teaching. Each tick mark represents an individual effect size and the line its corresponding confidence interval. The diamond shape at the bottom shows the overall effect size and the dotted line marks a null effect.

Figure A G.2. Forest plot for the effect of knowledge on student outcomes

The synthesis of 34 effect sizes from 8 studies results in an overall effect of ES = .13 (p < 01).



Note: Forest plot for the relationship between teachers' general pedagogical knowledge and student outcomes. Each tick mark represents an individual effect size and the line its corresponding confidence interval. The diamond shape at the bottom shows the overall effect size and the dotted line marks a null effect.