SURVEY PAPER

Are teacher expertise and teacher competence complementary or contradictory research paradigms? Reflections on a possible integration and first conceptualizations

Gabriele Kaiser[1,2] · Johannes König[3] · Stefan Krauss[4] · Nils Buchholtz[1] · Hans Gruber[4]

Abstract

Research on teacher competence and teacher expertise has remained unintegrated in recent decades, despite the two paradigms having common roots—a focus on teachers' knowledge, its significance for successful teaching, and expectations of teacher professionalization. In this survey paper, we identify the differences and commonalities between the two paradigms based on long-term work in the fields and high-standard handbooks; and we explore the possibilities of integrating and developing them further to underpin evidence-based theory development for the teaching profession. First, we describe the development of the teacher competence paradigm, which has strongly influenced the discourse on the professionalization of teachers in general and mathematics teachers in particular. The first conceptualizations of teacher competence focused mainly on cognition, affect, and motivation. Further developments integrated a situated perspective on teacher competence including teachers' noticing as situation-specific skills to better align with teachers' actual performance. Thereafter, we unfold the different perspectives developed within the general expertise paradigm, followed by specific approaches focusing teachers. Finally, we reflect on the characteristics of the two paradigms, namely the focus on dispositions of the competence paradigm or on performance as outstanding pedagogic practices of the expertise paradigm and on ways how to integrate them. We close the paper with first ideas for a research program integrating both paradigms by proposing a heuristic of teacher expertise including a competence-oriented perspective.

Keywords Expertise research · Competence research · Paradigmatic approaches · Teachers' professional development · Teacher professionalism · Teacher knowledge · Superior performance · Expert teachers

✉ G. Kaiser
gabriele.kaiser@uni-hamburg.de

J. König
johannes.koenig@uni-koeln.de

S. Krauss
Stefan.Krauss@mathematik.uni-regensburg.de

N. Buchholtz
nils.buchholtz@uni-hamburg.de

H. Gruber
hans.gruber@ur.de

[1] University of Hamburg, Hamburg, Germany

[2] East China Normal University, Shanghai, China

[3] University of Cologne, Cologne, Germany

[4] University of Regensburg, Regensburg, Germany

1 Introduction

Since the late 1990s, a growing number of empirical studies have examined teacher education and the professional development of teachers, rapidly expanding the field. Its growth has largely been driven by persistent criticisms of the limited effectiveness of teacher education in equipping teachers with sufficient professionalization (König et al., 2025). The discourse on teacher professionalism has largely been influenced by two paradigms: the competence paradigm, which focuses mainly on teachers' dispositions (Baumert & Kunter, 2006), and the expertise paradigm, which focuses on teacher performance (Berliner, 2001). Both paradigms have developed separately over the last decades but share common roots and are more closely related to each other than to other prominent approaches to the study of the teaching profession and teacher professionalization, such as biographical (Terhart, 2011) or sociocultural approaches (Potari et al.,

2023). Each paradigm has its own strengths and weaknesses that could complement each other and help overcome certain limitations. From this perspective the question arises how far these approaches could benefit from integrated theoretical development and joint empirical studies. Such studies could support efforts to address criticism of the low effectiveness of teacher education and professional development. A possible dialectical integration of the two research paradigms provides a dialogical way to bridge differences between them. This approach promises to address the inadequacies of both paradigms, such as the blind spot concerning intraindividual development processes in competence research and the blind spot in addressing teaching and teachers' interindividual development in expertise research. This may lead to a metaparadigm based on a reflective, multi-paradigmatic perspective (Johnson, 2017).

In this survey paper based on long-term work in both paradigms by the author group and on high-standard handbooks, we aim to critically question the implicit assumptions underpinning both research paradigms and further develop the discourse on quality-oriented teacher professionalization. In the following sections, we describe and compare the two research paradigms. Thereafter, we offer reflections on a possible integration and first, preliminary ideas for a research program based on a heuristic of teacher expertise considering a competence-oriented perspective, with the aim of integrating the two research paradigms. We also discuss how such a heuristic can add value to mathematics education and teacher education in general, as well as mathematics teacher education specifically, showing how it may facilitate new ways of conducting research on the teaching profession. Although the elaborations are mainly generic, focusing teachers and the teaching profession in general, most empirical studies, which underpin the theoretical conceptualizations have been done in the field of mathematics education with mathematics teachers claiming some kind of generalizability. An analysis of the subject specificity of this discourse goes beyond the scope of this paper and needs further research.

2 Conceptualizations of teacher competence

Research on teacher competence has developed in the last 60–70 years, with a significant increase in methodological elaboration over the last two decades, including use of the term "teacher competencies", the precise meaning of which remains quite often unclear, but can be broadly thought of as a set of skills that a teacher is able to perform in actual classroom situations with considerable expertise, agility, or fluency. For example, McClelland (1973) stated, "If someone wants to know who will make a good teacher, they will have to get videotapes of classrooms [. . .] and find out how

the behaviors of good and poor teachers differ" (p. 8). However, Blömeke et al. (2015) claimed that the further developed international competence discourse has been characterized by the "dichotomy of a behavioral assessment in real-life situations versus an analytical assessment of dispositions underlying such behavior" (p. 5), strongly influenced by the origins of these different approaches. The first approach stemmed from organizational psychology and the selection of the best (or most competent) candidates for the job, whereas the second originated from educational research and was aimed at identifying ways to foster the development of competence. Essential to the second approach was the identification of the characteristics underpinning a person's behavior and how they could be developed. Based on the assumption that these characteristics could be fostered by interventions, the relationship between educational inputs and competence outcomes was foregrounded as a research topic.

2.1 Central conceptualizations of teachers' competence: the focus on teacher knowledge

The competence discourse—-especially fostered in German-speaking countries—-focused largely on the dispositional perspective but less on behavioral assessment. This discourse was shaped by two seminal theoretical approaches: Shulman's (1986, 1987) conceptualization of teacher knowledge and Weinert's (2001) definition of competence. Shulman (1986, 1987) claimed that effective teaching requires more than just knowing facts; it necessitates a deep understanding of the subject's structure and the ability to convey its essence to students. He introduced a foundational framework for understanding teacher knowledge in which he distinguished different categories of such knowledge, three of which were of specific importance: content knowledge (CK), general pedagogical knowledge (GPK), and pedagogical content knowledge (PCK), with the latter described as a special amalgam of content knowledge and pedagogical knowledge that is highly important for the professional understanding of teachers. While Shulman's work focused on categorizing types of teacher knowledge, this knowledge is considered a key component within broader models of professional competence. In competence-oriented frameworks, such as that of Weinert (2001), knowledge is not seen as synonymous with competence, but as one essential dimension among others, such as beliefs, motivation, and self-regulation, that together enable professional action. Weinert (2001) described the professional competence of teachers as the specific ability to cope with the professional demands of teaching including "intellectual abilities, content-specific knowledge, cognitive skills, domain-specific strategies, routines, and subroutines, motivational tendencies, volitional

Fig. 1 Modeling competence as a continuum (Blömeke et al., 2015, p. 7)
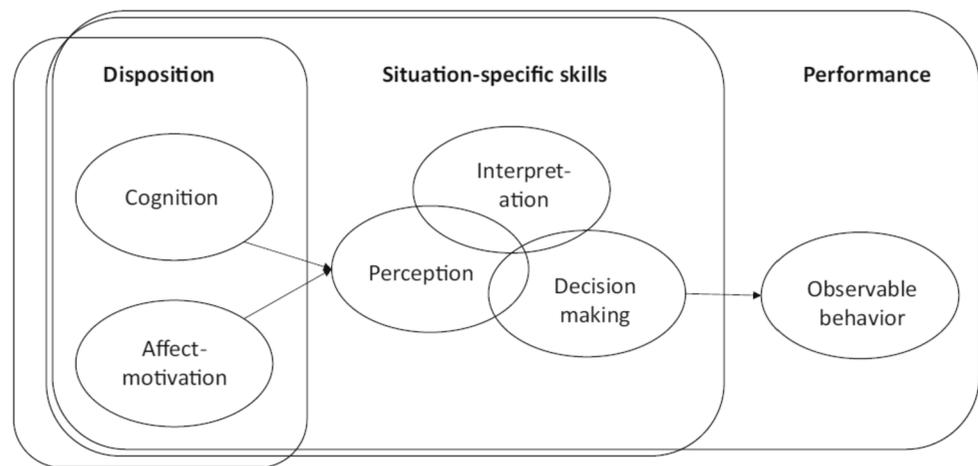
control systems, personal value orientation, and social behaviors". (p. 51). This approach was taken up specifically in the German-speaking discourse on teacher professionalism.

In the field of mathematics teacher competence research, these two seminal approaches have underpinned important large-scale studies on teacher education and teacher professional development in Germany—Professional Competence of Teachers, Cognitively Activating Instruction, and the Development of Students' Mathematical Literacy (COACTIV) project and the international comparative Teacher Education and Development Study in Mathematics (TEDS-M) study. In both large-scale studies conceptualizations of mathematics teachers' competence were developed.

Within the COACTIV project, Baumert and Kunter (2013) conceptualized competence as "the personal capacity to cope with specific situational demands" (p. 27) and distinguished between four aspects of competence (knowledge, beliefs, motivation, and self-regulation). Concerning mathematics education, these domains include a deep understanding of school mathematics (CK), together with PCK, defined amongst others as knowledge of students' mathematical thinking and knowledge of mathematical tasks. In the TEDS-M study besides mathematics content knowledge (MCK) and mathematics pedagogical content knowledge (MPCK), general pedagogical knowledge (GPK) was included as knowledge facets (Döhrmann et al., 2012).

Further central conceptualizations within the discourse on teacher professionalism focused on the construct of knowledge, the most important of which was the framework developed by the US Mathematics Teaching and Learning to Teach (MTLT) project based at the University of Michigan, which defined and distinguished between different knowledge facets that are functional for mathematics teaching (Ball et al., 2008). Although the previously described conceptualizations share commonalities, none cover the whole construct of teacher competence and its different components.

2.2 Competence as a continuum: the situated turn of the competence discourse

These cognitively oriented approaches within the competence paradigm have later been challenged by situated approaches calling for the inclusion of the social dimension of teaching, which incorporate a turn from a perspective on the education of individual future and practicing teachers towards emphasizing the social dimension in teacher education based on sociological and sociocultural theories (Kaiser et al., 2017). This turn included the emphasis on collaborative learning, teacher-inquiry groups, and communities of practice (Krainer & Llinares, 2010). However, there are two principally different views on the conceptualization of pedagogical content knowledge that can be distinguished, namely "whether mathematical knowledge in teaching is located 'in the head' of the individual teacher or is somehow a social asset, meaningful only in the context of its applications." (Rowland & Ruthven, 2011, p. 3). These differences in the kind of conceptualizations have consequences for the investigation and analysis of PCK, namely either component-wise, measurable outside of the classroom or holistically, based on classroom observations (Depaepe et al., 2013).

This situated turn within the competence discourse including a stronger focus on teachers' performance and classrooms, although knowledge has not become obsolete, led to the development of a theoretical framework to include situated perspectives and overcome the theoretical dichotomies of dispositions and performance by Blömeke et al. (2015). In this framework it is asserted that "competence ultimately refers to real-world performance, either as constituent of the construct or as a validity criterion" (p. 6; see Fig. 1). In this framework competence is "regarded as a process, a continuum with many steps in between. [...] More specifically, one interpretation is that competence is a continuous characteristic with higher and lower levels (more or less competent)" (p. 7). Considering the situated turn in the discourse,

the transformation of dispositions into performance within this model is mediated by so-called teachers' situation-specific skills, conceptualized "as a facet of teachers' cognitions" and not equal to observable teaching behavior (see Fig. 1). These skills are, additionally, "distinct from knowledge in that they represent cognitive processes prior to, during, or following real-life performance" (Blömeke & Kaiser, 2017, p. 790). Overall, the distinguished situation-specific skills (perception, interpretation, and decision-making) are important cognitive skills that, in the discourse on teachers and teacher education, have been conceptualized frequently as teacher professional noticing referring within this extensive discourse on a psychological-cognitive perspective (König et al., 2022; Sherin et al., 2011). These situation-specific skills have strong connections to Schön's (1983) notions of reflection in action and reflection on action, whereby, based on knowing in action, reflections lead to practitioners' reflective practices (known as the reflective practitioner approach).

Blömeke and Kaiser (2017) further developed the model of competence as a continuum, describing competencies as "personally, situationally, and socially determined" (p. 785) and generic attributes as influential factors that are integrated into dispositions and situation-specific skills, thus developing these constructs even stronger beyond a solely cognitive perspective.

The temporal dependence of the components of the Blömeke et al.'s (2015) model remains an open question, theoretically and empirically.

2.3 Further developments of the cognitive and situated perspectives on competence

Empirical research has challenged conceptualizations of teachers' professional competence, according to which teacher dispositions influence situation-specific skills and teaching behavior. For example, teaching practices as indicators of competence have been put in the foreground by work on Metsäpelto et al. (2021) who revised Blömeke et al.'s (2015) model and considered additional variables. In their model, bidirectionally connected individual competencies and teaching competencies influence students' learning, well-being, and engagement outcomes. Similarly, such a bidirectional relationship between teachers' dispositional factors and their situation-specific skills, was included in a further development of this model by Santagata and Yeh (2016) positing that "changes in competence would not be possible if teachers did not deliberately attend to and interpret practice and make decisions that create new knowledge and new beliefs" (p. 163).

Further studies within the TEDS Research Program (Kaiser, 2024) and the COACTIV Research Program (Krauss et al., 2020) share commonalities in their further

development of Blömeke et al.'s model, namely: their inclusion of teachers' instructional quality or instructional performance and their strong focus on activities in the classroom. In both approaches, the new conceptualizations included new additional mediators between the cognitive and situated elements of teachers' professional competence on the one hand and students' learning gains on the other have been introduced.

Another further development of the conceptualizations of the competence construct stems from science education—closely connected to mathematics education—is the refined consensus model (Carlson et al., 2019), which is based on Shulman's (1986, 1987) knowledge typology but additionally includes the construct of tacit knowledge (Polanyi, 1966), connecting it to its application in educational practice. In this model pedagogical content knowledge (PCK) is subdivided into different layers: collective PCK as publicly held codified knowledge, personal PCK acquired from collective knowledge, and enacted PCK described as the knowledge necessary to plan, teach, and reflect being implemented in teaching practice. Although this model is knowledge-oriented, like the previous approaches, it integrates teaching practice into conceptualizations of the different types of PCK. Tacit knowledge (described as experiential knowledge and impressions in episodic memory) is particularly important in this respect, since the enacted PCK partly reflects tacit knowledge in action generated flexibly at the moment of action as unarticulated knowledge (Alonzo et al., 2019).

2.4 Empirical results regarding the multidimensionality of the construct competence

The construct mathematics teachers' competence has been described theoretically as multidimensional and the question arises, whether this can be confirmed empirically. Based on their extensive literature reviews, Kaiser and König (2019) and Yang and Kaiser (2022) summarized the state-of-the-art research over the last two decades on pre- and in-service mathematics teachers' competence and professional development. According to their studies, empirical research confirmed the multidimensionality of mathematics teachers' professional competence, as described in Blömeke et al.'s (2015) model of competence as a continuum, and provided evidence that MCK, MPCK, and GPK can be theoretically and empirically separated (Blömeke et al., 2016; Krauss et al., 2008). The results of these studies confirmed the possibility of analytically examining teacher knowledge and evaluating the efficiency of teacher education and professional development programs. The COACTIV study showed that the MCK and MPCK of secondary mathematics teachers could be separated empirically, although both dimensions of knowledge correlated strongly (Baumert et al., 2010).

Fig. 2 Effect chain of teacher education (Kaiser & König, 2019, p. 602)
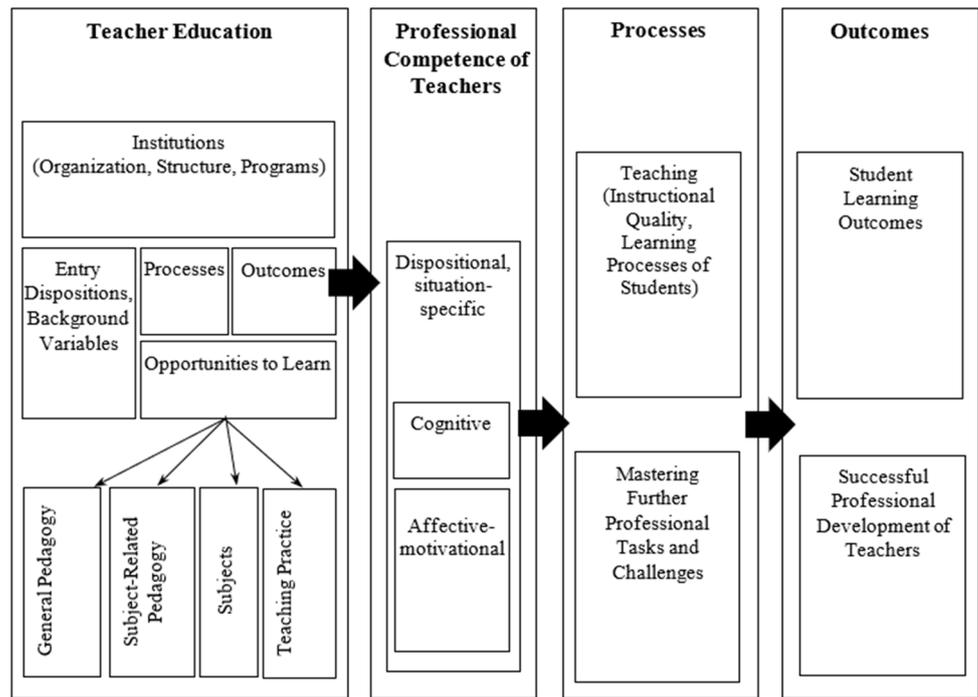
One key question addressed by the TEDS Research Program concerned changes—either increases or decreases—in teacher knowledge from the end of teacher education, through teachers' entrance into teaching, until four years thereafter. The aim was to examine whether early career teachers expanded their professional knowledge base through new learning opportunities and facing challenges as in-service teachers. A large increase was observed in their GPK (König et al., 2014), a statistically significant decrease in their MCK, but no significant change in their MPCK (Blömeke et al., 2014). Another important result concerning the relevance of practical experiences was identified: the ranking order concerning MCK of early career teachers did not change significantly, apart from a general decrease. In contrast, significant changes in the ranking order of early career teachers' MPCK and GPK were observed, indicating that pre-service teachers who performed poorly in MPCK and GPK at the end of their initial teacher education programs could still perform highly after four years of teaching practice and vice versa (Blömeke et al., 2014). These results highlight the relevance of teaching practice for structuring teachers' knowledge but also raise the question of how effective initial teacher education programs are for enhancing the quality of teachers' performance in classrooms.

2.5 The impact chain as a relationship between teacher education and teachers' performance

A central characteristic of the teacher competence paradigm is the focus on the direction of the professional competence of teachers on performance, conceptualized as teaching practice and instructional quality (Kaiser et al., 2017), and students' learning outcomes. The discourse on this issue largely concerns the opportunities to learn provided by teacher education and/or the professional development of teachers. Among others, Kaiser and König (2019) considered the direction and kind of influence of teacher education and proposed a so-called effect chain model (see Fig. 2), conceptualizing teachers' professional competence as a dependent variable for teacher education and an explanatory variable for processes and results in the teaching profession.

Based on their literature reviews, Kaiser and König (2019) and Yang and Kaiser (2022) summarized that the results of most current studies have aligned with the impact model of teacher professionalization, which connects opportunities to learn in teacher education or professional development activities with students' learning outcomes, including instructional quality and teaching practice as further mediators. For example, the results of the research programs of TEDS and COACTIV/COACTIV-R confirmed that MCK, MPCK, and GPK are relevant for pre-service teachers' learning during initial teacher education (Blömeke et al., 2010; Kleickmann & Anders, 2013). The results of analyses of pre-service teachers' learning at different stages of teacher education highlighted the positive influence of a higher number of opportunities to learn and practical activities during teacher education practicums on their professional knowledge (König et al., 2017). Although there is no doubt that the findings of large-scale assessments using surveys and longitudinal data have expanded our understanding

of teacher learning and professionalization as part of their competence development, it is important to emphasize that none of these studies confirmed deterministic or causal relationships between teacher education, teacher competence, and teaching. Instead, correlational studies in empirical educational research relied on probabilistic assumptions, and large-scale survey designs could not establish causal inference (König et al., 2025).

Despite the empirical evidence described above, the underlying assumptions of these impact or effect chain models have been criticized among others by Neuweg (2001, 2014) for assuming a direct linear application of the theoretical knowledge acquired in teacher education to professional teaching practices underestimating the complexity of pedagogical actions and the situated nature of professional expertise. This critique calls for a stronger integration of school practice into university education and has been taken up in various initiatives concerning teacher education and teacher professional development activities. It is therefore important to account for the increasing number of intervention studies examining teacher competence as it is supported through teacher education and professional development activities leading to favorable outcomes, in particular concerning instructional quality. A recently conducted synthesis applying meta-meta-analysis strategy referring to hundreds of empirical intervention studies provides strong evidence for the relevance of teacher competence, in particular teacher knowledge, for the quality of teaching students (König et al., 2025). In the light of these results it seems to be timely to reflect on further improvements of teacher education and professional development activities going beyond the competence paradigm and consider to include the construct of teacher expertise and its development as a new perspective for teacher professionalization and professional development.

3 Conceptualizations and definitions of teachers' expertise

3.1 Perspectives on expertise

In this chapter, we provide an overview of the discourse of teachers' expertise to explain the underlying theoretical assumptions of the expertise paradigm, which need to be understood to compare the expertise and competence paradigms. Since the discourse seems to be quite diverse, with hardly any consensus on how to conceptualize and define expertise in general or teacher expertise specifically, we distinguish various perspectives within the expertise discourse characterized by different theoretical frameworks and theoretical constructs based on own experience in the field and two recent, often quoted handbooks of expertise (Ericsson et al., 2018; Ward et al., 2020).

The concept of expertise has evolved considerably since its initial scientific formulations in the 1970s and 1980s; in recent decades, the discourse on expertise has moved beyond static, trait-based models to dynamic, developmental, and context-sensitive conceptualizations (Ericsson, 2018). Contemporary theoretical approaches are based on a multidimensional conceptualization of expertise and provide insights into how it is acquired, enacted, and refined.,

The perspective on expertise with a focus on individual differences in mental capacities has a long history. According to Ericsson (2018) the first empirical studies conducted in the nineteenth century foregrounded individual differences in general mental capacities. These differences have not been confirmed by recent studies because expertise is often domain-specific. Furthermore, differences between experts and less proficient individuals frequently reflect only the attributes acquired by experts during lengthy training. Recent studies have challenged the widely held perspective that 10,000 hours of deliberate practice are sufficient to achieve the required expertise (Ward et al., 2020).

A more methodologically oriented perspective that strongly influenced the historical discourse has been rooted in introspection and used "verbal report" approaches or think-aloud procedures based on the statements of outstanding people or highly accepted experts about their work. For example, in the seminal work by de Groot (1978/1965), international chess experts had been invited to describe their thinking while selecting the best moves for chess positions. This approach has been further developed by Ericsson and Simon (1980) on verbal reports as data, in which they claim that verbal reports are the main basis for studies with experts as these methods have the potential to evaluate the intraindividual development of knowledge structures.

Methodologically connected with these approaches is the theoretical perspective on expertise as elite achievement resulting from superior learning environment described by Ericsson (2018). This theoretical perspective foregrounds analyses of biographical data drawn from Nobel Prize winners and interviews with high performers in different domains.

Perhaps as the most important theoretical perspective on expertise can be seen a knowledge and representation oriented approach, sometimes called the classic expertise approach (Ward et al., 2020), which aligns well with the former perspective on expertise as skill acquisition via experience. This theoretical perspective has been grounded in cognitive psychology and artificial intelligence with the aim of uncovering the mental representations and problem-solving strategies that distinguish experts from novices. Foundational studies conducted in highly structured domains, such as chess, physics, or problem-solving, showed that experts are characterized by their organization of knowledge around deep structural principles (rather than surface features), efficient retrieval structures, and the storage of chunks of information in long-term memory (Gobet & Simon, 1996). In

particular, the concept of chunking, used as a mechanism by chess experts to circumvent the limits of short-term memory by grouping individual units of information into structured pieces of information and patterns, shaped the discourse (Chase & Simon, 1973). Overall, a consensus has been reached that expertise should be defined as the ability to consistently perform at a high level in a specific domain, relying on well-organized, domain-specific knowledge, efficient processing, and pattern recognition (Chi et al., 1981; Ericsson et al., 1993).

However, there has been a long-standing controversy as to whether highly experienced experts are capable of articulating their knowledge and methods of generating actions. Polanyi (1966) was among the first scholars to emphasize in his work the tacit dimension of knowing and the importance of the unconscious, intuitive, mediated parts of experts' actions. Polanyi (1966) argued that "we can know more than we can tell" (p. 4) and that tacit knowing is a foundational resource for a wide range of complex skills, from tool use to the application of the scientific method. Building on the idea of tacit knowing, Dreyfus and Dreyfus (1986) extended their model of the development of expertise based on traditional phase-based theories and incorporated five stages of skill acquisition: novice, advanced beginner, competent practitioner, proficient professional, and finally, expert. Novices were expected to progress from context-free, verbal- and rule-based behavior to experts who recognized important and relevant aspects of the situation and knew intuitively how to respond. Connected to Dreyfus and Dreyfus's (1986) model and Polanyi's (1966) tacit knowing is Schön's (1983) approach of the reflective practitioner, which emphasizes the role of tacit knowledge and reflection-in-action. According to this approach, expertise involves not only technical proficiency but also interpretive, context-sensitive thinking in the face of uncertainty and complexity. Somewhat akin to the Dreyfus-ian perspective is the situated nature of human knowledge perspective, in which it is claimed that humans are socially embedded and that knowledge and understanding are both societally determined and socially constructed (Collins, 2010). Acquisition of expertise takes place in this perspective by participation in relevant social practices that enable experiences.

Departing from the high importance of knowledge in the expertise paradigm as it distinguishes experts from laypersons (Kinchin & Cabot, 2010) knowledge restructuring as perspective has been proposed by several scholars. Knowledge restructuring through case processing (KR-CP) has been developed by Boshuizen et al. (2020) and is an influential domain-general perspective on expertise development based on the principle that knowledge restructuring occurs through intensive case processing. This perspective holds that expertise evolves as individuals encounter and mentally process authentic, complex cases, and these repeated engagements challenge and reorganize existing cognitive structures, facilitating deeper understanding and adaptability. Two mechanisms of change have been distinguished: script formation conceptualized as integrated schemas linking situational cues, underlying principles, and probable actions and knowledge encapsulation conceptualized as condensing detailed procedural knowledge into higher-level representations. The development of macro-concepts is important, which show a move toward more abstract and integrative concepts embedded in denser, more theoretically oriented knowledge structures. Overall, deliberate and varied case exposure, reflection, and case comparison in authentic cases foster the development of expertise. Further proposals of promoting expertise development are based amongst others on experience-based knowledge restructuring through simulation, in which repetitive practice opportunities are completed by adaptive and tailored instructional support by trainers covering preparation, briefing, and debriefing phases, which finally lead to an intraindividual knowledge restructuring going beyond pure automatization of processes (Jossberger et al., 2022). Another stance concerning knowledge restructuring as a way to develop expertise is taken by Kinchin and Cabot (2010) in their dual-processing knowledge approach, in which they distinguish between chains and nets as knowledge structures. Knowledge chains refer to linear teaching sequences and facilitate rote learning. To support the development of expertise these knowledge chains need to be complemented by knowledge nets as a more complex form of knowledge, which have to be connected to chains of practice. Overall, expertise development is seen as dual processing of the two formats, nets and chains, which emphasizes that expertise is strongly connected to the availability of multiple representations of knowledge.

The deliberate practice perspective developed by Ericsson et al. (1993) is based on the idea that expertise primarily results from sustained, goal-directed, and effortful practice over extended periods. Deliberate practice has been distinguished from mere experience by its reliance on immediate feedback, opportunities for error correction, and focused repetition aimed at specific performance improvements. This perspective highlights the role of adaptive skill refinement over time rather than innate talent. The deliberate practice perspective has permeated the expertise literature in the last three decades and has been used in diverse fields, such as soccer and clinical psychology.

Strongly connected to the deliberate practice perspective is the perspective of defining of expertise as superior performance on representative tasks, which has been proposed and developed by Ericsson et al. (1993) over the last three decades. Considering the limitations of a single or small number of unique groundbreaking studies, Ericsson et al.

(1993) proposed studying expertise with laboratory rigor using representative tasks to capture the essence of expert performance in the relevant domain. Since it is possible to reproduce the reliably superior performance of experts in a controlled setting, the mediating mechanism should be examined by employing experiments and process-tracing techniques, such as think-aloud procedures and verbal reports. The use of representative tasks to measure expert performance under standardized conditions permits the performance of less skilled individuals to be compared with that of expert performers. Experience has been shown to be important for the development of expertise, since "longitudinal studies … have shown that, even for the most talented individuals, a minimum of ten years of experience in a well-established domain (ten-year rule) seems to be necessary but not sufficient to become an expert" (Ericsson, 2018, p. 751). However, there are differences between the domains, and the number of years of working experience in a domain as the only predictor of attained performance is not reliable (Ericsson & Lehmann, 1996). Currently, this definition of expertise as reliably superior performance on representative tasks is probably the most widely cited definition of expertise.

As already mentioned, the expert performance perspective has mainly been applied to structured domains, such as chess, but rarely to less structured domains, such as teaching and learning, amongst others due to the fact that it is difficult for nonexperts to identify experts. A common approach has been to use experts nominated by peer professionals in the same domain, which has proven to be problematic because research has shown that people recognized by their peers as experts do not always display superior performance on domain-related tasks, even on tasks that are central to expertise (Ericsson, 2018). However, approaches based on this perspective have many advantages because they can be used in controlled settings, such as laboratories, permitting the study of the mechanisms that contribute to expert performance. In addition, using representative tasks to measure expert performance under standardized conditions in controlled settings allows the performance of differently skilled people on the same tasks to be measured and compared, revealing the processes that contribute to expertise. Knowledge about these processes is extremely important since empirical studies have shown that individuals starting as beginners or active professionals can increase their performance to an acceptable level; however, improvements beyond this point are difficult to predict and need specific support based on particular kinds of training tasks designed individually, leading to the necessity of deliberate practice.

3.2 Expertise of teachers

Due to the close connection of the discourse between teacher competence and teacher expertise and joint quantitative orientations compared to sociological and social science orientations in both research paradigms, we focus in the following sections on the currently most influential approach to expertise, defined from a performance-oriented perspective by Ericsson (2018, p. 4). According to this definition, "expert performance is characterized by superior reproducible performance on representative tasks that capture the essence of the respective domains." Ericsson (2018, p. 3) also described expertise as "characteristics, skills, and knowledge that distinguish experts from novices and less experienced people." The knowledge that experts develop in their domains of expertise is, according to Ericsson (2018), a particularly important difference between experts and others, emphasizing the strong connection to the discourse on teacher competence paradigm.

However, in education the conceptualization and measurement of expertise as superior reproducible performance on representative tasks are specifically difficult, due to a lack of public, fair competitions in Western cultures and the domain-dependence of expertise.

Against the background of these studies, Stigler and Miller (2018) proposed new theoretical approaches to evaluating the role of expertise in teaching. They pointed out that teaching is not an isolated activity but a complex system of interacting elements. Moreover, teaching is both a socially shaped activity and a cultural activity, meaning that expertise in teaching probably varies across different parts of the world. Under these conditions, they developed a model for expert teachers in which:

> Expert teachers are not defined as those who employ a set of best practices, but instead those who (1) have the ability to assess students' current knowledge state both prior to and during instruction, (2) formulate clear learning goals, (3) consider a large number of strategies and routines in their repertoire, (4) make good judgments about which strategies are most appropriate in any given situation, and (5) are able to implement the strategies effectively to create learning opportunities for students. (p. 440)

They concluded:

> Although the aim of improving teaching routines is to enable an average teacher to produce the desired outcomes, the nature of teaching will always necessitate a certain level of adaptive expertise on the part of the teacher. Teachers must have knowledge (knowing that), they must have skill (knowing how), and they must have judgment – the ability to size up a situation, see its structure the way an expert physicist sees the structure of a physics problem, and then bring the right knowledge to bear so as to achieve the instructional goals. (p. 448).

Based on these descriptions, Stigler and Miller (2018) proposed three criteria for the identification of expert teachers: 1) experience as a proxy for expertise in comparing beginning and experienced teachers, 2) studying teachers who have been identified as experts through a process of nomination or certification, and 3) identifying expert teachers based on student outcomes (the so-called value-added approach).

Another approach to teaching expertise based on research on expert performance was developed at the beginning of the discourse on teacher expertise by Sternberg and Horvath (1995), who proposed conceptualizing teaching expertise using a prototype approach rather than a definitional one. This means that:

> Teaching expertise can be viewed as a category that is structured by the similarity of expert teachers to one another rather than by a set of necessary and sufficient features. [. . .] Most importantly, a prototype view provides a way of thinking about expertise that incorporates standards (such that not every experienced practitioner is an expert) but also allows for variability in the profiles of individual experts. (p. 9)

Based on a literature review of expert performance, they identified three central dimensions in which experts differ from novices:

> The first difference pertains to domain knowledge. Experts bring knowledge to bear more effectively on problems within their domains of expertise than do novices. The second difference pertains to efficiency of problem solving. Experts do more in less time (in their domain of expertise) than do novices. The third difference pertains to insight. Experts are more likely to arrive at novel and appropriate solutions to problems [. . .] than are novices. (p. 10)

In a further development of this work, Berliner (2001), based on an empirical study conducted by Bond et al. (2000), described several features of teacher expertise as expert classroom performance consisting of a number of prototypic characteristics, including better usage of knowledge, extensive PCK, better problem-solving strategies, better adaptation and modification of goals for diverse learners, better decision-making processes, more challenging objectives, better classroom climate, better perception of classroom events, better ability to read the cues from students, greater sensitivity to context, better monitoring of learning, providing feedback to students, and greater respect for students. Examining the criteria for students' outcomes, the empirical studies reported by Berliner (2001) showed a clear relationship between teacher expertise and students' outcomes in terms of higher motivation, deeper understanding of the subject matter, and higher levels of achievement.

Especially important in German-speaking countries and other parts of Europe has been Bromme's (1992) study, which was closely connected to the work by Berliner. His conceptualization of teacher expertise as situated, adaptive, and cognitively complex has greatly shaped teacher education research in Germany, Austria, and Switzerland and conceptualizations of knowledge developed within the competence discourse. The aim of Bromme's (1992) empirically grounded reconstruction of teaching demands was to uncover the cognitive and contextual complexities of teaching by analyzing how expert teachers operate in real classrooms, thereby building a research-based understanding of teacher expertise connected to the expertise paradigm based on expert performance as superior reproducible performance on representative tasks. Bromme's (1992) study has currently been taken up by the German-speaking discourse on the professionalization of mathematics teachers especially concerning the relevance of task analysis to professionalization processes (Shure et al., 2025), which may contribute to the identification of representative tasks from the teaching profession that are important for formulating a performance-oriented definition of expertise.

Departing from the generally stated fact that no clear conception of an expert teacher currently exists, Anderson and Taner (2023) conducted a metasummary of teacher expertise based on the construct of the expert teacher prototype described by Sternberg and Horvath (1995) and Li et al. (2011). They used two selection criteria for participants to qualify as experts for their metasummary: sufficient experience (five years or more) and appropriate markers, such as social recognition and performance criteria. Overall, the most important aspects of a prototype of teachers' expertise were as follows: knowledge base, cognitive processes, beliefs, personal attributes, professionalism, and (most importantly) pedagogic practice.

Overall, Anderson and Taner (2023, pp. 9–11) identified several key features of expert teacher cognition. Central among these was PCK, as conceptualized by Shulman (1987), which integrates deep subject knowledge with instructional expertise. Expert teachers also demonstrate a nuanced understanding of learners—both in general development terms and at the individual level—as well as a strong familiarity with curricular demands. These characteristics contribute to the context-specific nature of teacher expertise. Concerning cognitive aspects, the analyzed studies highlighted expert teachers' heightened classroom awareness, including the ability to monitor students' behavior and progress in real time. Their conceptualizations of professional beliefs emphasized interpersonal relationships, valuing student engagement, individualization, and the creation of respectful and inclusive classroom climates. Expertise was also reflected in pedagogical practices, with 39 out of 89 themes in Anderson and Taner's (2023) dataset relating to instruction. Expert teachers are typically strategic but flexible planners who are responsive to learners' needs

Table 1 Comparison of the central characteristics of competence research and expertise research

Central characteristics of teacher competence research	Central characteristics of teacher expertise research
Central construct (competence): an analytical definition consisting of knowledge components and affective-motivational characteristics, extended to situation-specific skills and proficiency as teachers' long-term successful, professional practice based on practical experience	*Central construct (expertise):* a holistic definition of reliably superior performance on professionally representative tasks involving domain-specific long-term practical experience and deliberate practice
Conceptualization of dispositions and knowledge: relatively stable structures, conceptualized as generalizable knowledge acquired through formal learning processes, such as university education and professional development	*Conceptualization of dispositions and knowledge:* dynamic cognitive knowledge structures based on continuous individual, situated case-based knowledge restructuring and the encapsulation of knowledge
Focus: identification of central interindividual teachers' characteristics and their development in large teacher populations with the goal of analyzing the efficiency of educational structures	*Focus*: identification of central intraindividual changes in teachers' characteristics with the goal of comparing experts and novices and explaining and supporting the development of superior teaching performance

and curriculum goals, often adapting or supplementing standard materials. Despite their structured planning, they exhibit adaptive expertise, improvising when needed during lessons. In terms of classroom dynamics, expert teachers foster collaborative learning through group and pair work while balancing such learning with direct instruction and independent tasks. Their teaching aligns with constructivist principles, linking new content to students' prior knowledge, incorporating peer feedback, and promoting inductive, discovery-based learning. They also supported cognitive and metacognitive development, prioritizing higher-order thinking, creativity, and meaningful understanding over rote memorization.

To summarize, research on teacher expertise has developed in the past extensive prototypical characterizations without linking this to work of the competence paradigm, although many indicators for expertise have been examined in competence-oriented empirical studies. In the following chapter we explore the possibilities of integrating them to underpin evidence-based theory development for the teaching profession.

4 Connections between expertise and competence research paradigms

### 4.1 Comparison of the two research paradigms

Through its connections with large-scale studies, the competence paradigm has shaped the theoretical discourse on teachers' (especially mathematics teachers') professionalism and the related professionalization processes. Thus, the focus has differed from that of the detailed analyses of expertise and the kinds of knowledge distinguished as typical of the expertise paradigm. As a result, both approaches have developed in parallel over the last 20 years, partly resulting

in contradictions among implicit basic assumptions and conceptualizations (see Table 1). Thus, despite mutual efforts to establish common ground, especially by Krauss (2020), who presented the expertise paradigm as a key theoretical and empirical approach for understanding and advancing teacher professional development, both paradigms currently view teachers' professionalism and the relevant professionalization processes from different perspectives. Undoubtedly, it is timely to identify commonalities and contrasts between these paradigms to unlock the hitherto unrealized potential of integrating them.

Although Berliner's (1988, 2001) work has substantially influenced the discourse on teachers' professionalization his studies have received less attention in the theoretical conceptualizations and the accompanying empirical studies in the competence paradigm. The conceptualizations developed within the competence paradigm have implicitly been based on assumptions regarding the structural stability of dispositions, defined as knowledge and affective-motivational components, the acquisition of learnable skills, and their didactical acquisition. Researchers have focused on interindividual developments and their differences among (prospective) teachers, mainly for mathematics education. Thus, different models of teacher competence have been empirically supported by psychometric testing and complex research designs—especially within the framework of large-scale studies.

In expertise research approaches, such as those focusing on reliably superior domain-specific performance based on representative professional tasks (Ericsson, 2018), the development of expertise as a permanent restructuring of knowledge conceptualized as case-based knowledge (Boshuizen et al., 2020), and the focus on intraindividual changes in professional practice (Ericsson et al., 2018), have been developed quite independently of competence research, mainly focusing on observations of individuals in qualitative studies. Most studies have been conducted in structured do-

Fig. 3 Comparison of research from the competence and expertise paradigms (model adapted from Yang & Kaiser, 2022 and Kaiser & König, 2019). The arrows indicate bidirectional interdependence
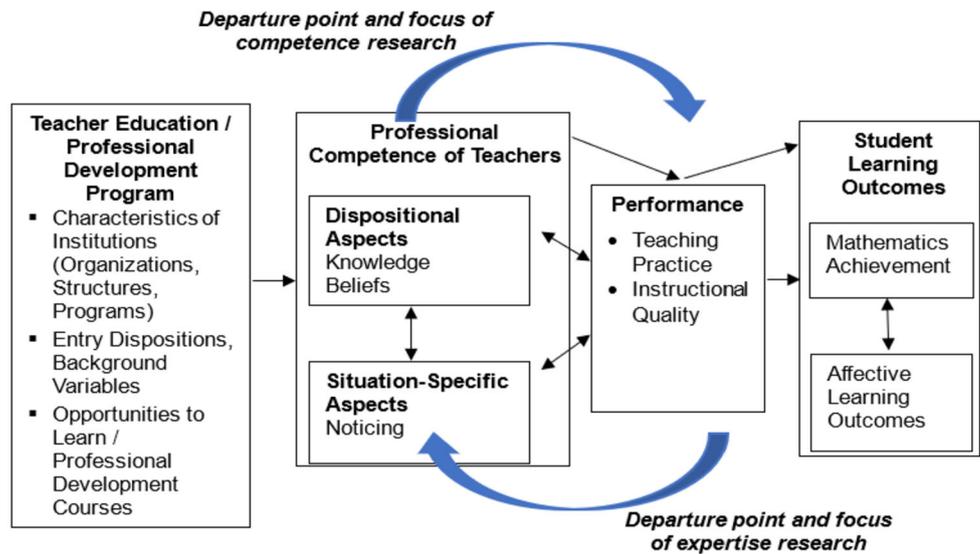
mains, such as chess or music, where superior performance can often be identified without prompting controversy. Much rarer are expertise studies in less structured domains. Regarding the teaching domain, studies have considered prototypical descriptions of expertise based on categorical descriptions of knowledge, attitudes/beliefs, and pedagogical practices as described above (Anderson & Taner, 2023; Berliner, 2001; Sternberg & Horvath, 1995). Thus, integrating the expertise paradigm with the competence paradigm is challenging due to a gap in determining the indicators of expertise (Ericsson, 2018) and, thus, in identifying teachers' superior performance and expertise in educational processes (Stigler & Miller, 2018).

Table 1 contrasts the central characteristics of both paradigms specialized for teacher competence and teacher expertise in terms of basic underlying assumptions about the nature of their central constructs, supporting an understanding of why both approaches developed separately from each other. This comparison may serve as a starting point for reflections how to integrate the two paradigms.

As the first approach to overcoming the dichotomy between the dispositions and performance of teachers in the classroom, the generic model of competence as a continuum proposed by Blömeke et al. (2015) embedded in a situated turn within the competence research paradigm takes a process-oriented view of competence. In empirical studies referring to this and further developments of the model, the performance of teachers is explicitly included conceptualized as teaching quality and students' learning gains.

Due to the strong situation-specific nature of expertise, definitional approaches to describing expertise have found little acceptance with regard to the expertise paradigm for teachers as described above; in contrast, prototypical approaches to teachers' expertise are again being advocated.

Although prototypical descriptions of expertise have many similarities with the findings of research on teachers' professional competence (e.g., the importance of work-related knowledge), many differences are also apparent. For example, intraindividual developments in expertise have received little attention from scholars due to the focus of approaches from the competence paradigm on large teacher populations and psychometric constructs. Similarly, the strong domain specificity of expertise, its marked individual orientation and situational dependence, and its temporal development have posed theoretical and empirical barriers to its conceptualization and empirical evaluation (Mulder & Gruber, 2011). Another hurdle to integrating findings from the expertise and competence paradigms into teachers' development is the problem of distinguishing experts from novices, for which the different existing measures—such as the length of professional experience, students' achievements, and/or external assessments or observations of expert teachers' behaviors—all have distinct problems, particularly at the normative level (Hoffman, 2023; Palmer et al., 2005; Stigler & Miller, 2018).

In summary, research on the so-called chain of effects from teachers' competencies to their performance in the classroom has followed two analytical directions: analyses based on the competence paradigm, tracing teachers' performance in the classroom from their dispositions (from left to right in Fig. 3), and analyses based on the expertise paradigm, which starts from teachers' performance in the classroom and focuses the underpinning conditional structures (i.e., dispositions are considered flexible and unstable; from right to left in Fig. 3).

To advance the discourse on the teaching profession by bringing together, the competence and expertise paradigms, the restrictions of both must be overcome. The competence paradigm has to overcome, at least partly, its assumption of

relatively stable dispositions and its neglect of the evaluation of intraindividual competence/expertise development. Regarding the expertise paradigm, it is necessary in particular to move from research in strongly structured domains to research in the less structured domain of teaching. In addition, the construct of representative tasks needs to be detailed for the teaching profession as a strongly context-dependent and situated holistic activity. However, the aim is not an amalgamation of the two paradigms, rather the specific strengths of the two paradigms are to be retained, and new strengths are to be added by stimuli from the respective other paradigm.

4.2 Proposal of a heuristic of expertise from a competence-oriented perspective

Our analysis of state-of-the-art research showed that there are barriers to integrating the two paradigms but also considerable promise in doing so. When joined, the paradigms have the potential to enrich attempts to support the effective development of teachers and their professionalization. To overcome these barriers, we suggest differentiating the simplifying assumptions of both approaches and identifying a common foundation. To further this development, we suggest the following heuristic of expertise including a competence-oriented perspective as a first attempt (see Fig. 4). Aligned with this heuristic are the following basic assumptions and considerations, which are taking up central characteristics of both paradigms and integrate them into our heuristic:

(1) Change and development. The new multidimensional conceptualization considers the development of abilities and skills over time, which is important, in particular, for the expertise paradigm, with its focus on contrasts and comparisons of experts and novices. In the professional competence paradigm, the (relative) stability of competence structures is assumed for evaluative reasons, but at the same time, the acquisition of competencies and their further development in teacher education and professional development are emphasized (Blömeke, 2025). Our new multidimensional conceptualization of expertise including a competence-oriented perspective covers temporal development of competence as a central component for developing expertise.

(2) Focus on knowledge and its restructuring. The heuristic draws on the relevance of professional knowledge of teachers, which plays a central role in both the competence paradigm (Blömeke et al., 2015) and the expertise paradigm because it distinguishes experts from laypersons (Kinchin & Cabot, 2010). However, to develop expertise, it is not enough for *knowledge to be accumulated*; *knowledge restructuring* processes must also take place. This is stressed in dual processing approaches, which hold that knowledge is processed either linearly in chains or connected in knowledge nets (Kinchin & Cabot, 2010), and in the case process-
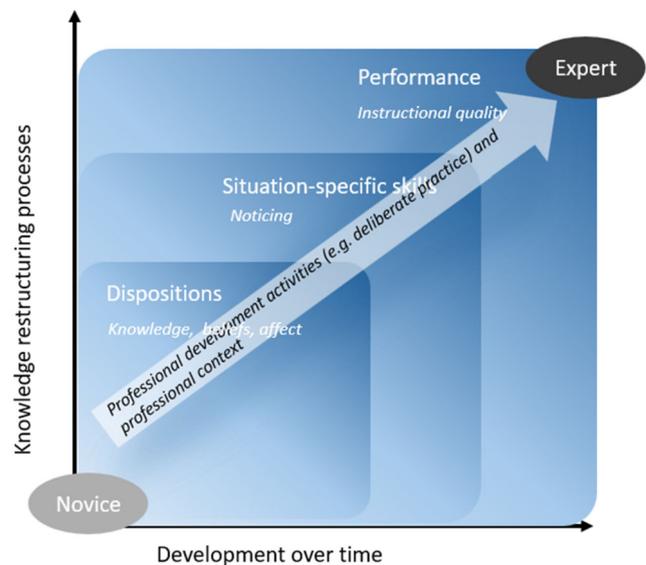

Fig. 4 Heuristic of expertise including a competence-oriented perspective

ing approach, where script formation and knowledge encapsulation or the development of macro-concepts as more abstracted and integrative concepts are used to bridge generic and domain-specific approaches and generalize expertise development across domains (Boshuizen et al., 2020). In addition, experience-based simulation activities supported by tailored and adaptive support can foster intraindividual knowledge restructuring (Jossberger et al., 2022).

(3) Principle of parsimony. Following the parsimony principle (Occam's razor), the heuristic focuses on a selection of constructs that play key roles in both paradigms. For example, in the model of competence as a continuum (Blömeke et al., 2015), which includes dispositions and situation-specific skills, the latter act as mediators from dispositions to performance, and our heuristic is based on these central constructs. Considering dispositions and situation-specific skills, *teacher expertise* is thus defined as an *individual* teacher's *reliably superior performance* on tasks representative of the teaching profession, such as planning, teaching, diagnosing and reflecting on their professional practice (Carlson et al., 2019; Ericsson, 2018), including the ability to promote students' learning. Finally, we propose *expertise development* as a central construct conceptualized as knowledge restructuring over time.

(4) Usage of Pentapod principle for identifying expert teachers. The identification of expert teachers—which is not a common issue in the competence paradigm so far—should be based on the criteria developed in the discourse (Blömeke et al., 2022; Palmer et al., 2005; Stigler & Miller, 2018): length of professional experience, high instructional quality implemented by the teacher, high social recognition or specific roles in teacher education or professional development institutions, high students' learning gains. To overcome the

equivocal results concerning the length of professional experience needed to achieve expertise (Berliner, 1988), two criteria should be used in succession—a selection criterion and a confirmation criterion—in line with the Pentapod principle, according to which at least two ideally three of the five distinct methods for the identification of experts should be used (Hoffman, 2023).

In detail (see Fig. 4), the development of expertise from novice to expert, including a competence-oriented perspective, should consider dispositions (knowledge and affective aspects) and situation-specific skills, conceptualized as noticing (Kaiser et al., 2017; König et al., 2022), which influence teachers' performance (i.e., the implemented instructional quality). Expertise development is driven by professional development activities, especially deliberate practice, which has proven effective in promoting expertise in many studies (Ericsson & Harwell, 2019) and the professional context, including classroom activities. Cognitively oriented knowledge restructuring processes can occur either linearly in chains or connected in knowledge nets (Kinchin & Cabot, 2010) or be case-based, using scripts or macro-concepts (Boshuizen et al., 2020) supported by experience-based simulations (Jossberger et al., 2022).

Although this heuristic is strongly influenced by the expertise paradigm, elements of the teacher competence paradigm are also important. Especially based on the competence as continuum model, dispositions are highly relevant, covering various kinds of knowledge, such as PCK (Krauss et al., 2020), and beliefs should be considered as affective disposition that underpins teacher competence (Voss et al., 2011). Furthermore, situation-specific skills, including diagnostic competence as a specific sub-competence, and specifically teachers' ways of dealing with student errors, may be highly relevant to the further development of the heuristic (Hoth et al., 2022; Larrain & Kaiser, 2022). The conceptualization of superior teacher performance at the expert level is based on the prototypical description of expert teachers (Anderson & Taner, 2023). Since teacher performance is strongly connected with instructional quality, which has been conceptualized and measured in both the COACTIV and TEDS research programs covering generic and subject-specific dimensions (Jentsch et al., 2021; Krauss et al., 2020; Schlesinger et al., 2018), instructional quality can serve as an indicator of superior teacher performance from a competence-oriented perspective.

4.3 First ideas for conceptualizations integrating competence and expertise

Our arguments contributing to the theoretical underpinning of the heuristic of expertise including a competence-oriented perspective have various implications for teaching in general and mathematics teaching specifically, teacher education,

and the professionalization of (mathematics) teachers. The connectedness of knowledge, skills, and performance is the common ground between the two paradigms. This is where the shared understandings of both paradigms are concentrated, and there is common ground regarding the profile of a professional teacher being an expert as well as being competent. Therefore, a major implication of this joint research program is the need for future research to link teacher knowledge, noticing as situation-specific skills, and performance to each other—both theoretically and empirically. This has been highlighted as a research desideratum based on a literature review (Scheerens & Blömeke, 2016) claiming that research on teacher dispositions and knowledge facets has not been sufficiently related to research on instructional practice and quality, thus clearly showing the need for bringing together specific research paradigms.

One challenge of this research program will be that conceptualizing, modeling, and measuring knowledge, noticing as situation-specific skills, and performance in all their complexities is highly ambitious. Blömeke et al. (2022) were only recently able to address this challenging issue in the context of mathematics teachers and teaching mathematics, thus providing a possible approach to "open up the black box" of the impact chain comprising teacher competence, instructional quality, and student learning progress in mathematics. Blömeke et al.'s outstanding (2022) analysis exemplifies what empirical educational research is capable of achieving (including sampling, measuring, and other psychometric issues), and may be used as a basis for future research designs to facilitate findings with high relevance for basic research related to our heuristic, with implications for teaching and teacher professionalization.

As a long-term perspective, evidence of the relationships and interdependence among knowledge, noticing as situation-specific skills, and performance, as described in our heuristic, has the potential to support activities to establish and clarify substantial goals for initial teacher education and teacher professional development, overcoming the critique of the uselessness and inefficiency of teacher education. On a micro level, an evidence-based understanding of knowledge, skills, and performance will support curriculum design. For example, methods for providing opportunities to learn in higher education, such as case-based learning activities for prospective teachers using digital resources, can be improved using evidence of the significant role teacher noticing may play in instructional quality or how it can be informed by professional knowledge (e.g., CK or PCK). Referring to the deliberate practice approach as important for the central perspective on teacher expertise as stable superior performance on representative tasks in the field, various tailored activities seem to be possible, such as theory-connected feedback activities in school practical activities during teacher education or professional development courses for practicing teachers. The communities of

practice proposed by Wenger (1998), which are prominent in Western countries, could adopt the characteristics of the lesson study approach (Ding et al., 2024) prominent in Eastern contexts to underpin longstanding programs aimed at developing mathematics teachers' expertise. On a macro level, governance measures for teacher education programs can be enhanced by considering fundamental research related to our heuristic (e.g., when deciding in which order prospective teachers should be exposed to academic coursework, professional practice, or a combination of both). Teacher education may profit from evidence-based descriptions of what constitutes the high-quality teaching future teachers should strive for. Whereas chess or music novices quickly learn what makes a great chess player or musician because they know popular performers, novice teachers are rarely provided with a vision to strive for during their teacher professionalization processes. Generating evidence for our heuristic may be highly relevant for future teachers in creating such a vision of the professional teacher, as both expert and competent, to encourage teachers to strive to achieve that proficiency level during their careers as professional teachers.

In the long term, our heuristic may contribute to the development of an evidence-based theory of teacher professionalization. Whereas, as this paper has shown, both the expert and competence paradigms have convinced numerous scholars to conduct empirical research over the decades, it is timely now to go a step further and profile specific research on teachers and teaching to generate excellent research on teacher professionalism. In times of teacher shortages, disruptions, and crises in many countries worldwide, strengthening the professional teacher workforce and ensuring high-quality macro-level education are more important societal issues than ever, with great potential for fostering the sustainable well-being of future generations.

Declarations

Competing Interests The authors declare no conflict of interests.

References

Alonzo, A. C., Berry, A., & Nilsson, P. (2019). Unpacking the complexity of science teachers' PCK in action: Enacted and personal PCK. In A. Hume, R. Cooper, & A. Borowski (Eds.), *Repositioning pedagogical content knowledge in teachers' knowledge for teaching science* (pp. 273–288). Springer. https://doi.org/10.1007/978-981-13-5898-2_15.

Anderson, J., & Taner, G. (2023). Building the expert teacher prototype: A metasummary of teacher expertise studies in primary and secondary education. *Educational Research and Reviews*, *38*, 100485. https://doi.org/10.1016/j.edurev.2022.100485.

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, *59*(5), 389–407.

Baumert, J., & Kunter, M. (2006). Stichwort: Professionelle Kompetenz von Lehrkräften. *Zeitschrift für Erziehungswissenschaft*, *9*(4), 469–520. https://doi.org/10.1007/s11618-006-0165-2.

Baumert, J., & Kunter, M. (2013). The COACTIV model of teachers' professional competence. In M. Kunter, J. Baumert, W. Blum, U. Klusmann, S. Krauss, & M. Neubrand (Eds.), *Cognitive activation in the mathematics classrooms and professional competence of teachers* (pp. 25–48). Springer. https://doi.org/10.1007/978-1-4614-5149-5_2.

Baumert, J., Kunter, M., Blum, W., Brunner, M., Voss, T., Jordan, A., Klusmann, U., Krauss, S., Neubrand, M., & Tsai, Y.-M. (2010). Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress. *American Educational Research Journal*, *47*(1), 133–180. https://doi.org/10.3102/0002831209345157.

Berliner, D. C. (1988). *The development of expertise in pedagogy*. American Association of Colleges of Teacher Education Publications.

Berliner, D. C. (2001). Learning about and learning from expert teachers. *International Journal of Educational Research*, *35*(5), 463–482. https://doi.org/10.1016/s0883-0355(02)00004-6.

Blömeke, S. (2025). Intelligence, knowledge, skills, behavior. Refining the Blömeke, Gustafsson, and Shavelson model of competence-as-a-continuum. In A. Gegenfurtner & R. Stahnke (Eds.), *Teacher professional vision* (Vol. *1*, pp. 57–70). Routledge.

Blömeke, S., Busse, A., Kaiser, G., König, J., & Suhl, U. (2016). The relation between content-specific and general teacher knowledge and skills. *Teaching and Teacher Education*, *56*, 35–46. https://doi.org/10.1016/j.tate.2016.02.003.

Blömeke, S., Gustafsson, J.-E., & Shavelson, R. (2015). Beyond dichotomies. Competence viewed as a continuum. *Zeitschrift für Psychologie*, *223*(1), 3–13. https://doi.org/10.1027/2151-2604/a000194.

Blömeke, S., Jentsch, A., Ross, N., Kaiser, G., & König, J. (2022). Opening up the black box: Teacher competence, instructional quality, and students' learning progress. *Learning and Instruction*, *79*, 101600. https://doi.org/10.1016/j.learninstruc.2022.101600.

Blömeke, S., & Kaiser, G. (2017). Understanding the development of teachers' professional competencies as personally, situationally, and societally determined. In D. J. Clandinin & J. Husu (Eds.), *International handbook of research on teacher education* (pp. 783–802). Sage. https://doi.org/10.4135/9781526402042.n45.

Blömeke, S., Kaiser, G., & Lehmann, R. (Eds.) (2010). *TEDS-M 2008 – Professionelle Kompetenz und Lerngelegenheiten angehender Mathematik-Lehrkräfte für die Sekundarstufe I im internationalen Vergleich*. Waxmann.

Blömeke, S., König, J., Busse, A., Suhl, U., Benthien, J., Döhrmann, M., & Kaiser, G. (2014). Von der Lehrerausbildung in den Beruf – Fachbezogenes Wissen als Voraussetzung für Wahrnehmung, Interpretation und Handeln im Unterricht. *Zeitschrift für Erziehungswissenschaft*, *17*(3), 509–542.

Bond, L., Smith, T., Baker, W. K., & Hattie, J. A. (2000). The certification system of the National Board for Professional Teaching Standards: A construct and consequential validity study. University of North Carolina at Greensboro.

Boshuizen, H., Gruber, H., & Strasser, J. (2020). Knowledge restructuring through case processing: The key to generalise expertise development theory across domains? *Educational Research and Reviews*, *29*, 100310. https://doi.org/10.1016/j.edurev.2020.100310.

Bromme, R. (1992). *Der Lehrer als Experte. Zur Psychologie des professionellen Wissens*. Huber.

Carlson, J., Daehler, K. R., Alonzo, A. C., Barendsen, E., Berry, A., Borowski, A., ... Wilson, C. D. (2019). The refined consensus model of pedagogical content knowledge in science education. In A. Hume, R. Cooper, & A. Borowski (Eds.), *Repositioning pedagogical content knowledge in teachers' knowledge for teaching science* (pp. 77–94). Springer. https://doi.org/10.1007/978-981-13-5898-2_2.

Chase, W. G., & Simon, H. A. (1973). The mind's eye in chess. In W. G. Chase (Ed.), *Visual information processing* (pp. 215–281). Academic Press.

Chi, M., Feltovich, P., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science*, *5*(2), 121–152. https://doi.org/10.1207/s15516709cog0502_2.

Collins, H. M. (2010). *Tacit and explicit knowledge*. University of Chicago Press.

de Groot, A. (1978/1965). *Thought and choice in chess* (2nd ed.). Mouton.

Depaepe, F., Verschaffel, L., & Kelchtermans, G. (2013). Pedagogical content knowledge: A systematic review of the way in which the concept has pervaded mathematics educational research. *Teaching and Teacher Education*, *34*, 12–25.

Ding, M., Huang, R., Pressimone Beckowski, C., Li, X., & Li, Y. (2024). A review of lesson study in mathematics education from 2015 to 2022: Implementation and impact. *ZDM – Mathematics Education*, *56*, 87–99. https://doi.org/10.1007/s11858-023-01538-8.

Döhrmann, M., Kaiser, G., & Blömeke, S. (2012). The conceptualisation of mathematics competencies in the international teacher education study TEDS-M. *ZDM – Mathematics Education*, *44*(3), 325–340. https://doi.org/10.1007/s11858-012-0432-z.

Dreyfus, H. L., & Dreyfus, S. E. (1986). *Mind over machine: The power of human intuition and expertise in the era of the computer*. Free Press.

Ericsson, K. A. (2018). An introduction to the second edition of the Cambridge handbook of expertise and expert performance: Its development, organization, and content. In K. A. Ericsson, R. R. Hoffman, A. Kozbelt, & M. A. Williams (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 3–20). Cambridge University Press. https://doi.org/10.1017/9781316480748.001.

Ericsson, K. A., & Harwell, K. W. (2019). Deliberate practice and proposed limits on the effects of practice on the acquisition of expert performance: Why the original definition matters and recommendations for future research. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.02396.

Ericsson, K. A., Hoffman, R. R., Kozbelt, A., & Williams, A. M. (Eds.) (2018). *The Cambridge handbook of expertise and expert performance* (2nd ed.). Cambridge University Press. https://doi.org/10.1017/9781316480748.

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review*, *100*, 363–406.

Ericsson, K. A., & Lehmann, A. C. (1996). Expert and exceptional performance: Evidence on maximal adaptations on task constraints. *Annual Review of Psychology*, *47*, 273–305.

Ericsson, K. A., & Simon, H. A. (1980). Verbal reports as data. *Psychological Review*, *87*(3), 215–251. https://doi.org/10.1037/0033-295X.87.3.215.

Gobet, F., & Simon, H. A. (1996). Templates in chess memory: A mechanism for recalling several boards. *Cognitive Psychology*, *31*(1), 1–40. https://doi.org/10.1006/cogp.1996.0011.

Hoffman, R. R. (2023). Identifying experts for the design of human-centered systems: The pentapod principle. *Journal of Expertise*, *6*(3), 259–266.

Hoth, J., Larrain, M., & Kaiser, G. (2022). Identifying and dealing with student errors in the mathematics classroom: Cognitive and motivational requirements. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2022.1057730.

Jentsch, A., Schlesinger, L., Heinrichs, H., Kaiser, G., König, J., & Blömeke, S. (2021). Erfassung der fachspezifischen Qualität von Mathematikunterricht: Faktorenstruktur und Zusammenhänge zur professionellen Kompetenz von Mathematiklehrpersonen. *Journal für Mathematik-Didaktik*, *42*, 97–121. https://doi.org/10.1007/s13138-020-00168-x.

Johnson, R. B. (2017). Dialectical pluralism: A metaparadigm whose time has come. *Journal of Mixed Methods Research*, *11*(2), 156–173. https://doi.org/10.1177/1558689815607692.

Jossberger, H., Breckwoldt, J., & Gruber, H. (2022). Promoting expertise through simulation (PETS): A conceptual framework. *Learning and Instruction*, *82*, 101686. https://doi.org/10.1016/j.learninstruc.2022.101686.

Kaiser, G. (2024). The TEDS research program. Its origin and development (in memoriam Sigrid Blömeke). In J. König, Ch. Hanisch, P. Hanke, Th. Hennemann, K. Kaspar, M. Martens, & S. Strauß (Eds.), *Auf die Lehrperson und ihren Unterricht kommt es an* (pp. 261–287). Waxmann. https://doi.org/10.31244/9783830998761.

Kaiser, G., Blömeke, S., König, J., Busse, A., Döhrmann, M., & Hoth, J. (2017). Professional competencies of (prospective) mathematics teachers – cognitive versus situated approaches. *Educational Studies in Mathematics*, *94*(2), 161–182, 183–184. https://doi.org/10.1007/s10649-016-9713-8. Erratum: https://doi.org/10.1007/s10649-016-9724-5.

Kaiser, G., & König, J. (2019). Competence measurement in (mathematics) teacher education and beyond: Implications for policy. *Higher Education Policy*, *32*, 597–615. https://doi.org/10.1057/s41307-019-00139-z.

Kinchin, I., & Cabot, L. (2010). Reconsidering the dimensions of expertise: From linear stages towards dual processing. *London Review of Education*, *8*(2), 153–166.

Kleickmann, T., & Anders, Y. (2013). Learning at university. In M. Kunter, J. Baumert, W. Blum, U. Klusmann, S. Krauss, & M. Neubrand (Eds.), *Cognitive activation in the mathematics classroom and professional competence of teachers* (pp. 321–332). Springer.

König, J., Blömeke, S., Klein, P., Suhl, U., Busse, A., & Kaiser, G. (2014). Is teachers' general pedagogical knowledge a premise for noticing and interpreting classroom situations? A video-based assessment approach. *Teaching and Teacher Education*, *38*, 76–88.

König, J., Heine, S., Weyers, J., Arntz, C.-G., Kramer, Ch., Strauß, S., Gerhard, K., Mühle, J., Engartner, T., Großschedl, J., Hanisch, Ch., Hanke, P., Hennemann, Th., Jost, J., Kaspar, K., & Rott, B. (2025). Effectiveness of interventions in teacher education: Synthesis of reviews (2010-2024). *Zeitschrift für Erziehungswissenschaft*, *28*(6). https://doi.org/10.1007/s11618-025-01319-x.

König, J., Ligtvoet, R., Klemenz, S., & Rothland, M. (2017). Effects of opportunities to learn in teacher preparation on future teachers' general pedagogical knowledge: Analyzing program characteristics and outcomes. *Studies in Educational Evaluation*, *53*, 122–133.

König, J., Santagata, R., Schreiner, Th., Adleff, A.-K., Yang, X., & Kaiser, G. (2022). Teacher noticing: A systematic literature review on conceptualizations, research designs, and findings

on learning to notice. *Educational Research and Reviews*, *36*, 100453. https://doi.org/10.1016/j.edurev.2022.100453.

Krainer, K., & Llinares, S. (2010). Mathematics teacher education. In P. Peterson, E. Baker, & B. McGaw (Eds.), *International encyclopedia of education* (pp. 702–705). Elsevier.

Krauss, S. (2020). Expertise-Paradigma in der Lehrerinnen- und Lehrerbildung. In C. Cramer, J. König, M. Rothland, & S. Blömeke (Eds.), *Handbuch Lehrerinnen und Lehrerbildung* (pp. 154–162). Klinkhardt. https://doi.org/10.35468/hblb2020-018.

Krauss, S., Bruckmaier, G., Lindl, A., Hilbert, S., Binder, K., Steib, N., & Blum, W. (2020). Competence as a continuum in the COACTIV study: The "cascade model". *ZDM – Mathematics Education*, *52*, 311–327. https://doi.org/10.1007/s11858-020-01151-z.

Krauss, S., Brunner, M., Kunter, M., Baumert, J., Blum, W., Neubrand, M., & Jordan, A. (2008). Pedagogical content knowledge and content knowledge of secondary mathematics teachers. *Journal of Educational Psychology*, *100*(3), 716–725.

Larrain, M., & Kaiser, G. (2022). Interpretation of students' errors as part of the diagnostic competence of pre-service primary school teachers. *Journal für Mathematik-Didaktik*, *43*(1), 39–66. https://doi.org/10.1007/s13138-022-00198-7.

Li, Y., Huang, R., & Yang, Y. (2011). Characterising expert teaching in school mathematics in China – a prototype of expertise in teaching mathematics. In Y. Li & G. Kaiser (Eds.), *Expertise in mathematics instruction: An international perspective* (pp. 167–195). Springer. https://doi.org/10.1007/978-1-4419-7707-6_9.

McClelland, D. C. (1973). Testing for competence rather than for "intelligence". *The American Psychologist*, *28*(1), 1–14. https://doi.org/10.1037/h0034092.

Metsäpelto, R.-L., Poikkeus, A.-M., Heikkilä, M., Husu, J., Laine, A., Lappalainen, K., Lähteenmäki, M., Mikkilä-Erdmann, M., Warinowski, A., In collaboration with Iiskala, T., Hangelin, S., Harmoinen, S., Holmström, A., Kyrö-Ämmälä, O., Lehesvuori, S., Mankki, V., & Suvilehto, P. (2021). A multidimensional adapted process model of teaching. *Educational Assessment, Evaluation and Accountability*, *34*, 143–172. https://doi.org/10.1007/s11092-021-09373-9.

Mulder, R., & Gruber, H. (2011). Die Lehrperson im Lichte von Professions-, Kompetenz- und Expertiseforschung – die drei Seiten einer Medaille. In O. Zlatkin-Troitschanskaia (Ed.), *Stationen Empirischer Bildungsforschung* (pp. 427–438). VS Verlag für Sozialwissenschaften. https://doi.org/10.1007/978-3-531-94025-0_30.

Neuweg, G. H. (2001). *Könnerschaft und implizites Wissen. Zur lehr-lerntheoretischen Bedeutung der Erkenntnis- und Wissenstheorie Michael Polanyis*. Waxmann.

Neuweg, G. H. (2014). Das Wissen der Wissensvermittler. In E. Terhart, H. Bennewitz, & M. Rothland (Eds.), *Handbuch der Forschung zum Lehrerberuf* (2nd ed., pp. 583–614). Waxmann.

Palmer, D., Stough, L., Burdenski, T., & Gonzales, M. (2005). Identifying teacher expertise: An examination of researchers' decision making. *Educational Psychologist*, *40*(1), 13–25. https://doi.org/10.1207/s15326985ep4001_2.

Polanyi, M. (1966). *The tacit dimension*. Doubleday.

Potari, D., Jaworski, B., & Petropoulou, G. (2023). Theorizing university mathematics teaching: The teaching triad within an activity theory perspective. *Educational Studies in Mathematics*, *114*, 1–16. https://doi.org/10.1007/s10649-023-10244-x.

Rowland, T., & Ruthven, K. (2011). Introduction: Mathematical knowledge in teaching. In T. Rowland & K. Ruthven (Eds.), *Mathematical knowledge in teaching* (pp. 1–5). Springer.

Santagata, R., & Yeh, C. (2016). The role of perception, interpretation, and decision making in the development of beginning teachers' competence. *ZDM – Mathematics Education*, *48*, 153–165. https://doi.org/10.1007/s11858-015-0737-9.

Scheerens, J., & Blömeke, S. (2016). Integrating teacher education effectiveness research into educational effectiveness models. *Educational Research and Reviews*, *18*, 70–87. https://doi.org/10.1016/j.edurev.2016.03.002.

Schlesinger, L., Jentsch, A., Kaiser, G., König, J., & Blömeke, S. (2018). Subject-specific characteristics of instructional quality in mathematics education. *ZDM – Mathematics Education*, *50*(3), 475–490. https://doi.org/10.1007/s11858-018-0917-5.

Schön, D. (1983). *The reflective practitioner: How professionals think in action*. Basic Books.

Sherin, M., Jacobs, V., & Philipp, R. (Eds.) (2011). *Mathematics teachers' noticing. Seeing through teachers' eyes*. Routledge.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 1–22. https://doi.org/10.3102/0013189x015002004.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*, 1–22. https://doi.org/10.17763/haer.57.1.j463w79r56455411.

Shure, V., Lehmann, M., Friesen, M., Roesken-Winter, B., & Prediger, S. (2025). Professional development research on promoting productive practices for teachers' handling of typical tasks of mathematics teaching: A systematic review. *ZDM – Mathematics Education*, *57*(4). https://doi.org/10.1007/s11858-025-01659-2.

Sternberg, R., & Horvath, J. (1995). A prototype view of expert teaching. *Educational Researcher*, *24*, 9–17. https://doi.org/10.3102/0013189x024006009.

Stigler, J. W., & Miller, K. F. (2018). Expertise and expert performance in teaching. In K. A. Ericsson, R. R. Hoffman, A. Kozbelt, & M. A. Williams (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 431–452). Cambridge University Press. https://doi.org/10.1017/9781316480748.024.

Terhart, E. (2011). Lehrerberuf und Professionalität. Gewandeltes Begriffsverständnis – neue Herausforderungen. *Zeitschrift für Pädagogik*, *57*, 202–224. Beiheft.

Voss, T., Kunter, M., & Baumert, J. (2011). Assessing teacher candidates' general pedagogical/psychological knowledge: Test construction and validation. *Journal of Educational Psychology*, *103*(4), 952–969.

Ward, P., Schraagen, J. M., Gore, J., & Roth, E. M. (Eds.) (2020). *The Oxford handbook of expertise*. Oxford University Press.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge University Press.

Weinert, F. E. (2001). Concept of competence: A conceptual clarification. In D. S. Rychen & L. H. Saganik (Eds.), *Defining and selecting key competencies* (pp. 45–65). Hogrefe & Huber.

Yang, X., & Kaiser, G. (2022). The impact of mathematics teachers' professional competence on instructional quality and students' mathematics learning outcomes. *Current Opinion in Behavioral Sciences*, *48*, 101225. https://doi.org/10.1016/j.cobeha.2022.101225.