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Research paper

Modelling, structure and development of domain-specific professional knowledge of Latin teachers

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ABSTRACT

In this paper, the content knowledge and pedagogical content knowledge of teachers of Latin as a foreign language are modelled and examined using a convenience sample ($N = 216$) with newly validated test instruments. Bivariate correlations show significant relationships between domain-specific professional knowledge and indicators of school or academic success, but no relationships with professional experience. In a confirmatory factor analysis, the two categories of knowledge can be separated according to theory. Their correlation is lower among in-service teachers than pre-service teachers, as multigroup analyses suggest. Furthermore, in-service teachers have more content knowledge and pedagogical content knowledge than pre-service teachers.

1. Introduction

1.1. Research on teacher's professional competence

Professional competence of teachers is considered one of the most important factors determining instructional quality and student learning, not only according to Hattie's meta-meta-analysis (2009), but also in research on expertise (e.g., Anderson & Taner, 2023; Berliner, 2001, 2004; Bromme, 1992) and competence (e.g., Baumert & Kunter, 2006, 2013; Blömeke et al., 2015; Krauss et al., 2020). Here, the focus is on the one hand on affective-motivational features of teachers such as their beliefs, values as well as goals, motivational orientations, self-regulation, and enthusiasm (e.g., Baumert & Kunter, 2006, 2013; Keller et al., 2016; Moè & Katz, 2022; Schilcher et al., 2021). These and the adoption of motivating teaching styles (e.g., Aelterman et al., 2019; Moè et al., 2022) can raise student learning and motivation, especially in challenging school subjects such as mathematics, science, or foreign languages (e.g., Kunter et al., 2011; Moè et al., 2021).

On the other hand, teachers' cognitive dispositions, especially their professional knowledge, are closely related to and interact with affective-motivational characteristics and are seen very relevant (Baumert & Kunter, 2006, 2013; Blömeke et al., 2015). They are regarded as prerequisites for their competent behavior and enable them to successfully meet the typical demands of their profession (e.g., Berliner, 2001; Bromme, 1992; Darling-Hammond & Bransford, 2007; Gitomer & Zisk, 2015; König et al., 2016; Krauss et al., 2020; Shulman, 1986, 1987). In his influential taxonomy, Shulman (1986, 1987) describes seven different areas of teachers' professional knowledge, of which general pedagogical knowledge (GPK; e.g., for an overview, König, 2014; König et al., 2023; Mulder et al., 2017; Voss et al., 2015) and content knowledge (CK) and pedagogical content knowledge (PCK) have received the most attention in research (e.g., for an overview Kunter, Klusmann et al., 2013; Krauss et al., 2017, 2020).

Studies on these three areas of professional knowledge dealt with their own as well as each other's structure (e.g., Blömeke et al., 2016; Jüttner et al., 2013; Kirschner et al., 2017; Kleickmann et al., 2014; Lindl & Krauss, 2017), their acquisition processes and development during teacher education and in the career (e.g., Blömeke et al., 2013; Großschedl et al., 2015; Kleickmann et al., 2013, 2014; König, 2013; König et al., 2016, 2018; Krauss et al., 2017; Schmidt et al., 2011; Tatto et al., 2008, 2012; Tröbst et al., 2018, 2019) and, in particular, their associations with and importance for teacher and student performance (e.g., Baumert et al., 2010; Blömeke et al., 2022; Ergönenc et al., 2014; Förtsch et al., 2016, 2017, 2018; Hill et al., 2005; Kelcey et al., 2019; Kersting et al., 2010, 2012; Kunter, Klusmann et al., 2013; Mahler et al., 2017; Sadler et al., 2013; Tröger et al., 2017).

However, an overview of the effects of CK and PCK on instructional quality and student outcomes (for reviews see, e.g., Anderson & Taner, 2023; Charalambous et al., 2020) reveals not only heterogeneous findings in the individual school subjects and across disciplines, but also an almost exclusive focus of previous studies on mathematics and science subjects. This is particularly problematic because Shulman (1986)

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already emphasized the great importance of subject-specific aspects for teaching and learning processes, which was underlined by the meta-analysis of Seidel and Shavelson (2007). Therefore, further research on domain-specific professional knowledge seems necessary, also in other school subjects, to identify generalizable commonalities and subject-typical differences (König et al., 2016; Krauss, Brunner et al., 2008; Schilcher et al., 2021). This requires domain-specific theoretical modelling as well as empirical measurement and investigation of teachers' professional knowledge for different school subjects. To date, there are no corresponding approaches in the classical languages (Kuhlmann, 2020; for an overview Lindl & Kloiber, 2017), although they are still taught as foreign languages at (academic track) high schools in many European countries (e.g., Germany, France, the Netherlands, Austria, Switzerland, Italy, Spain, United Kingdom; European Commission/EACEA/Eurydice, 2017).

The present study addresses this desideratum. Against the theoretical background of research on teachers' professional competence, a domain-specific conceptualization and operationalization of the content knowledge and pedagogical content knowledge of Latin teachers are presented for the first time. Based on this, a psychometric test instrument was newly developed and validated. Then, it is analyzed how professional knowledge is related to external criteria (such as grade point average, professional experience, etc.) and which differences exist between pre-service and in-service teachers in the level and structure of both knowledge areas. On the one hand, this can be seen as a first step for further studies that examine if and to what extent findings from mathematical-scientific studies can be transferred to the language subject of Latin or its teachers. On the other hand, this offers the first opportunity to reflect on the content, focus and structures in the training of Latin teachers based on empirical findings and to discuss implications for its future optimization.

1.2. Teaching Latin as foreign language

Before examining the domain-specific professional knowledge of Latin teachers, we will briefly outline the position of Latin as a school subject and the training of Latin teachers in Germany.

Supply and demand. In the German school system, Latin is taught (almost) exclusively at (academic track) high schools ('Gymnasien'), where students must acquire at least two foreign languages to obtain the 'Abitur', the higher German school certificate for university admission. To this end, they are often free to choose between Latin and several modern foreign languages (especially English, French, Spanish, Russian, and Italian). Most students learn Latin as a second foreign language (after English) from the 6th grade onwards. However, there are also a few schools that offer Latin as a first foreign language from the 5th grade and English as a second foreign language from the 6th grade onwards. So, Latin is the foreign language with the third-largest number of learners in Germany after English and French (about 500,000 Latin students; German Federal Statistical Office, 2022).

On the one hand, the demand for Latin instruction results from a basic interest in the language and literature as well as ancient culture, which still shape many areas of work and life today (e.g., legislation, political system, cultural events, educational language, philosophy; Maier, 2008; Westphalen, 1992). On the other hand, it also persists because of assumed positive transfer effects regarding the promotion of linguistic skills (concerning German and the Romance foreign languages; e.g., Groβe, 2017; Haag & Stern, 2002; Siebel, 2017) and certain ways of thinking and working (Haag & Stern, 2003), which are (socially) attributed to learning Latin (Gerhards et al., 2021), but have hardly been empirically investigated so far (Lindl, 2023). In addition, knowledge of Latin (sometimes even in-depth) is required for admission to or obtaining various university degrees (e.g., history, medicine, law, theology) and is therefore already acquired in school to pave the way for potential career paths.

General curriculum, contents, and objectives. In Latin lessons, the language itself takes centre stage (Kuhlmann, 2011; Pinter, 2011). The fundamental – and at the same time ambitious – goal is to enable students to read and interpret Latin literature independently and critically, and to engage intensively with ancient culture and the intellectual world. To this end, the focus in grades 5 or 6 to 8 is on learning vocabulary and grammar. Texts written for learning purposes or adapted original texts representing central questions and typical topics of the subject are used. In the following school years (9th to max. 12th or 13th grade), the emphasis is on author- or genre-specific reading and intensive study of the corresponding content. This includes fables (Phaedrus), love poetry (Catullus, Ovid), epigrams (Martial), speeches (Cicero), letters (Pliny the Younger, Cicero), philosophical writings (Cicero, Seneca the Younger), satire (Horace), historiography (Caesar, Livius, Sallust) and epics (Virgil). In addition to the author, language and stylistics, genre character and other literary aspects, the thematic complexes of Roman religion and myth, private and public life, art and topography of Rome, history, politics and society, and ancient philosophy also represent important learning contents.

How to become a Latin teacher? The training of high school teachers in Germany is divided into two phases (for an overview, Cortina & Thames, 2013; Schilcher et al., 2021). First, a course of study in at least two subjects, the future teaching subjects, is completed at the university. Usually only the 'Abitur' is required for this, regardless of its grade point average. It takes at least 4.5 years (9 semesters) and is completed with a master's degree or first state examination. The focus is on theoretical and subject-related content, such as Latin philology here. On the one hand, the prospective teachers' linguistic competence in Latin is developed and improved. On the other hand, they acquire and expand their knowledge of authors, works, genres, prosody and metrics, stylistics as well as (intellectual) historical, political, social, philosophical, and cultural backgrounds through intensive study of Latin literature. Furthermore, there are introductory courses in the methods of classical philology, the history of Greco-Roman antiquity, Greco-Roman mythology, ancient philosophy as well as ancient culture and its tradition. In comparison, courses on subject matter teaching and learning take up only a small proportion of time (about one tenth of the degree, a total of only a paltry 3–5 courses). They theoretically address and reflect on aspects of domain-specific teaching, diagnosis, and assessment, as well as the teaching and communication of Latin content. Practical teaching experience is only provided in short-term internships, which are organized differently from state to state. In Bavaria, for example, internships of three whole weeks at the beginning and six whole weeks in the middle of the study programme are scheduled, as well as a semester internship in which pre-service teachers spend one day per week at the school. In contrast to the in-depth studies of two disciplines, teaching practice plays a rather subordinate role in the training phase at the university (Schilcher et al., 2021).

This is followed by a two-year practice-oriented induction phase at public school, which ends with the second state examination, enabling regular employment in the state school system. In special, rather small seminar groups, the prospective teachers are accompanied by mentors who are distinguished by their academic and practical expertise. This phase allows for own practical teaching experiences and includes guided as well as independent teaching experiments and a theory-based reflection of the first lessons. The emphasis is on subject-specific aspects of the design of lessons and learning environments, motivational foundations of performance and learning development, diagnosis and promotion of individual learning processes, performance measurements and assessments. This aims at a successive transformation process of the often highly specialized academic knowledge from an abstract-theoretical to an application-oriented, action-oriented form (e.g., Kleickmann et al., 2013; Neuweg, 2014). Thus, in-service teachers should not only have more domain-specific professional knowledge than pre-service teachers, but this knowledge should also be structured differently. But how can this be modelled and analyzed?

2. Theoretical framework

Shulman's (1986, 1987) taxonomy of professional knowledge is the basis for the majority of conceptualizations of the two knowledge domains CK and PCK so far. This includes, among others, Baumert and Kunter's (2006, 2013) modelling of professional competence in the context of the COACTIV study (Kunter, Baumert et al., 2013; Kunter, Klusmann et al., 2013), towards which the present study is primarily oriented.

2.1. Content knowledge

CK is essentially shaped by the academic reference disciplines of the respective school subject (Freeman, 2002; König et al., 2016) and is often also referred to as subject matter knowledge (Abell, 2007; Jüttner et al., 2013; Shulman, 1986). To what extent and at what level this knowledge is required for teachers is one central issue of current research discussions and, accordingly, conceptualized in different ways (e. g., Ball et al., 2008; Dreher et al., 2018; Heinze et al., 2016; Hill et al., 2005; Lindmeier, 2011; Sadler et al., 2013). Krauss, Baumert, et al. (2008), Krauss, Brunner et al. (2008), Krauss et al. (2013), for example, differentiate four different levels on the continuum between pure academic mathematics knowledge and everyday mathematics knowledge to describe a mathematical CK, namely an everyday knowledge that all adults should have, a command of school-level knowledge (at about the level required of an average to good student in the grade in question), a deep understanding of the content of the secondary school curriculum (e.g., knowledge from a higher standpoint), and a university-level knowledge. However, considering Shulman's view that "content knowledge requires going beyond knowledge of the facts or concepts of a domain" (1986, 9), Krauss and colleagues (2008a, 2008b, 2017) ultimately opt for a conceptualization at the level of an in-depth background knowledge on the contents of the secondary-level curriculum. For teachers, such a knowledge base includes not only knowledge of facts, concepts, and principles of the domain, but also insight into their basic structures and mutual interrelationships, as well as a strong understanding of their (domain-)internal logic and validity, and – possibly domain-specific – heuristics for testing them (Schwab, 1978; Shulman, 1986).

2.2. Pedagogical content knowledge

PCK is the category of knowledge that "most likely […] distinguishes the understanding of the content specialist from that of the pedagogue" (Shulman, 1987, 8; cf. Schilcher et al., 2021). Therefore, according to Shulman (1986, 1987), it forms its own unique profession- and domain-specific knowledge category that is required for subject-specific teaching and learning processes (Krauss, Brunner et al., 2008). This already includes, for Shulman (1986), on the one hand, the facet of a knowledge of the most useful forms of explanation and representation – "in a word, the ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986, 8). On the other hand, he postulates a knowledge of typical domain- and topic-specific (mis)conceptions, errors, and learning difficulties of students – "an understanding of what makes the learning of specific topics easy or difficult" (Shulman, 1986, 9) – and of diagnostic and intervention strategies in this regard – "knowledge of the strategies most likely to be fruitful in reorganizing the understanding of learners" (Shulman, 1986, 9).

These two basic facets of PCK have since been taken up in numerous studies of teacher PCK and often supplemented with other aspects (for an overview, Baumert & Kunter, 2013; Depeape et al., 2013; Dreher et al., 2018; Krauss, Baumert, et al., 2008; Lee & Luft, 2008; Park & Oliver, 2008; Schmelzing et al., 2013; Van Driel et al., 1998). Since teaching is significantly influenced by the disposition of different demands, the selection, use, and type of processing of teaching materials such as tasks, texts, realia, etc. are of central relevance in this regard. Therefore, Krauss, Baumert, et al. (2008), Krauss, Brunner et al. (2008), among others, also conceptualized a specific knowledge about the potential for multiple solutions to tasks as a facet of PCK. In more general fashion, Krauss et al. (2017) called it knowledge about the cognitive potential of teaching-learning materials and tasks in the respective subject. Compared to the previous two, the modelling of this PCK facet is thus more domain-specific and content-based (Krauss, Brunner et al., 2008; Krauss et al., 2017; Lindl & Krauss, 2017).

2.3. Relationship between CK and PCK

The mutual relationship between CK and PCK (and GPK) has meanwhile been examined many times, but mainly in mathematical-scientific settings. In the foreground is Shulman's (1987) hypothesis, which defines PCK as a conceptually distinct category of knowledge, distinguishable from CK (as well as from GPK) but not disjunct from them. This is empirically suggested by studies on teachers' professional knowledge in mathematics (e.g., Krauss, Brunner et al., 2008; Hill et al., 2004; Blömeke et al., 2011; for an overview Charalambous et al., 2020) as well as in biology, chemistry, and physics (Kirschner et al., 2017). Similar findings are also apparent in the school subjects German as native language (Bremerich-Vos & Dämmer, 2013; Pissarek & Schilcher, 2017) and English as foreign language (Jansing et al., 2013; Kirchhoff, 2017; König et al., 2016). According to Shulman's assumption that PCK is a "special amalgam of content and pedagogy" (1987, 8), the interdependent, reciprocal relationship of CK, PCK, and GPK (Neuweg, 2014) is especially focused on in relation to the theoretical modelling of teachers' professional knowledge (e.g., Carlson et al., 2019) as well as the empirical investigation of its acquisition and development process (Tröbst et al., 2018, 2019). In particular, CK is considered to be a necessary but not sufficient prerequisite for PCK (Abell, 2007; Van Driel et al., 1998). It also determines the developmental space of PCK and the domain-specific instructional flexibility of a teacher with a differentiated repertoire of presentation, diagnostic, planning, and action strategies (Baumert et al., 2010; Baumert & Kunter, 2006; Depaepe et al., 2013; Groβschedl et al., 2014; Kleickmann et al., 2013; König et al., 2016; Krauss et al., 2013; Lindl & Krauss, 2017; Mahler et al., 2017; Park & Oliver 2008; Shulman, 1986, 1987).

2.4. CK and PCK as action-related knowledge categories

According to Weinert's understanding of competence (2001) and in the context of the competence paradigm of research on teachers (e.g., Krauss, 2020), their professional knowledge and skills (Bromme, 1992) in dynamic interplay with other aspects of competence such as occupational motivation, beliefs, or attitudes are considered a basic cognitive disposition and represent a necessary prerequisite for their professional behavior in the multiple demands of teaching situations (Baumert & Kunter, 2006; Knievel et al., 2015; Krauss et al., 2017; Lindmeier, 2011). This assumption also underlies current theoretical models, such as the 'Competence as Continuum model' of Blömeke et al. (2015; cf. also Kaiser et al., 2015, 2017), 'the refined consensus model' of Carlson et al. (2019), or the 'Cascade model' of Krauss et al. (2020). In these models, cognitive dispositions such as domain-specific professional knowledge represent theoretically formal, scientifically objectifiable (e.g., collective PCK) or also derived from subjective practical experiences (e.g., personal PCK; Carlson et al., 2019), constantly changing and expandable knowledge elements and structures (cf. already Fenstermacher's, 1994, concepts of a formal vs. practical knowledge; on this also Berliner, 2004; Knievel et al., 2015). These are in part explicit, i.e., verbalizable, and in part implicit, i.e., not necessarily conscious, and only reconstructible (e. g., Gruber & Harteis, 2018; Knievel et al., 2015; Neuweg, 2014). They influence (professional) perception, interpretation, as well as decision-making in concrete situations, such as in the planning, implementation, and follow-up of lessons. These so-called situation-specific competencies (Blömeke et al., 2015) or – in other words – the enacted

PCK (Carlson et al., 2019) or situated PCK (Krauss et al., 2020) have a mediating effect on teacher's behavior that can be observed (Blömeke et al., 2015; Carlson et al., 2019; Krauss et al., 2020). This provides an educational proposal that – under advantageous conditions and circumstances (e. g., motivation, intelligence, etc.) – can lead to a change in performance among recipients (according to common offer-use models, e. g., Carlson et al., 2019; Helmke, 2022; Krauss et al., 2020; Vieluf et al., 2020).

2.5. Measuring CK and PCK

To assess teachers' (domain-specific) professional knowledge, distal measures, such as the number of university courses attended, university final grades or certificates, but also self-assessment questionnaires, have proven to be of limited validity (Baumert et al., 2010; Baumert & Kunter, 2013; Blömeke et al., 2022; Hill et al., 2005; Jüttner et al., 2013; Krauss, Baumert, et al., 2008; Krauss, Brunner et al., 2008; Pajares 1992). Instead, a variety of qualitative (for an overview see, e.g., Baumert et al., 2010; Depaepe et al., 2013) and quantitative methods (for an overview see, e.g.., Krauss et al., 2020; Lindl et al., 2023) are used, which show an enormous methodological diversity (e.g., interviews, classroom observations through field notes, video or audio recording, document analyses, paper-pencil tests, etc.; in sum Groβschedl et al., 2014; Kleickmann et al., 2013). In quantitative approaches, psychometric test instruments are currently considered the gold standard (Tchoshanov, 2011).

However, it has not yet been clarified whether paper-pencil testing or video-based formats are more appropriate, and thus valid and conclusive arguments are put forward for both approaches (e.g., Bruckmaier et al., 2016; Kaiser et al., 2015, 2017; Knievel et al., 2015; Krauss et al., 2020; Lindmeier, 2011; Neuweg, 2015; Riegel & Macha, 2013; Rutsch et al., 2018). Also, regarding the predictive validity of one or the other method, no silver bullet could be identified thus far (e.g., Hill et al., 2005; Kersting et al., 2012; Kunter, Baumert et al., 2013). Nevertheless, DePaepe et al. (2013) emphasize that the choice of instrument essentially depends on the survey context and the target construct, and thus primarily on whether the cognitive or situated perspective is focused on (see also Kaiser et al., 2015, 2017; Rowland & Ruthven, 2011). Accordingly, paper-pencil tests are still a suitable method for assessing domain-specific professional knowledge as a cognitive disposition (Bridgeman & Lewis, 1994; Groβschedl et al., 2014; Krauss et al., 2020; Lindl et al., 2023; Schoenfeld, 2007; Öz & Özturan, 2018).

For instance, there are numerous approaches for teachers of mathematics (e.g., Hill et al., 2005; Krauss et al., 2013; Schmidt et al., 2011; Tatto et al., 2008, 2012) and of science school subjects (e.g., physics: Ergönenc et al., 2014; biology: Jüttner et al., 2013; Förtsch et al., 2016; chemistry: Strübe et al., 2014; in sum Kirschner et al., 2017); however, they are still comparatively rare for languages or the humanities (e.g., German as native language: Bremerich-Vos & Dämmer, 2013; Pissarek & Schilcher, 2017; English as foreign language: Jansing et al., 2013; Kirchhoff, 2017; König et al., 2016), as also shown by the overviews in Krauss et al. (2017, 2020). So far, there are neither modelling approaches for the CK and PCK of Latin teachers nor psychometric test instruments for their assessment.

2.6. Research questions and hypotheses

Against this background, the first aim of the present study is to construct and validate a new domain-specific professional knowledge test for teachers of Latin as a school subject based on Shulman's (1986; 1987) knowledge taxonomy and its modelling in the COACTIV study (Kunter, Baumert et al., 2013). So, the first research question is:

Can the domain-specific professional knowledge (CK and PCK) of Latin teachers be measured objectively, reliably, and validly?

If this is true regarding central psychometric quality criteria of the developed test such as evaluation objectivity, internal consistency, and face validity, the following questions arise:

Can the CK and PCK knowledge domains of Latin teachers be empirically separated?

According to Shulman (1986), CK and PCK represent two related, yet conceptually as well as empirically distinct domains of knowledge ($H_{1.1}$). If this assumption is also true for Latin teachers, the following research question emerges:

How do the level and structure of domain-specific professional knowledge differ between pre-service and in-service Latin teachers? Do in-service Latin teachers have more CK or PCK than do pre-service teachers, and does the relationship between the two domains of knowledge differ between the two groups?

It can be assumed that in-service teachers have on average a more extensive CK ($H_{1.2}$) than pre-service teachers due to their previous academic studies and a higher PCK ($H_{1.3}$) due to their time spent in the induction phase. As their areas of knowledge are more differentiated and specialized, the correlation between CK and PCK is also lower for in-service teachers than for pre-service teachers ($H_{1.4}$).

3. Method

3.1. Participants

The convenience sample consisted of $N = 216$ teachers of Latin at Bavarian (academic track) high schools ('Gymnasien'). Of these, 107 in-service teachers (43% female) taught Latin regularly. Ten individuals (80% female) were in the first year of their induction phase at school. Since they did not differ significantly from in-service teachers (but from pre-service teachers) regarding their CK and PCK in (corrected for multiple comparisons via the Bonferroni method) post-hoc tests in analyses of variance (CK: $F(2,213) = 29.31, p < .01$, PCK: $F(2,213) = 42.13, p < .01$), they are (simplifyingly) subsumed under the group of teachers in the analyses below. The mean age of this group was 44.2 years ($SD = 11.2$, range 26–62) and their mean professional experience in Latin was 15.6 years ($SD = 10.6$, range 1–35). In contrast, there were 99 pre-service teachers (58% female) who were studying Latin for high school teaching degree in the university phase. Their mean age was 23.0 years ($SD = 2.1$, range 19–28) and their mean number of semesters in the subject was 6.4 semesters ($SD = 2.6$, range 1–12).

3.2. Assessment of CK and PCK

The CK and PCK tests were each developed in the light of the theoretical foundations presented in Section 2 and with a focus on the learning opportunities during training and the classroom demands of professional Latin teachers (see Subsection 1.2). Experts from teacher education, classroom practice and educational administration were involved in the multi-step process of constructing and optimizing the items; in addition, the items were piloted in several rounds to select suitable items for the final test instruments and the main study. Further explanation of the item development and piloting process can be found in Lindl and Kloiber (2015); the comments below refer to the final tests.

3.2.1. CK test

The CK of Latin teachers is conceptualized as in-depth background knowledge on the contents of the school curriculum in grades 5 to 13 (cf. Section 2; Krauss, Baumert, et al., 2008; Krauss et al., 2013). That is, it captures a level of knowledge that ensures sovereign mastery of the entire teaching canon and associated domain-specific methods in everyday classroom practice due to solid knowledge that goes beyond the content of the lessons and is, in principle, inexhaustible (Maier, 1979). This implies excellent linguistic competence that enables a confident dealing with

original Latin texts at a high level. To represent the thematic breadth of the CK in Latin instruction at the high school to some extent, the CK test comprises a total of ten items with content focus on or prototypical demands for the topics authors and genres, politics and history, and grammar and language. Of the ten items, four have a closed-response format and six have an open-response format. A sample item can be found in Table 1.

3.2.2. PCK test

According to the conceptualization (cf. Section 2), PCK is divided into the three facets knowledge about explaining and representing ('instruction'; six items), knowledge of Latin-related student cognitions ('student'; six items), and knowledge about the multiple cognitive potential of teaching-learning materials and tasks in Latin instruction

Table 1
Sample items and corresponding (correct) sample responses from the content knowledge (CK) test and from the three subscales of the pedagogical content knowledge (PCK) test (instruction, student, material).

Knowledge Category (Facet)	Sample item	(Correct) sample response
CK	***'Bellum iustum'*** As is well known, *bellum iustum* is a fundamental principle of Roman imperialism. According to the Roman *ius fetiale*, what three criteria must a war fulfill to be just? 1) 2) 3)	***'Bellum iustum'*** According to Cicero (rep. 3,35; off. 1,36), a just war must fulfill the following three criteria: 1) It must be announced (*denuntiatum*). 2) It must be declared lawful (*indictum*). 3) It must be conducted for valid reasons (*de repetitis rebus; ulciscendi aut propulsandorum hostium causa*).
PCK Instruction	**'Gerund or Gerundive?'** Provide as many explanations as you know of to help your students understand the difference between gerund and gerundive in Latin! If necessary, illustrate them with meaningful examples!	**'Gerund or Gerundive?'** One solution could graphically contrast the different syntactic constructions of gerund and gerundive using a concrete example. Gerund: Gen.attr. *Caesar hostes petendi cupidus fuit.* Acc.obj. Gerundive: Gen.attr. *Caesar hostium petendorum cupidus fuit.* CNG
PCK Student	**'Difficult translation'** What typical student errors can occur when translating the following sentence? Name and explain as many as possible! *Hac audita pugna maxima pars Aquitaniae sese Crasso dedidit obsidesque ultro misit.* (Caes. Gall. 3,27,1)	**'Difficult translation'** Two correct answers are, for example: 1) Because of the similarity of the endings, the references are made incorrectly. 2) Because of the postposition of *-que*, *obsides* is drawn to the first part of the main clause.
PCK Material	**'Categorization of a language exercise'** Indicate as many different learning goals as possible that could be addressed by the following exercise from a Latin book! "Give the prefix in the basic form and the infinitive of the verbum simplex (with German translation) in each case: *oppressit, collocavit, surrexissem, apparuit, cognovi, afferte, allatus esset, commota, occurrit, accedunt, irrupimus, effugiturus, completa, suppetivit, traduxisti, redeo*."	**'Categorization of a language exercise'** Two correct answers are, for example: 1) This exercise is designed to make students aware of the rules of full and partial assimilation of consonants. 2) The students will learn basic principles of word composition in Latin and thus expand their vocabulary.

('material', four items). Teachers need to know, for example, how to introduce new grammatical phenomena or present vocabulary, how to explain complex philosophical theories, or how to make the specifics of an author or work understandable according to the students' level of learning, and which of the various modes of presentation is most likely to be effective for learning and at what point. Also, Latin teachers should know which words, grammatical or syntactical constructions typically cause comprehension difficulties and misconceptions for students and how they can counter these a priori or post hoc or use them specifically as learning opportunities. They need to be aware of how to control individual learning processes through the way they select and present materials and to contribute to students' cognitive activation. For this purpose, they should also know, among other things, which of the numerous different forms of exercise is most appropriate for which learning level, when it is useful to include which cultural realia, or which texts are suitable for joint reading in class or as an examination task.

The total of 16 items are thematically distributed among such different teaching contents of grades 5 to 13. They are arranged in ten vignettes, which are formulated as action-oriented hypothetical scenarios based on the professional practice of Latin teachers and in which the participants – despite a relatively short time required for completion – are placed in typical challenging situations when teaching or during the preparation or follow-up of lessons. A total of 15 out of the 16 items have an open-response format and demand the naming of (substantially different) processing and solution approaches. This not only reduces the risk of merely testing recognition effects or tendencies of social or didactic desirability of responses and does not limit the instructional creativity of teachers (Baxter & Lederman, 1999). Moreover, it enables the measurement of a broad theoretical-formal as well as experiential PCK tied to episodes and provide information about teachers' individual logic of their knowledge base. According to Shulman (1986; 1987) and Bromme (2008), this represents the comprehensive, available repertoire of PCK that allows teachers to spontaneously develop a wide variety of adequate options for action in a variety of critical teaching situations, to choose the most appropriate one in each case, and to act flexibly. Sample items for all three facets of PCK can be found in Table 1.

3.2.3. Scoring scheme

To evaluate the responses in the CK and the PCK tests, a coding scheme with detailed descriptions and concrete examples of incorrect and correct answers was created based on theoretical approaches, relevant research literature and consensus, and – as far as available – empirical findings. This was also expanded, refined, and optimized in preceding pilot studies. Missing or incorrect responses were scored with 0 points, correct ones with 1 point; for tasks that call for multiple processing and solution alternatives, the score is the sum of all correct responses.

In this coding manual, two experienced pre-service Latin teachers with good academic performance were trained. They independently coded the 21 open-ended CK and PCK items in 117 test booklets (54% of all test booklets). Their mean agreement, determined based on the ordinal scoring system using Spearman's ρ as an indicator of interrater reliability (Shavelson & Webb, 1991), was $\overline{\rho}_{CK} = .79$ ($SD = .04$, range .72–.83) for the CK items and $\overline{\rho}_{PCK} = .82$ ($SD = .15$, range .56–1.0) for the PCK items, respectively. Cases in which the two raters disagreed were discussed together with the test developers and a score was finally determined by consensus.

3.2.4. Procedure

For the pre-service teachers, the CK and PCK tests were carried out in the context of relevant university courses, for the teachers mostly in the afternoon of a workday. Participation was voluntary and unpaid and unrelated to required course work or in-service training. The country-specific ethical and data protection regulations were considered, a strictly confidential handling of the collected data was assured, and informed consent was obtained from all participants before they started to complete a short questionnaire on a few demographic details prior to the testing.

The administration of the CK and PCK tests was supervised by a trained test administrator and took place as a power test with no time limit. The average time required to complete the 26 items was approximately 90 min (approx. 30 min for the CK and 60 min for the PCK instrument). Auxiliaries such as dictionaries, encyclopedias, reference books, or translations were not permitted.

3.3. Data processing and preliminary analyses

3.3.1. Data transparency, openness, and processing

All data and analysis code have been made publicly available at the Open Science Framework (OSF) and can be accessed at https://osf.io/72ku9/. Data pre-processing and all analyses were conducted using R statistical software (R Core Team, 2021) and the add-on packages 'car' (Fox & Weisberg, 2019), 'lavvan' (Rosseel, 2012), and 'psych' (Revelle, 2021). Effects for differences and correlations are interpreted according to Cohen's (1992) criteria; evaluation of model fit indices follows Hu and Bentler (1999) as well as the related caveat formulated by Heene et al. (2011). They recommend values of $\chi^2 \leq 3$ *df*, $p \geq .01$, *CFI* (Comparative Fit Index) $\geq .95$, *RMSEA* (Root-Mean-Square Error of Approximation) $\leq .08$ and *SRMR* (Standardized Root Mean Residual) $\leq .10$ for an acceptable model fit (cf. also Lindl et al., 2020; Schermelleh-Engel et al., 2003).

The six sum scores considered below were approximately normally distributed (skewness ranged from −0.24 to 0.23; kurtosis ranged from −0.87 to −0.38) and had no missing values due to the coding (cf. coding scheme). Several covariates, however, yielded missing values: grade point average (GPA) of 'Abitur' (5%), grade of first or second state examination (concluding the first academic or second practice-oriented phase of teacher training: 21% and 24%, respectively), semester (2%), years of professional experience (3%). These were only considered in individual further analyses and were estimated there using the full information maximum likelihood algorithm (e.g., Enders, 2010).

3.3.2. Confirmatory factor analysis

The structure of Latin teachers' professional knowledge was investigated using a confirmatory factor analysis in which CK and PCK were modelled as latent constructs based on their manifest indicators (cf. Fig. 1a). To obtain robust parameter estimates given the total of 26 items of the CK and PCK tests and the present sample of 216 teachers, we used the scores of the subscales or appropriately formed parcels as indicators instead of relying on the scores of individual items. For PCK, the sum scores of the three theoretically formed knowledge facets 'instruction', 'student', and 'material' were suitable here; for CK, the items were grouped into three manifest parcels according to the recommendations of Little et al. (2002). This resulted in an appropriate parameter-to-person ratio of 1:16.6 (for details, Kline, 2011; Little et al., 2002; Marsh et al., 1998).

3.3.3. Multigroup analysis

This ratio between parameters and participants was also tolerable (1:8.1) in the further specified multigroup model (Fig. 1b). With this, on the one hand, the differences between students and teachers were analyzed according to the third research question. On the other hand, this countered the objection that tests developed for teachers' professional knowledge are summarily applied to different populations of pre-service and in-service teachers (e.g., Kleickmann et al., 2013, 2014). This is because, before the latent means and correlations of the two groups can be compared, it is necessary to examine whether the constructs measured have the same meaning for both (e.g., Vandenberg & Lance, 2000). To do this, a series of model tests ranging from configural (M_0: equivalence of model form) to partial scalar invariance

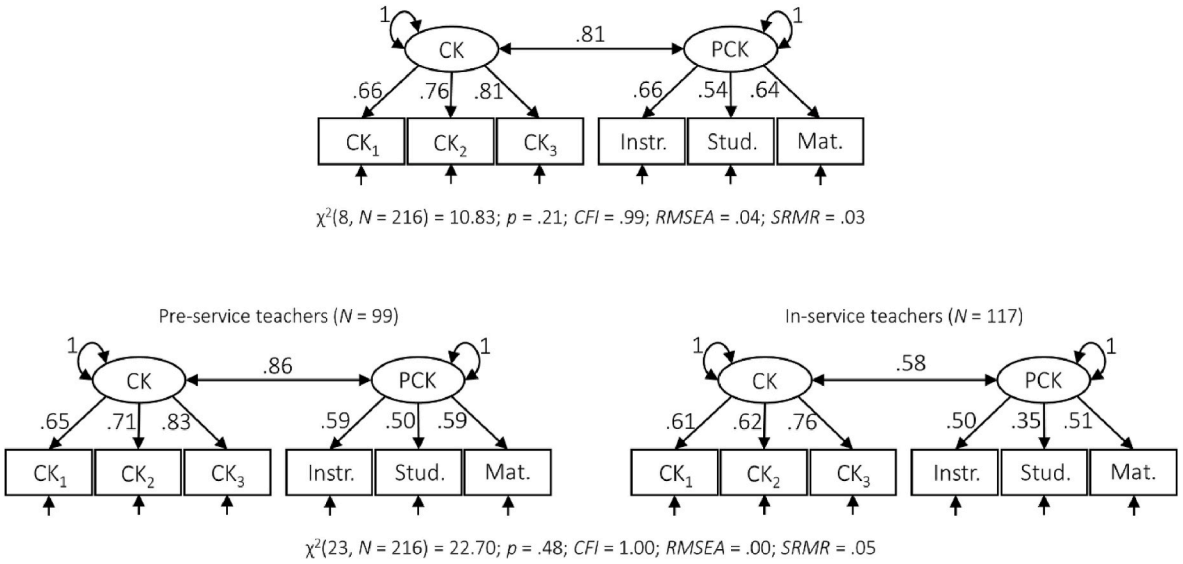

Fig. 1. (a) Confirmatory factor model for the whole teacher sample, (b) multigroup model for pre- and in-service teachers.
Note. Instruction, student, and material are the subscales of pedagogical content knowledge (PCK); CK_1, CK_2, and CK_3 are the parcels of content knowledge (CK). Standardized model parameters are shown. Values of $\chi^2 \leq 3df$ (df = degrees of freedom), $p \geq .01$, *CFI* (Comparative Fit Index) $\geq .95$, *RMSEA* (Root-Mean-Square Error
of Approximation) $\leq .08$, and *SRMR* (Standardized Root Mean Residual) $\leq .10$ indicate acceptable model fit (e.g., Hu & Bentler, 1999; Schermelleh-Engel et al., 2003).

Table 2
Series of models investigating measurement equivalence for the multigroup model.

Model							Difference: M_{i-1}, M_i		
	χ^2	*df*	*p*	*CFI*	*RMSEA*	*SRMR*	$\Delta\chi^2$	Δdf	*p*
Configural invariance (M_0)	20.06	16	.22	.98	.05	.04	–	–	–
Metric invariance (M_1)	20.83	20	.41	1.00	.02	.04	.76	4	.94
Scalar invariance (M_{2a})	33.21	24	.10	.96	.06	.06	12.39	4	.01
Partial scalar invariance (M_{2b})[a]	22.70	23	.48	1.00	.00	.05	1.88	3	.60

Note. Values of $\chi^2 \leq 3df$ (df = degrees of freedom), $p \geq .01$, *CFI* (Comparative Fit Index) $\geq .95$, *RMSEA* (Root-Mean-Square Error of Approximation) $\leq .08$, and *SRMR* (Standardized Root Mean Residual) $\leq .10$ indicate acceptable model fit (e.g., Hu & Bentler, 1999; Schermelleh-Engel et al., 2003). [a] intercept of ck_2 freely estimated.

(M_{2b}: equivalence of parcel intercepts while releasing the intercept of ck_2) were conducted (Table 2). According to Byrne et al. (1989), measurement equivalence could be assumed in both groups and the model could be used to test the hypotheses $H_{1.2}$ to $H_{1.4}$.

3.3.4. Power analyses

Following the method of Satorra and Saris (1985) and Jak et al. (2021), the statistical power of the latent modelling approaches used was examined to determine for each of the four central hypotheses ($H_{1.1\text{-}1.4}$) the probability of rejecting the null hypothesis ($H_{0.1\text{-}0.4}$) if it was false (Table 3). Null models were specified for $H_{0.1}$ to $H_{0.4}$ (e.g., for $H_{0.1}$, the latent correlation in Fig. 1a was restricted to 1) and the difference was formed from the chi-square test statistic of the original model (e.g., with latent correlation of 0.81; Fig. 1a) and the corresponding null model. This yielded a chi-squared (difference) test statistic equal to the noncentrality parameter required to determine statistical power using a noncentral chi-squared distribution. As shown in Table 3, the statistical power was sufficient to test the hypotheses based on the present sample ($N = 216$), given a targeted minimum of $1 - \beta = .8$.

4. Results

Before examining the hypotheses about the level and the structure of the CK and PCK in the two groups (*Qu 3*), the psychometric properties of the test scales are reported very briefly (*Qu 1*) and the question of the discriminability of the two knowledge categories (*Qu 2*) is considered on the whole sample.

Table 3
Power Analysis ($N = 216$; $\alpha = .05$).

Null hypothesis to reject	$\Delta\chi^2$	Δdf	Power ($1 - \beta$)
H_{01}: Latent correlation $r_{PCK,\ CK}$ is 1 in the total sample.	12.68	1	.95
H_{02}: Latent mean of CK is identical in both groups.	35.09	1	1.00
H_{03}: Latent mean of PCK is identical in both groups.	67.73	1	1.00
H_{04}: Latent correlation $r_{PCK,\ CK}$ is identical in both groups.	5.51	1	.65

CK: content knowledge, PCK: pedagogical content knowledge.

4.1. Psychometric properties of PCK and CK, descriptive information, and correlations with external criteria

4.1.1. Psychometric Properties

The psychometric properties of the CK (10 items) and PCK (16 items) scales can be described using parameters of classical test theory. Both scales showed satisfactory reliabilities, with an $\alpha = .78$ for the CK scale and $\alpha = .72$ for the PCK scale. The items belonging to each scale discriminated adequately, as was evident from their (part-whole corrected) item-total correlations (CK: $M = .45$, $SD = .13$, range .17–.59; PCK: $M = .31$, $SD = .10$, range .15–.46). In addition, all teachers ($n = 117$) were asked to rate all items on a four-point scale (1 = does not apply, …, 4 = applies) regarding their relevance to everyday teaching practice, which can be considered an indicator of the items' face validity. On average, teachers rated the items as very relevant to their practice (CK: $M = 3.34$, $SD = 0.51$, range 2.88–3.59; PCK: $M = 3.68$, $SD = 0.31$, range 3.18–3.90), so that overall face validity of the test could be considered satisfactory.

4.1.2. Descriptive information

The means and standard deviations for the scales CK and PCK and their parcels and subscales, respectively, can be found together with their corresponding intercorrelations in Tables 4 and 5. Table 4 shows the descriptive scores for the total sample; Table 5 differentiates between pre-service and in-service teachers. Overall, these analyses indicated that the tests provide a reliable and valid measurement of the knowledge categories CK and PCK among (pre-service) Latin teachers.

4.1.3. Correlations with external criteria and convergent validity

Examination of product-moment correlations (of zeroth order) between CK and PCK with distal indicators of school, academic, and professional success revealed predominantly expectancy-conforming relationships, indicating convergent validity of the test scales. For example, CK ($r = -.40$, $p < .01$) and PCK ($r = -.53$, $p < .01$) were, descriptively, slightly more highly associated with GPA for pre-service than for in-service teachers (CK: $r = -.26$, $p < .01$; PCK: $r = -.27$, $p < .01$),[1] with better GPA associated with higher test scores in both knowledge categories. In addition, for in-service teachers, the grade in the first state examination that concludes university education (CK: $r = -.27$, $p < .01$; PCK: $r = -.21$, $p = .04$), as well as the grade in the second state examination at the end of the induction phase (CK: $r = -.31$, $p < .01$; PCK: $r = -.45$, $p < .01$), showed a significant relationship with professional knowledge.

Table 4
Measures of teachers' professional knowledge (subscales and parcels): Correlations and descriptive statistics for the total teacher sample.

Correlations	Instruction	Student	Material	ck_1	ck_2	ck_3
PCK						
Instruction (6 items)	1.00					
Student (6 items)	.45	1.00				
Material (4 items)	.40	.30	1.00			
CK						
ck_1 (4 items)	.33	.22	.35	1.00		
ck_2 (3 items)	.40	.33	.46	.50	1.00	
ck_3 (3 items)	.41	.34	.45	.55	.60	1.00
M	8.46	7.32	6.71	5.66	5.47	5.69
SD	3.04	1.96	2.46	2.77	2.93	2.79

Note. Instruction, student, and material are the subscales of pedagogical content knowledge (PCK); ck_1, ck_2, and ck_3 are the parcels of content knowledge (CK). All correlations are significant at $p \leq .01$.

Table 5
Measures of teachers' professional knowledge (subscales and parcels): Correlations and descriptive statistics by teacher group.

Correlations	Instruction	Student	Material	ck_1	ck_2	ck_3
PCK						
Instruction		.47**	.24**	.31**	.28**	.43**
Student	.26**		.26**	.30**	.40**	.33**
Material	.25**	.11		.29**	.41**	.43**
CK						
ck_1	.18*	.01	.24**		.49**	.56**
ck_2	.19*	.06	.21*	.39**		.56**
ck_3	.18	.19*	.25**	.45**	.48**	
Pre-service teacher						
M	7.03	6.66	5.47	4.81	3.89	4.55
SD	2.99	1.89	2.40	2.68	2.41	2.52
In-service teachers						
M	9.67	7.89	7.75	6.38	6.80	6.66
SD	2.52	1.85	1.99	2.65	2.66	2.65
Cohen's *d*	0.97	0.66	1.05	0.59	1.15	0.82

Note. The correlations for pre-service teachers and in-service teachers are above and below the diagonal, respectively; instruction, student, and material are the subscales of pedagogical content knowledge (PCK); ck_1, ck_2, and ck_3 are the parcels of content knowledge (CK); positive *d* values indicate that in-service teachers outperformed pre-service teachers. According to Cohen (1992), $d = 0.3$ represents a small effect, $d = 0.5$ represents a medium effect, and $d = 0.8$ represents a large effect. *: $p \leq .05$, **: $p \leq .01$. All mean differences are significant at $p \leq .01$.

CK ($r = .26$, $p < .01$), but not PCK (PCK: $r = .01$, $p = .91$), was related to the number of semesters of Latin studies of the pre-service teachers, which is plausible given the low proportion of courses on subject matter teaching and learning during academic training (see Subsection 1.2). The teachers' professional experience – measured by the number of years in the job – did not correlate with either of the professional knowledge categories (CK: $r = .13$, $p = .17$; PCK: $r = -.07$, $p = .45$).[2] This finding in particular seems worthy of discussion against the theoretical background (McDaniel et al., 1988; cf. Section 5).

4.2. Distinguishability of PCK and CK

To address *Qu 2*, a confirmatory factor analysis was conducted based on the total sample, the results of which can be seen in Fig. 1a. Both their global and local fit indices indicated that the structure of domain-specific professional knowledge of Latin teachers was well reflected by two latent constructs representing CK and PCK (e.g., Hu & Bentler, 1999). The high latent correlation between the two knowledge categories ($r = .81$), indicated that teachers with higher CK tended to also have higher PCK and vice versa.

To test the first hypothesis, whether CK and PCK are empirically distinguishable constructs, a second model was estimated in which their latent correlation was fixed to 1. This led to a statistically significant deterioration of the model fit, as could be shown using a chi-square difference test: $\Delta\chi^2(1, N = 216) = 12.68$, $p < .01$. From a statistical point of view, it was therefore indicated that CK and PCK represent different constructs despite their relatively high correlative relationship – at least considering the total sample.

4.3. Level of knowledge and cognitive connectedness in the two groups

The mean level in CK and PCK differed substantially, as expected, between pre-service and in-service teachers (cf. Table 5). Regarding Cohen's *d* (1992), the overall differences between the groups and especially concerning the PCK facets were particularly evident. This underlined the assumption that teachers already have a more extensive

[1] Note that in Germany, lower grades signify higher (better) performance, which is why the correlations have negative signs.

[2] Graphical inspection and further analysis also ruled out non-linear relationships.

professional knowledge due to their training and practical experience (cf. $H_{1.2}$ and $H_{1.3}$). At the same time, this was an indication of the training sensitivity and criterial validity of both the CK and the PCK tests. This result was also supported by the findings of the multigroup model, in which CK and PCK were estimated simultaneously in both groups as latent constructs (eliminating measurement error; Fig. 1b). In-service teachers had a more comprehensive knowledge base than pre-service teachers in both knowledge domains, as again their latent means (CK: −2.06; PCK: −2.64) were substantially different from those of in-service teachers, each fixed at 0. The corresponding effect sizes were $d = -1.01$ for CK and $d = -1.76$ for PCK. These differences were also statistically significant, as evidenced by two separate chi-square difference tests between the model in Fig. 1b and models in which the latent means of CK and PCK are fixed equally (i.e., at 0) across groups (CK: $\Delta\chi^2(1, N = 216) = 35.09,\ p < .01$; PCK: $\Delta\chi^2(1, N = 216) = 67.73,\ p < .01$).

Furthermore, it was evident from the multigroup model (Fig. 1b) that the knowledge structure also differed between the two groups ($H_{1.4}$). Namely, the latent correlation between CK and PCK was not the same in both groups and was substantially higher for pre-service ($r = .85$) than for in-service teachers ($r = .58$). The difference between these correlations was statistically significant, as suggested by a chi-square difference test ($\Delta\chi^2(1, N = 216) = 5.51,\ p = .02$). Since, as further analyses showed, the two groups did not differ significantly with respect to their cognitive entrance selectivities, which were approximated by the high school GPA (pre-service: $M = 1.67$, $SD = 0.49$, in-service: $M = 1.77$, $SD = 0.47$; $t(204) = -1.48$, $p = .14$, $d = 0.21$); thus, the differing means and correlations could not be directly attributed to different entry qualifications and differences prior to teacher training. The latter, too, required comparable prerequisites in its basic features for both groups, possessed a corresponding curriculum, and posed similar requirements.

5. Discussion and limitations

5.1. Discussion

Considering the results presented the newly developed test for Latin teachers' domain-specific professional knowledge shows good psychometric properties (e.g., evaluation objectivity, internal consistency, face validity). Using this test, Shulman's (1986; 1987) hypothesis that CK and PCK represent two distinguishable, but not disjunctive categories of domain-specific professional knowledge was confirmed for the first time for Latin teachers. The magnitude of the correlation was like that found by Krauss, Brunner et al. (2008), Krauss et al. (2013) or Schmidt et al. (2011) for mathematics, by Kleickmann et al. (2014) for biology, chemistry, physics and mathematics, and by Großschedl et al. (2014, 2015) for biology. It is similar to the results of Blömeke et al. (2013) for German, English, and mathematics and König et al. (2016) for English. However, it was slightly higher than the correlations between CK and PCK found by Jüttner et al. (2013) and Kirschner et al. (2017) for biology, chemistry and physics. On the other hand, an assumption often only implicitly made in this research context, that the same professional knowledge test could be used for in-service teachers as well as for pre-service teachers (e.g., Kleickmann et al., 2013, 2014), was also empirically proven here.

In addition, there were hypothesis-consistent differences between pre-service and in-service teachers regarding their mean CK and PCK, which reveal the different professional status of both groups in large effect sizes and, as far as possible based on cross-sectional data, first indications of the effectiveness of teacher training. In particular, it seems plausible that the difference in the PCK was somewhat larger than in the CK, since pre-service teachers have already undergone the predominantly theory-oriented academic training at the university, but they lack the intensive practice-oriented training and teaching experience of the induction phase that in-service teachers have received (Cortina & Thames, 2013; Schilcher et al., 2021). While the preparation for the first state examination at the end of the university phase has conditions of deliberate practice (e.g., Ericsson, 2006) regarding the CK, the induction phase at the school has them regarding PCK, so that the results reflect the time-shifted emphasis in the professionalization process of teachers in Germany. We consider this as evidence for the curricular validity of the tests, but at the same time this result also raises the question to what extent such a pronounced varying focus on content in teacher education makes sense.

The large differences in all facets of PCK and the missing correlation between PCK and the number of semesters of pre-service teachers indicate that the development of PCK should already receive more attention during university training and that additional or at least differently designed learning opportunities would be necessary. The minimum of eight ECTS points (European Credit Transfer and Accumulation System) provided for this purpose in the Bavarian teacher education curriculum, for example, seems (too) scarce for a cumulative and sustainable acquisition of knowledge (especially in comparison to CK, where about the tenfold number of points must be acquired by the end of the study programme, see also Section 1.2). Apart from a quantitative increase, however, a high-quality design and use of existing learning opportunities can also offer valuable approaches. More practice may only lead to the establishment or freezing of supposedly unfavourable behavior and routines (Bromme, 1992; Schocker-v. Ditfurth, 2001; Weinert, 1996). Instead, pre-service teachers should be given opportunities during their university training to reflect on their own and other people's teaching, to analyze it based on theory and specific cases, and to train concrete core practices – for example, explaining and representing subject-related content, diagnosing domain-specific misconceptions, or creating tasks appropriate to the learning level (e.g., Fraefel & Scheidig, 2018; Grossman, 2018; Schilcher et al., 2021). However, such measures can only be implemented effectively if the didactics of small school subjects such as ancient languages also have the necessary university resources. That there are deficits in this regard is underlined, among other things, by the fact that there are only five corresponding chairs in the German-speaking countries (Kuhlmann, 2020; Lindl & Kloiber, 2017). At other teacher training universities, the subject is usually only represented by seconded teachers.

Furthermore, there was also a difference between pre-service and in-service teachers in the measurement error-adjusted latent correlation of CK and PCK, which was smaller for in-service teachers. This is remarkable, since Krauss, Brunner et al. (2008), when comparing mathematics teachers of non-academic and academic track schools, find just an inverse relationship, that is, the larger correlation for individuals with more extensive knowledge and explain this finding with reference to expertise research. Thus, they conclude that the areas of knowledge are better structured and more interconnected among experts (e.g., Berliner 2001, 2004; Gruber & Harteis, 2018) and therefore the correlation between CK and PCK is also higher among academic track teachers. In principle, the high correlation between CK and PCK among Latin teachers does not contradict such an assumption. Nevertheless, CK and PCK emerge much more clearly as separate, but not disjunctive constructs (than among the academic track mathematics teachers) and possibly form more clearly defined and structured categories of knowledge, both within themselves and in relation to each other. Perhaps due to insufficient opportunities during teacher training at university, pre-service teachers apparently do not yet reach this degree of concretization. This sometimes also benefits from prototypical case knowledge from individual teaching practice, so that in the progressive professionalization process of Latin teachers, the special thing is not necessarily to be sought only in a fusion of knowledge from different origins (Bromme, 1997; Depaepe et al., 2013; Shulman, 1987). Rather, we can also assume an increasing specialization and specification of knowledge categories which can be activated and used as modular units relatively independently of each other and combined in a variety of ways, influenced by individual affective-motivational characteristics

such as beliefs or values (Bromme, 1992; Schocker-v. Ditfurth, 2001).

Finally, it is also worth noting the initially counterintuitive finding that there was no relationship between domain-specific professional knowledge and the professional experience of Latin teachers, especially since they rated the items per se as highly relevant to their profession (cf. Section 4). Because similar findings are now available in numerous other studies (e.g., Groβschedl et al., 2014; Kirschner et al., 2017; Kleickmann et al., 2013; Krauss, Baumert, et al., 2008; in sum Lindl & Krauss, 2017), the meaning of Shulman's (1986, 9; cf. Berliner, 2004) concept of a "wisdom of practice" needs to be critically questioned. Teaching and promoting CK and PCK are certainly core content and task of teacher education, but are there any learning opportunities for this at all during professional practice and, if so, enough to trigger a cumulative learning process or are teachers still willing to engage in further training (Groβschedl et al., 2014)? Do classrooms represent suitable feedback systems for further development on the part of teachers or is there an early solidification in too little reflected routine (Schocker-v. Ditfurth, 2001; Weinert, 1996), which in turn is detrimental according to Ericsson's (2006) deliberate practice theory as well as Hattie's (2009) findings? Is the undoubted growth in teachers' professional experience possibly more evident in other aspects of professional competence (e.g., GPK, situational skills, self-regulation, motivation, beliefs, values, etc.)? To what extent are existing instruments sufficiently sensitive to teachers' increasing experience-based knowledge (Groβschedl et al., 2014) or would this possibly require different item contents and formats that have an even stronger focus on action (Lindl & Krauss, 2017)? There is a need for further research on these issues.

5.2. Limitations

The last thoughts highlight the central limitation of the present study: the lack of longitudinal data. Therefore, remarks that are cautiously related to aspects of knowledge acquisition and development must be considered under this very caveat and can and should provide first indications and starting points for further investigations only. The present tests on the CK and PCK of Latin teachers are – also because of their pioneering character – explicitly not a high-stakes instrument to be used for purposes of teacher licensing and certification (such as, e.g., Cambridge Teaching Language Assessment or Educational Testing Service). Rather, it is intended to be used, for example, to evaluate the aptitude of pedagogical personnel in an objective, reliable, and valid way. It also makes it possible for the first time to monitor implementation measures and programs for the education and training of Latin teachers and phases, sequences, or dependencies in the acquisition processes of Latin-related CK and PCK (e.g., for mathematics, Kleickmann et al., 2014; Tröbst et al., 2018, 2019).

Another limitation of the present study is the convenience sample, which may represent a positive selection due to voluntary study participation. Its statistical power was sufficient to investigate the focused hypotheses but only includes (prospective) high school teachers in the German state of Bavaria. Although it can be assumed that certain parallels exist between the Bavarian and other school systems and teacher education systems, it nevertheless remains unclear to what extent certain research findings are transferable to other countries or cultural contexts (see also König et al., 2016). Here, replication studies in the primary target population, (prospective) Latin teachers, seem necessary, but also in contrast populations with knowledge of Latin (e.g., classical philologists, historians, or librarians) for discriminant validation would seem useful (cf. Krauss, Baumert, et al., 2008).

Finally, despite a careful theoretical construction process, high face validity, and expected correlations with external indicators, the present professional knowledge test only represents a certain section of the domain-specific professional knowledge of Latin teachers in the items. Admittedly, it would also have been possible to focus on other content areas or to record additional knowledge facets. In addition, the selected item and response format focus primarily on cognitive dispositions of teachers, possibly limiting their action relevance and ecological validity. However, this approach also has many advantages, including a greater level of abstraction, and has so far proven successful in assessing teachers' professional knowledge. This is because this measurement method in particular has been able to provide empirical evidence of significant correlations between this and teaching quality and student achievement, and thus the relevance of CK and PCK to action (cf. Section 1).

Such a prognostic validation is, thus, considered the gold standard against which a domain-specific professional knowledge test should be measured (König et al., 2016). At the same time, this implies several questions: How are cognitive and affective-motivational characteristics interrelated in Latin teachers? How do they mutually influence their development, level, and type? Can the chain of effects from teacher competence (including cognitive and affective-motivational characteristics) via teaching quality to student performance, as assumed, for example, in the cascade model (Krauss et al., 2020) and proven with varying success for mathematics and science subjects (cf. Section 1, and Blömeke et al., 2022), can also be demonstrated for Latin?

6. Conclusion

Using a validated test instrument for the professional knowledge, CK and PCK, of high school Latin teachers, this study extends the research discourse on teachers' domain-specific competencies to include another school subject and specific findings from Latin. The findings also support – for Latin teachers – Shulman's hypothesis Shulman (1986, 1987) that CK and PCK are two separable, but not disjoint categories of professional knowledge, and can be objectively, validly, and reliably measured for both pre-service and in-service teachers. Differences in mean knowledge levels and interrelationships between CK and PCK on the one hand, and between both knowledge categories and external criteria on the other hand, can be attributed to different phases of teacher education and their specifics. They indicate their strengths (e.g., average high PCK after the induction phase) and weaknesses (e.g., average low PCK during the university phase), and thus offer an evidence-based foundation for their optimization (e.g., through additional learning opportunities under deliberate practice conditions during the different training phases, but also later in the profession). However, final conclusions are only possible to a limited extent due to the explicit focus of the study on cognitive characteristics of teachers and of the cross-sectional sample. In any case, more research and, in particular, longitudinal studies are needed to further analyze the development of subject-specific competencies of Latin teachers during their training or even to investigate their effectiveness regarding teaching quality and student achievement.

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Declaration of competing interest

The authors declare no potential conflict of interest that could have appeared to influence the work reported in this paper.

Data availability

All data and analysis codes presented in this study have been made publicly available at the Open Science Framework (OSF) and can be accessed at https://osf.io/72ku9/

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