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Research Article

Towards a Comprehensive Model of AI-related Competences for Teachers: Insights from a Scoping Literature Review

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Abstract

The increasing integration of AI into educational practice places new demands on teachers and requires an expanded, systematically grounded competence profile. While numerous studies address AI in education, a structured overview of existing AI-related competence models for teacher education remains lacking. This scoping review aims to systematically examine and synthesise competence models that address AI-related competences for teachers, with a particular focus on their conceptual foundations and competence dimensions. Therefore, a scoping review was conducted across three databases (Web of Science, ERIC, and Fachportal Pädagogik). Forty-two studies published between 2016 and March 2025 were included, of which seventeen explicitly focus on AI. Both independently developed competence models and adapted frameworks, including those based on TPACK or DPaCK, were analysed using a deductive-inductive qualitative content analysis grounded in Weinert's competence definition with the help of Rayyan and MAXQDA. The results reveal a strong emphasis on cognitive competence dimensions, particularly technical understanding of AI systems, ethical reflection, and the pedagogical use of AI tools. In contrast, motivational, volitional, and social dimensions, as well as explicit competences related to teaching about AI, are scarcely addressed. Additionally, few models provide a coherent structure that integrates AI as both a teaching tool and a curricular subject. Based on these findings, the paper proposes a conceptual, layered competence model that integrates (1) instructionally relevant AI knowledge, (2) AI-related curricular content, (3) a distinct dimension of AI didactics focused on teaching about AI, (4) subject-specific didactics, and (5) transversal motivational, volitional, and social dispositions, complemented by progression levels. This model offers a structured foundation for curriculum design, teacher education, and future empirical validation of AI-related teacher competences.

Keywords

AI-related Competence, Competence Model, Teacher Education, Systematic Literature Review

1. Introduction

The increasing use of AI technologies in private and professional life is making AI-related competences continuously more important [1, 2]. The relevance is acknowledged by the European Council, which calls for «a sufficient level of AI literacy of [...] persons dealing with the operation and use of AI systems» [3]. This goal is to be achieved through awareness, training, and education measures, especially in schools [4]. At the same time,

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AI tools raise pedagogical and ethical concerns in education, demanding a better understanding of systems and algorithms for evaluating their outputs [5, 6].

To implement such measures effectively in education and to account for ethical and pedagogical implications, teachers and higher education instructors must possess appropriate AI-related competences. Furthermore, it is necessary to integrate these into curricula [7-9]. Initial approaches aiming at fostering such competences in future teachers are presented in higher education concepts by Seyferth-Zapf, Mikula, and Ehmann [10] or Schmidt [11]. Additionally, there is a growing demand for a comprehensive competence model that can serve as a foundation for educational measures in this area [10]. Therefore, conducting a scoping literature review on AI-related teacher competences is necessary in order to gain a broad and structured overview of the topic.

Although several literature reviews have already been conducted in the field of «AI and education,» these have not primarily focused on competence models. Instead, they have addressed topics such as definitions of AI in educational contexts [12], the conceptualisation of AI literacy [13], understandings of AI literacy in teacher education [14], or reviews on AI-related questionnaires [15]. However, a systematic literature review that specifically investigates competence models related to the use of AI in the context of teacher education is still lacking.

This study addresses this research gap by conducting a scoping review to provide a systematic overview of existing competence models for AI-related competences in teaching. A scoping review is particularly suitable for mapping the existing literature and therefore identifying, organising, and analysing the structures, concepts, and content dimensions of existing models [16]. The aim is to promote a deeper understanding of the requirements emerging for actors in education policy, teacher training, and teaching practice. Therefore, the study is driven by the following research questions:

RQ1: How can the academic literature on (AI-related) competence models in teacher education be systematically categorised in terms of publication type, geographical origin, target group, and thematic focus?

RQ2: What competence dimensions and sub-competences characterise existing AI-related competence models for teachers?

Another challenge is the inconsistent use of key terms in educational research, including «literacy», «competence» and «competency». In the Anglo-American context, «literacy» is increasingly interpreted in a domain-specific and practice-oriented perspective [17, 18]. In contrast, in European discourse, the term «competence» emphasises the integration of knowledge, skills, motivation, and responsibility [19-21]. Meanwhile, the term «competency», also common in Anglo-American literature, typically focuses on observable performance indicators [22]. In this paper, the term «competence» is used, since it is well established as a comprehensive umbrella concept in the European educational discourse. It enables not only cognitive and functional aspects but also motivational and social dimensions of individual agency to be taken into account [21-23]. Thus, it provides a conceptual foundation characterized as both theoretically robust and applicable in educational research and pedagogical contexts.

2. Methods

This study employs a scoping review as its methodological framework to systematically examine existing competence models concerning AI-related competences for teachers. A traditional systematic review would have been less suitable, as such reviews are typically focused on narrow research questions and require a critical appraisal of study quality [24, 25]. In contrast, the current study addresses a broad, conceptual field encompassing various model approaches, terminologies, and structural logics. A scoping review suits the objectives of mapping this field, identifying core dimensions, and using this foundation to inform the development of a competence model.

The methodological approach follows the framework proposed by Arksey and O'Malley [26], extended by Levac, Colquhoun, and O'Brien [24]. Based on the research questions outlined in the introduction, a scoping literature search was conducted, guided by clearly defined inclusion and exclusion criteria. The selection process followed a two-stage screening procedure, while relevant data were extracted using a structured charting template (see Table 2). Subsequently, the articles were analysed qualitatively to identify central competence dimensions. Results are presented in accordance with the PRISMA-ScR checklist and visualised using a PRISMA flow diagram [25, 27].

2.1. Identification of Relevant Studies

The database search was conducted on March 23, 2025, in Web of Science, ERIC and Fachportal Pädagogik. These databases were chosen to include both German-language and international publications. Two search strings were used:

1) (AI OR «artificial intelligence») AND (literacy OR skills OR knowledge OR competence)) AND (scale OR test OR questionnaire OR model OR framework)) AND (teachers OR educators)
2) («digital literacy» OR «digital skills» OR «digital competence» OR «digital knowledge») AND (scale OR test OR questionnaire OR model OR framework) AND (teachers OR educators)

The first string targeted studies focusing on AI-related competences of teachers, specifically mentioning competence models, frameworks, or empirical measurement tools. The second string broadened the scope to include teacher digital competence models. This was based on a preliminary analysis revealing that many AI-related models are conceptually grounded in or adapted from broader digital competence frameworks. Examples are DIKOLAN^{KI} by Huwer et al. [28], which builds on the DPACK model by Thyssen et al. [29]

about digital competences of teachers, or Intelligent-TPACK by Celik [30], which extends TPACK [31] to AI competences [10]. To identify such conceptual foundations and examine potential transferability for the AI-related competence models, relevant studies on digital teacher competences were systematically included in the review.

The search was limited to titles, abstracts, and keywords in English and German from 2016 to 2025, since the data corpus is already large. A translation of the search strings into German was not necessary, since pilot tests yielded identical results. The search delivered a total of 5,720 results.

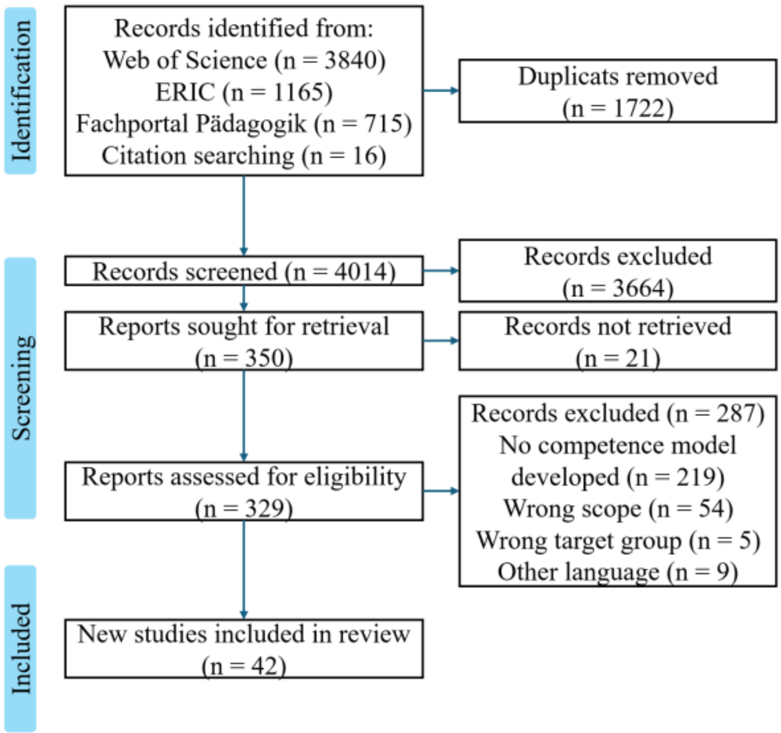

Figure 1. *Study selection.*

2.2. Study Selection

The search results, including associated abstracts, were imported into the review management platform Rayyan. The tool was also used to identify potential duplicates, of which Rayyan automatically flagged n = 2,494. No additional duplicates were found beyond this automated detection, confirming the high reliability of the tool. Entries were only merged when titles were identical, accounting for differences in capitalisation. Using this method, n = 1,356 duplicates were automatically removed. The remaining potential duplicates were manually reviewed, resulting in the exclusion of another n = 366 entries. In total, n = 1,722 duplicates were removed from the corpus (see Figure 1).

After the removal of duplicates, a two-stage screening process was conducted to identify publications that met the previously defined inclusion and exclusion criteria (see Table 1), which were discussed thoroughly with other researchers to ensure argumentative validity [32]. This involved structured discussions with two researchers experienced in educational science. Feedback from these sessions led to several refinements of the inclusion and exclusion criteria, especially regarding the transferability of general models. Since the screening was conducted by a single person, the process was supported by a feature in Rayyan that algorithmically calculates the probability of inclusion or exclusion based on prior assessments and provides corresponding recommendations. This function is designed to reduce potential selection bias in the review process [33]. All final inclusion and exclusion decisions were made by the reviewer following the predefined criteria. Potential risks of algorithmic bias or reinforcement of early screening decisions were mitigated by continuous manual verification and critical reflection, in line with current recommendations for the cautious use of automated assistance in systematic review processes. In the first screening phase, the titles and abstracts of the remaining publications were assessed. During this phase, n = 3,664 publications were excluded, and n = 334 contributions were identified as potentially relevant and moved forward for full-text review. Of these, n = 21 studies could not be included due to the inaccessibility of the full texts.

Table 1. *Inclusion and exclusion criteria.*

Inclusion	Exclusion
Studies on competence models for teachers	Publications without development of a competence model
Publications focusing on AI-specific competences (including outside education if transferable)	Non-educational studies with no AI-related competence focus
Published 2016 – March 2025	Models aimed specifically at students or other specific groups
In German, English, or French	Publications older than 2016
Peer-reviewed articles, conference papers, academic theses, or monographs	Languages other than German, English, or French

In the second screening phase, the full texts of the remaining studies were thoroughly reviewed. As a result, n = 29 studies from the initial systematic database search fully met the inclusion criteria, while n = 284 publications were excluded at this stage. For example, Karataş and Ataç [34] analysed various AI-related competence models in their work, but they did not present a model of their own and were therefore excluded. In addition, a targeted backward search was conducted by scanning the reference lists of all studies included in the full-text review. This yielded n = 16 additional potentially relevant studies, of which n = 13 also met the inclusion criteria and were incorporated into the analysis. The final corpus thus comprised n = 42 publications, which were included in the subsequent analysis (see Figure 1). To ensure high reliability, a retest was carried out with 10% of the studies [35]. Therefore, 31 random articles were reviewed four months after the first full-text review again, and a correlation of Cohen's kappa of .82 was found, indicating almost perfect reliability [36].

2.3. Charting the Data – Data Coding and Processing

To systematically analyse the included studies, a template was developed to extract key information such as author, title, year of publication, disciplinary field, publication type, competence dimensions, target groups, and central findings (see Table 2). In addition, a quantitative descriptive analysis was conducted for all identified studies on competence models, regardless of their AI relevance. This analysis served to provide a structural overview of the field.

Moreover, a qualitative content analysis was conducted using the software MAXQDA, into which the full texts were imported. The detailed qualitative analysis initially focused on those studies explicitly addressing AI-related competences, aligning with the thematic orientation of the review. The decision to conduct an in-depth qualitative content analysis exclusively on those studies was made deliberately. These studies directly engage with AI-specific technological, ethical, and pedagogical requirements and therefore allow for a focused and conceptually coherent analysis of AI-related competences. The remaining studies on digital, media, or information-related competence models were not excluded from the analysis but used as contextual reference points. They served to identify transferable structural elements and to contextualise underrepresented dimensions, most notably the competence of teaching about AI, which is more explicitly developed in adjacent competence domains. This differentiated analytical strategy is consistent with the exploratory and mapping-oriented purpose of a scoping review and supports both depth and breadth of conceptual insight.

The qualitative analysis followed a deductive–inductive approach based on Kuckartz and Rädiker [37], aiming to identify overarching competence dimensions and extract specific competences. Based on the definition of competences by Weinert [20, 21], a set of categories was first developed deductively. These categories were then inductively expanded using a first round of open coding based on the texts. The inductively derived subcategories were grouped under the main deductive categories, and the data were re-coded accordingly. Throughout the process, the category system was continuously refined for better conceptual alignment with the source material. The initial coding was conducted by one researcher. However, selected categories were discussed with other researchers to validate the coding scheme in the form of argumentative validation [32]. This involved structured discussions with two researchers experienced in computer science education and competence modelling. Specifically, the deductive derivation from Weinert [20, 21] and a subset of inductively developed subcategories were reviewed collaboratively. The discussions focused on category definitions, boundary cases, and alignment with theoretical foundations. Feedback from these sessions led to small refinements of category labels, definitions, and groupings. This form of argumentative validation does not aim at establishing interrater reliability but at strengthening theoretical coherence and interpretive transparency. The process of coding and category refinement was repeated multiple times to improve conceptual clarity and ensure accurate representation of the content.

Table 2. *Extract of the charting template.*

Autho	Year	Titel	Field	Publication Type	Main Target Group	Key Message
Williams [38]	(2024)	Impact. AI: Democratizing AI through K-12 Artificial Intelligence Education	AI	Doctoral Thesis	Students	This framework is a competence model for AI education that integrates conceptual knowledge, practical application and critical reflection. Its goal is to empower students to act as technological change agents who not only understand AI but also engage with it ethically.
Wu [39]	(2024)	Digital Literacy: Evolution, Evaluation and Enhancement.	Digital	Contribution in Blended learning	Teachers	This model comprises five dimensions – from digital awareness to professional development – and aims to prepare educators for a technology-driven educational landscape. It is based on international frameworks but was adapted to the Chinese educational context and validated by experts.
Yue et al. [40]	(2025)	Students as AI Literate Designers: A Pedagogical Framework for Learning and Teaching AI Literacy in Elementary Education	AI	Article in Journal of Research on Technology in Education	Students	The competence model includes AI knowledge, skills, ethics, and attitudes as core competences, supported through an iterative design and research process. Additionally, an exemplary intervention within the SAIL framework is presented.

3. Results

A total of n = 42 studies were included in the analysis, of which n = 17 were explicitly focused on AI (see Figure 3). These seventeen studies formed the base for the in-depth qualitative analysis. Following RQ1, this section begins by describing the current state of research on (AI-related) competence models. The second part focuses on core characteristics of existing AI-related models. For structuring the identified competence dimensions, the definition by Weinert [20, 21] is used, which distinguishes between cognitive abilities and skills, and motivational, volitional, and social behaviour and abilities. These dimensions serve the purpose of providing an analytical basis for comparing the various models.

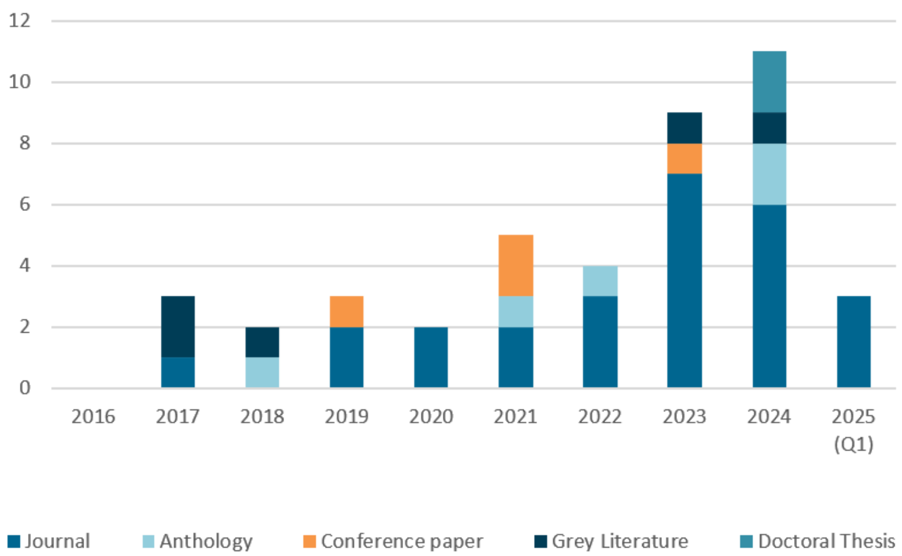

Figure 2. *Distribution by publication type.*

3.1. RQ1: Existing (AI-related) Competence Models

Most competence models identified in this review were published in academic journals (n = 26), typically in the fields of educational science and technology.

Notably, some models were found in grey literature (n = 5) published by organisations including UNESCO or the EU [19, 41] (see Figure 2). The global relevance of the topic is reflected in the geographical distribution of the first authors and the increasing number of publications (see Figures 2 & 3). The majority of first authors came from China (n = 10) and Germany (n = 8). Other contributing countries included Spain (n = 5), the UK (n = 3), the USA (n = 3), France (n = 2), Switzerland (n = 2), and Australia, Belgium, Fiji, Finland, Greece, Luxembourg, Malaysia, Nepal, and South Africa (each n = 1).

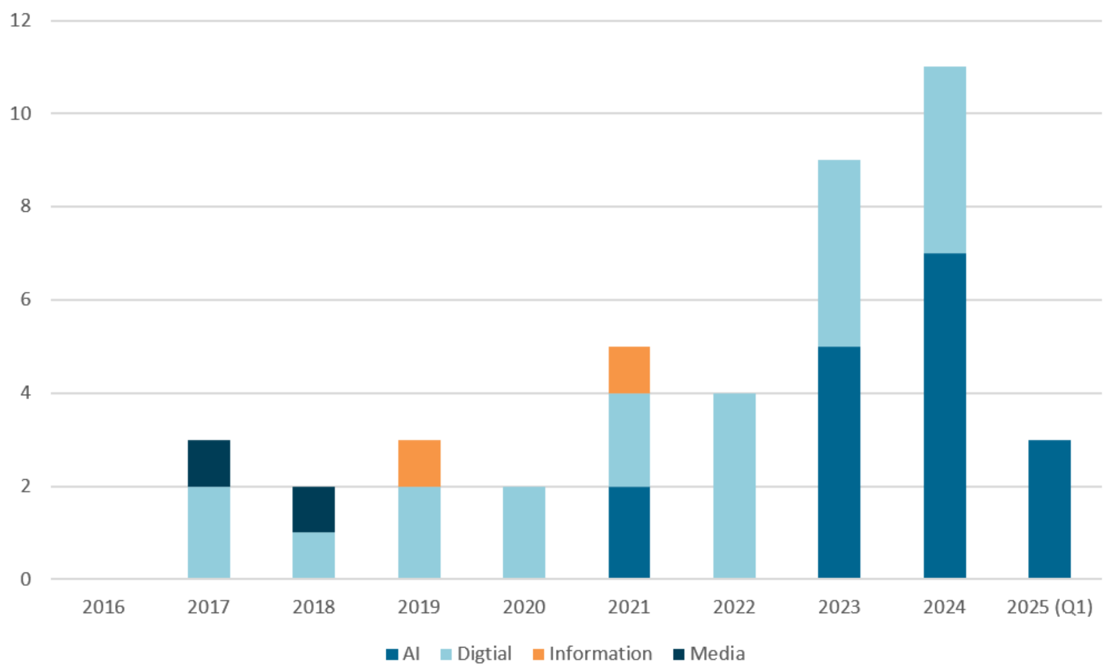

Figure 3. *Distribution of publications by focus.*

Of the 42 studies included, n = 19 were conceptual in nature, while n = 23 were empirical. Among the empirical studies, n = 16 employed quantitative methods, n = 4 used qualitative approaches and n = 3 followed a mixed-methods design. Questionnaires were the most frequently used instrument for quantitative data collection [42, 43]. Some studies also analysed open questionnaire items qualitatively [12]. Other qualitative studies relied primarily on semi-structured interviews [44]. In the mixed-methods studies, a typical procedure was the usage of Delphi studies with expert interviews to develop a framework, which was then quantitatively validated [45, 46]. Conceptual models were sometimes developed based on grounded theory [47] or qualitative content analysis [48], while in several cases new models were derived from or adapted to existing competence frameworks [28, 49, 50].

The identified studies can be categorised thematically into four overarching areas based on the research questions and key topics: AI-, digital-, information- and media-related competence models. (see Figure 3). The media-related studies present structural models that comprise three interconnected domains: media pedagogy, media education, and school development processes in relation to media [51, 52]. Information-related studies, by contrast, address competences in the areas of data and information literacy, digital content creation, communication and collaboration, analytical thinking, and critical reflection on information sources [53, 54]. A substantial portion of the literature (n = 22) deals with digital competence models. These studies examine the skills teachers and learners need in order to use digital technologies in a pedagogically meaningful, reflective, and effective manner. In most cases, the focus goes far beyond technical proficiency and includes ethical, societal and professional dimensions of digitalisation in education [19, 49]. Seventeen studies specifically addres AI-related competence models. These models incorporate competences related to understanding the technical foundations of AI, the pedagogical use of AI tools, ethical reflection, awareness of societal implications, and attitudes toward AI [30, 55, 56]. Particularly in this field, a significant increase in research activity can be observed (see Figure 3). Whereas only two relevant studies were published in 2021, the number rose to seven by 2024. In the first quarter of 2025 alone, three additional studies were already published, indicating a clear upward trend in scholarly engagement with this topic.

3.2. RQ2: Foundations, Characteristics, and Contents of AI-related Competence Models

Building on the general overview presented in response to RQ1, this section now focuses specifically on competence models explicitly addressing AI. The analysis centres on the questions of which competence dimensions and specific competences are addressed, which theoretical framework the models are based on, and which thematic focuses can be identified. The following discussion first categorises the AI-related models and then analyses recurring competence dimensions in line with the definition of competence proposed by Weinert [20, 21]. Finally, the models are examined comparatively regarding their content focus, extensions, and potential conceptual gaps.

Table 3. *Underlying competence models.*

Base model	Titlenumber in Appendix
TPACK by Mishra and Koehler (2006) [31]	3, 6, 13, 19, 23, 24, 25, 32
DpaCK by Döbeli Honegger (2021) [57], Huwer et al. (2019) [49], and Thyssen et al. (2023) [29]	13, 22
DigCompEdu by Redecker (2017) [19]	24
Partnership for 21st Century Learning (2019) [58]	24
Long and Magerko (2020) [17]	40
DiKoLAN by Becker et al. (2020) [59]	13
UNESCO (2018) [41]	37
Bloom (1956) [60]	23, 24, 42
Weinert (2014) [21]	32
Balfe, Sharples and Wilson (2018) [61]	39
Calvani et al. (2008) [62]	39
Without a base model	7, 8, 20, 21

Typologically, the reviewed AI-related competence models can be divided into two main categories. One group comprises models adapted from existing frameworks. These are typically derived from well-established models such as DigCompEdu [19], Bloom’s taxonomy [60], or TPACK [31] and are then extended to include AI-specific components. Examples of such adaptations include Intelligent-TPACK [30], DiKoLAN^{KI} [28], or GenAI-TPACK [63] (see Table 3). These models were often built on the established interplay of TK, PK, and CK, enriching it with competences concerning the use of AI tools, ethical considerations, or didactic implementation. This anchoring in recognised frameworks facilitates conceptual compatibility and curricular integration.

In contrast, the second group includes models that were developed independently and without reference to pre-existing frameworks (see Table 3). These include, for example, the models proposed by Long and Magerko [17] or by Delcker, Heil, and Ifenthaler [55], which emerged from empirical studies, Delphi procedures, or conceptual analyses. Such models tend to introduce independent competence dimensions and address not only technical skills, but also critical reflection, societal responsibility, and ethically grounded pedagogical action.

Most of the AI-related models are primarily aimed at teachers, particularly in the context of pre-service or in-service training. Only a few mainly focus on students or more general school contexts. Likewise, few models provide detailed differentiation according to educational levels or specific fields of application, limiting their direct applicability in diverse educational settings.

Among the models analysed, the most frequently used point of reference is the TPACK framework by Mishra and Koehler [31], which conceptualises the interrelation between TK, PK, and CK. The central question it poses is «what teachers need to know to effectively integrate technology into their teaching practice» [64]. In TPACK, technology is not considered in isolation, but rather in interaction with subject matter and pedagogy. The intersecting areas, as TPK, TCK, PCK, and especially the core domain of TPACK reflect this integrated approach [65].

Nonetheless, several researchers have criticised TPACK for adopting a predominantly technological perspective and focusing more on knowledge than on actual competences in practice. Furthermore, the framework does not sufficiently address how such competences should be taught [49, 66]. In response, a number of extensions, including the DPaCK models by Döbeli Honegger [57], Huwer et al. [49], and Thyssen et al. [29], have emerged to incorporate digital components that go beyond technical knowledge [49]. These models also draw on the Dagstuhl Triangle, which emphasises application-related perspectives on functionality, impact, and usage, and its research-focused extension, the Frankfurt Triangle [67, 68]. Based on these frameworks, additional dimensions – analytical competence and socio-cultural contexts – are incorporated [29]. The focus thus shifts towards an integrative perspective on digital media in education and emphasises competence over mere knowledge [57].

In addition to TPACK-based models, the European DigCompEdu framework [19] also plays a central role, particularly since it frequently aligns with other models in its structure or is directly adopted or modified [42, 50, 69]. DigCompEdu targets the professional digitalisation of teachers and is organised into six competence areas comprising twenty-two sub-competences. Unlike TPACK, it addresses not only instructional design but also cross-cutting issues such as professional development, collaboration, and the digital competence of learners [19].

Some models also refer to Bloom's taxonomy of cognitive learning objectives [60], which hierarchically categorises learning processes from knowledge recall to the creation and evaluation of complex ideas. In AI-related contexts, Bloom's taxonomy is used to structure the cognitive demands associated with reflection and judgment in the use of AI systems, particularly in relation to ethical assessment and critical engagement with algorithmic decision-making [13, 40].

It is noteworthy that in most of the reviewed studies, the foundational frameworks are taken as structural scaffolds without critically examining their suitability for addressing AI-specific challenges. Whether models like TPACK, DigCompEdu, or Bloom's taxonomy offer sufficient conceptual space for engaging with the ethical, societal, and creative dimensions of AI often remains unanswered.

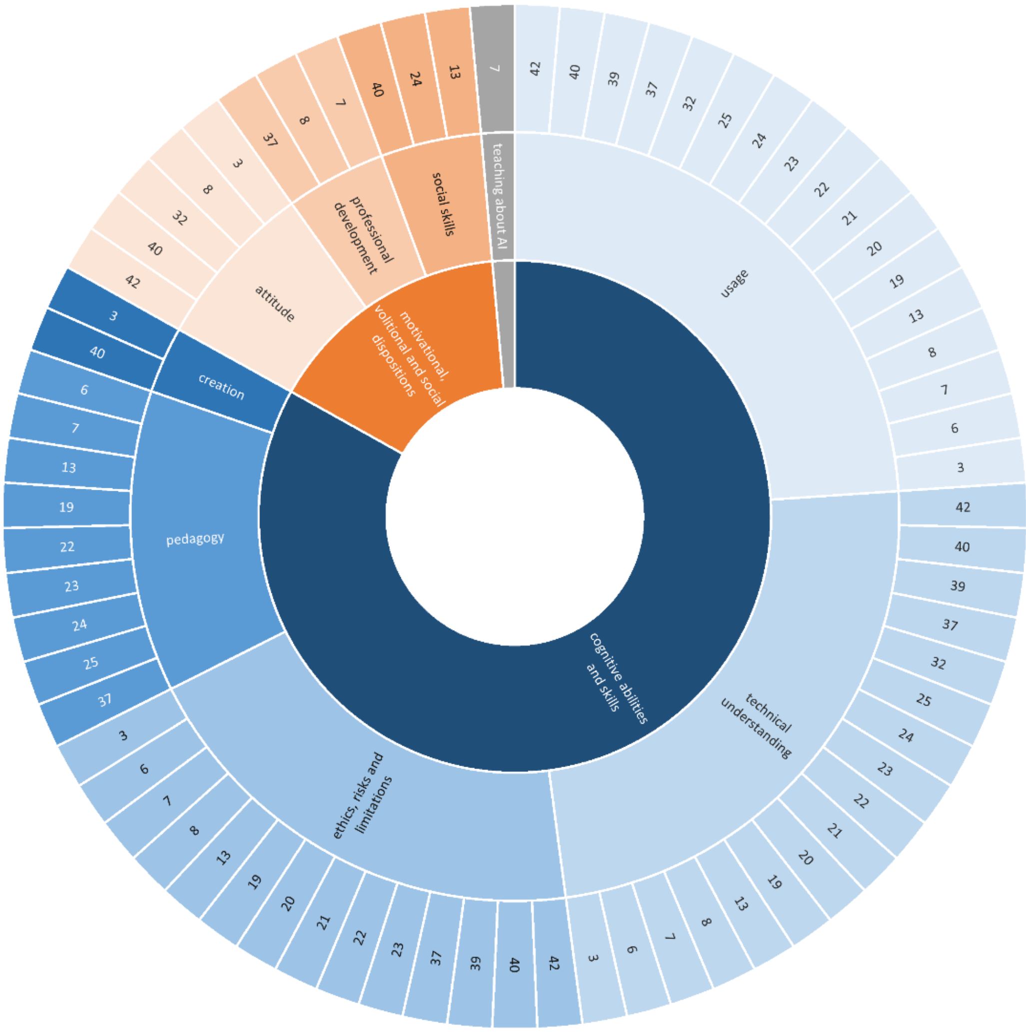

Figure 4. Competence dimensions from the literature.

Drawing on Weinert's [21] definition, which differentiates between cognitive abilities and skills on the one hand and motivational, volitional, and social dispositions and abilities on the other, the 17 AI-related studies were analysed qualitatively. The findings show that all models address cognitive aspects, while motivational, volitional, and social dimensions are only present in eight cases (see Figure 4). A set of subcategories was developed inductively from the texts. Within the cognitive dimension, frequently mentioned areas included the use of AI technologies, technical understanding, pedagogical application, content creation, as well as ethical issues, risks, and limitations. For the affective and social domain, the categories included attitude, professional development, and social abilities. One additional dimension, teaching about AI, could not be clearly assigned to either overarching category. To ensure high reliability, a retest was carried out with approximately 20% of the studies [35]. For this purpose, three random articles were coded two months after the first coding again, and a correlation of Cohen's kappa of .90 was found, indicating almost perfect reliability [36].

A consistently addressed cognitive dimension is usage (n = 17). It refers to the ability to purposefully employ AI technologies in teaching contexts. [30, 43]. Teachers should be capable of using AI tools for planning, conducting, or reflecting on lessons and for integrating them appropriately into pedagogical processes [30, 55]. Another cognitive dimension found in all seventeen studies is technical understanding. Core elements include a sound understanding of «how machine learning models are trained, validated and tested [and] the difference between general and narrow AI» [46]. In addition to theoretical knowledge about foundational technologies, including «machine learning, deep learning, data mining, or artificial neural networks» [55], teachers also require «conceptual knowledge and transferable operational skills that teachers need to understand and apply in order to support their selection, application, and creative customization of AI tools» [70].

Ethics, risks, and limitations dimension (n = 14) includes knowledge of principles like «bias in AI, legal responsibility, and intellectual property» [71]. It also involves the ability to critically reflect on societal effects [38] and assess risks in applying AI systems [46]. Further, it includes «knowledge about limitations and potentials» [28] and skills to act responsibly and shape educational processes accordingly [13].

The pedagogy dimension (n = 9) refers to the reflective use of AI in instruction. It includes knowledge of pedagogical applications, such as «personal and timely feedback» [30] and the ability to use AI both ethically and didactically [70]. Teachers should be able «to articulate subject concepts using AI technologies» [72] and «to improve […] pedagogical approaches» [63].

Creation (n = 2) is mentioned less frequently. It includes «training, programming and prototyping tools [and the ability] to determine to what extent a problem can be addressed with AI» [38]. Equally relevant is «scientific and technological knowledge applied in research-based learning to address practical problems» [71].

As part of the motivational, volitional, and social dispositions and abilities, attitude (n = 5) covers beliefs, values, and motivation. Teachers should «be open to AI and engage with AI» [55], show «interests and motivation to use or learn AI» [40] and develop identity in an AI-driven world. It also includes «perspectives […] around responsible AI engagement» [38], like digital maturity and critical judgment. This dimension connects knowledge about AI with the abilities and dispositions to use it.

Professional development (n = 3) refers to competences needed «to use AI to drive their own lifelong professional learning and collaborative professional development in view of transforming their teaching practice» [70]. It includes building «a professional network with colleagues» [55] and supporting peers in «designing engaging and effective learning activities» [45].

Social skills (n = 3) refer to teachers' ability to organise synchronous or asynchronous collaboration among individuals or groups using AI tools, aiming at a shared goal [28]. Further competences include offering «automatic feedback, self-diagnosing and promoting online collaboration among learners» [50].

Teaching about AI as a dimension appears explicitly in only one AI-related model and cannot be allocated clearly. It focuses on the «capacity to effectively teach students about ethics, emphasizing the importance of integrity and accountability in their interactions with technology" [45]. Implicitly, this competence is addressed more often. Some models state that teachers need the «competence to teach about AI» [55] and should help learners «develop AI literacy in terms of learning artefacts, pedagogical approaches and subject matters» [13].

On top of this, progression levels were found in six models. Frequently, they are based on Blooms's [60] taxonomy, using stages including know, understand, apply, and evaluate [13, 50, 71]. Alternatively, the TPACK model is structured hierarchically, starting with CK, PK, and TK as the base, followed by PCK, TCK, and TPK, and culminating in integrated TPACK competence [72].

A notable finding is the rarity with which the dimension of teaching about AI, despite the view that «[teachers] need the competence to teach about AI» [55], was made explicit in competence models and therefore remains difficult to define. To gain a more comprehensive understanding of this dimension, the n = 25 competence models without explicit reference to AI were also qualitatively analysed regarding this category. In n = 8 models, a dimension of teaching about could be identified. A central component is the expectation to develop the related competences in students [73, 74], which, in the context of digital competences, goes beyond general pedagogical, subject-specific, and didactic teacher competences [49, 75]. This includes knowledge components like computer science, pedagogy, subject matter, and didactics, as well as action components in the form of planning, implementation, evaluation, and reflection regarding the teaching of content in the specific domain [51, 52]. Overall, the focus is on motivating learners through appropriate teaching and learning strategies and fostering awareness of boundaries, risks, application possibilities, and underlying mechanisms [19, 47].

4. Discussion

This scoping review provides a comprehensive overview of existing AI-related competence models for teachers. It focuses on two main research questions: how scientific literature on (AI-related) competence models can be systematically structured, and which competence dimensions and sub-competences characterise AI-related models.

4.1. Interpretation of Key Findings

The results clearly show that although there is a growing academic interest in AI-related competences, neither have the key dimensions been sufficiently researched, nor has a comprehensive AI-oriented competence model been developed. Moreover, the results contribute to a foundational understanding of teachers' AI-related competences and pave the way for future studies aiming to explore this topic in depth.

Regarding RQ1, a growing international interest in the topic has become evident, especially within the past three years. The broad spectrum of studies identified, ranging from digital and media-related to explicitly AI-related models, underlines that AI skills are increasingly seen as an integral part of the professional profile of teachers. The analysis of the competence dimensions regarding RQ2 reveals a primary focus on cognitive aspects in most existing models. These include, in particular, technical, ethical, and pedagogical-didactic competences concerning AI. The thematic focus reflects central challenges in handling AI in educational settings, e.g., the appropriate assessment of algorithmic decisions, competent integration of AI tools into teaching, and critical reflection on societal implications teachers face in their daily work with AI.

In contrast, motivational, volitional, and social dimensions are underrepresented in many models. Although aspects including attitudes toward AI and willingness for professional development are occasionally mentioned, they are often not systematically embedded in the model structure. This is problematic considering the explicit emphasis placed on these dimensions as part of individual action competence in Weinert's [21] definition.

Particularly noteworthy is the dimension of *teaching about AI*, which appears only sporadically in explicitly AI-related competence models. Given the widely recognised need to promote AI-related competences among students [5, 76], this constitutes a significant gap in non-computer science subjects. It is striking when compared to digital or media-related models, where the promotion of skills among learners is better developed through approaches related to computer science, pedagogy, or didactics. The discrepancy points to a prevailing focus in current AI-related models on receptive use and ethical reflection by teachers, with comparatively little attention given to their active role in fostering students' AI-related competences. This indicates a promising transfer area for future integration into competence model development.

The content foundations of many models are based on adaptations of established frameworks such as TPACK [31] or DPaCK [49]. While this connection can facilitate curricular integration, it also entails conceptual risks. TPACK, for instance, focuses strongly on knowledge components, largely neglecting motivational-volitional aspects, with the teaching dimension being entirely absent. An uncritical adaptation of such frameworks may result in AI-specific requirements being insufficiently addressed. There is therefore a risk that important action-related and attitude-related aspects essential for a comprehensive understanding of AI-related competences in education will be overlooked and not integrated into a new model. The findings suggest that the development of AI-related competence models should proceed in a more theory-driven and, at the same time, more context-sensitive manner in the future. For example, both pedagogical, technological, and ethical perspectives and the aspect of imparting this knowledge to students could be integrated into a coherent conceptual framework.

4.2. Model Conceptualisation

Building on these findings, a preliminary conceptual model that addresses the identified gaps and integrates AI-related competence dimensions into a coherent framework is proposed. The model has instructional practice as the output layer and a variety of interconnected input dimensions influencing the output. Each input dimension contributes a distinct but independent function that ultimately shapes the teaching and learning with and about AI (see Figure 5). The model is illustrated using an example from economics education.

As the first input layer (blue), the model includes the *instructionally relevant AI knowledge*. It encompasses teachers' cognitive abilities and skills of how AI systems function, including underlying algorithmic processes, the role of data, typical application contexts, and the usage of AI tools. What distinguishes this dimension is its direct instructional relevance: it enables teachers to evaluate and select appropriate AI tools for teaching subject content and to design learning opportunities around AI-related topics. In this sense, it provides the cognitive and professional foundation for both the integration of AI as a teaching instrument and the treatment of AI as a curricular topic, especially in non-computer science subjects.

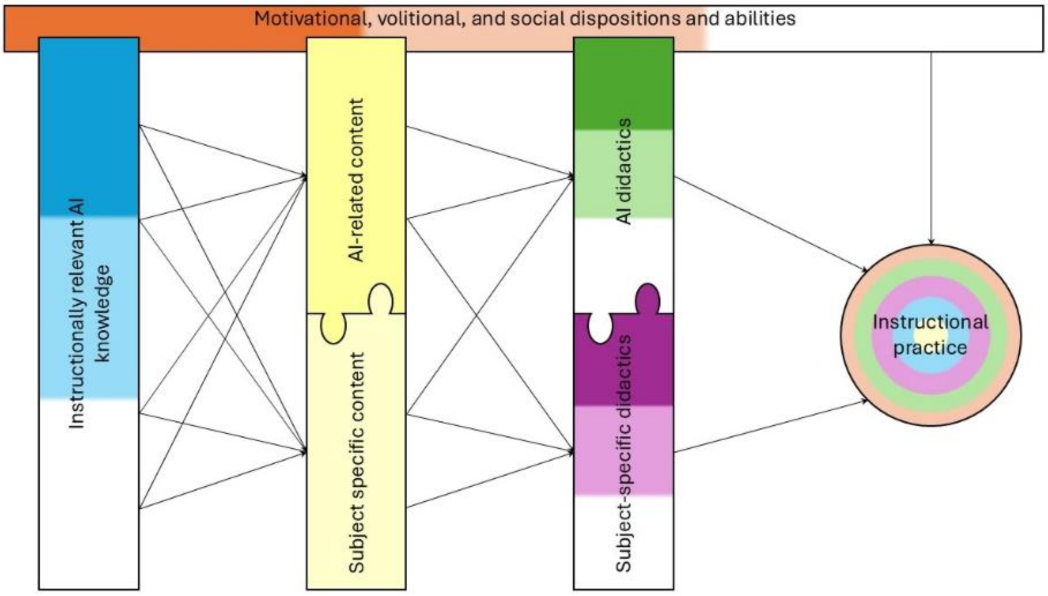

Figure 5. Proposed competence model.

The foundation leads to the next input layer (yellow) of *AI-related content*, which refers to those thematic elements of AI that become part of the classroom subject matter. This domain involves the selection, structuring, and presentation of AI-related topics as learning content. An example could be in economics education, the role of AI in labour markets, its function in recommendation systems, or ethical and societal problems occurring with the usage of AI. Teachers need the ability to identify and frame aspects of the first input layer meaningfully within their own subject area. Connected to that is the area of *subject-specific content*, where AI is mainly used as a tool for class. The subject-specific content refers to all content included in the subject curricula and, in the example, can be considered as the labour market without the aspect of AI.

One of the central innovations of the model is the explicit inclusion of *AI didactics* (green) as an independent competence domain. It is not a subcategory of general didactics, subject-specific didactics, or technology-enhanced teaching, but a distinct dimension that addresses the question of how to teach about AI. Unlike approaches that focus on the use of AI as a tool (e.g., to support lesson planning or personalize learning), the notion of AI didactics refers to the teaching about AI, including foundational concepts, technological mechanisms, ethical questions, and societal consequences. This form of didactic competence is especially relevant in non-computer science contexts where teachers are nonetheless expected to develop a basic understanding of AI and its implications among their students. This perspective draws from the understanding that digital education requires its own didactic framework and should not be addressed using general didactic approaches [49, 75]. This idea can be transferred to AI and appears even more urgent in this context. For example, in the context of economics education, a teacher might design a unit on the labour market. Beyond simply using AI tools in the lesson, the teacher enables students to understand how AI-based hiring systems function, to evaluate their fairness, and to consider the impact of AI on workplaces. This requires specific didactic strategies: simplifying technical concepts without distorting them [75, 78], creating ethical discussion formats, and integrating economic, technological, and social perspectives. Such practices illustrate that AI didactics is not simply an extension of *subject-specific didactics* (purple), but a new pedagogical task that intersects with content knowledge, societal relevance, and disciplinary framing. At the same time, it also requires close coordination with subject-specific didactics to ensure that AI-related topics are meaningfully embedded within the epistemic structures and curricular goals of the respective subject.

Complementing those layers, the model integrates motivational, volitional, and social dispositions and abilities (red) as a transversal component that influences all others. These include, for example, attitudes toward AI, willingness to engage in continuous learning, to use AI, and the transfer of knowledge about AI – especially in non-computer science subjects – such as the impact of AI on the labour market in economics education. In addition, progression levels are included in the form of coloured gradations in the various input layers. This visual colour gradient symbolises progress – from initial awareness and basic understanding to critical innovation – in reference to Bloom [60].

4.3. Conclusions and Outlook

The structure of the preliminary model provides conceptual clarity and opens possibilities for empirical validation. The connections between the components can be interpreted as weighted relationships that represent the varying degrees of influence each area has on the resulting teaching practice.

These weights could be empirically investigated through operationalisation to determine which combinations of competencies are most effective in promoting students' AI competence. In addition, qualitative expert interviews could be conducted in a subsequent research step. Firstly, to validate and further develop the identified dimensions and test their applicability in educational practice; further, to underpin the dimensions with specific competences [79]. Moreover, this review offers structured guidance for educational researchers and curriculum designers. The identified competence dimensions can serve as a starting point for the development or refinement of professional development programs, course syllabi, or higher education didactic concepts.

4.4. Methodical Reflection and Limitations

Despite the systematic and structured approach taken in this scoping review, certain limitations must be acknowledged. The analysis was conducted by a single person, so distortions in the selection and coding process cannot be completely ruled out. Although quality assurance measures, including the use of PRISMA standards, automated tools, selective argumentative validation, and reliability checks of the coding, were applied, these do not replace full intersubjective review.

Only English-, French-, and German-language publications were included, while none of the final forty-two works were in French. Relevant work from other linguistic regions, particularly from non-Western contexts, may thus be underrepresented. The decision to conduct an in-depth qualitative analysis exclusively on AI-related models, while digital competence models were used only to contextualise the dimension of teaching, represents a deliberate thematic focus. However, it cannot be ruled out that relevant dimensions from related models have been overlooked.

Despite these limitations, the study provides a first systematic overview of existing structures and gaps in the field of AI-related competence models. The findings offer important guidance for the conceptual and empirical development of a domain-specific, pedagogically grounded AI-related competence model, which needs to be further developed and evaluated.

Abbreviations

AI	Artificial Intelligence
CK	Content Knowledge
DigCompEdu	European Framework for the Digital Competence of Educators
DiKoLan	Digitale Kompetenzen für das Lehramt in den Naturwissenschaften
DPaCK	Digitality-related Pedagogical and Content Knowledge
GenAI	Generative Artificial Intelligence
PCK	Pedagogical Content Knowledge
PK	Pedagogical Knowledge
PRISMA	The Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RQ	Research Question
TK	Technological Knowledge
TCK	Technological Content Knowledge
TPK	Technological Pedagogical Knowledge
TPACK	Technological Pedagogical and Content Knowledge

Author Contributions

Luca Mikula: Conceptualization, Data curation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing.

Conflicts of Interest

The author declares no conflicts of interest.

Appendix

Table 4. *Studies included in the review.*

Nr.	Author	Year	Country	Area	Focus
1	Alarcón, R., Del Jiménez, E. P., Vicente-Yague, M. I. de [42]	2020	Spain	Digital	Development and validation of DIGIGLO, which considers external factors such as digital resources and adds two further areas.
2	Alberti, V., Strauch, A., Brandt, P. [48]	2022	Germany	Digital	Relationship between pedagogical and digital skills and representation in a competence model for teachers in adult and continuing education based on the GRETA model
3	Ayanwale, M. A., Adelana, O. P., Molefi, R. R., Adeeko,	2024	South Africa	AI	A quantitative study examining the AI competence of 529 teachers

Nr.	Author	Year	Country	Area	Focus
	O., Ishola, A. M. [71]				who are not yet established in their profession in areas such as ethics, use, recognition, and creation.
4	Borukhovich-Weis, S., Brinda, T., Burovikhina, V., Beißwenger, M., Bulizek, B., Cyra, K., Gryl, I., Tobinski, D., Barkmin, M. In: Passey, D., Leahy, D., Williams, L., Holvikivi, J., Ruohonen, M. (eds.) [75]	2022	Germany	Digital	Model of digital skills for teacher training. Integrates teaching with digital media and learning about digitalisation.
5	Castañeda, L., Esteve-Mon, F. M., Adell, J., Prestridge, S. [44]	2022	Spain	Digital	Qualitative study on a holistic framework for teaching in the digital age based on teachers' perspectives from their professional practice (cross-context, cross-cultural and cross-disciplinary) through interviews with experienced teachers from Australia, Europe, and Latin America.
6	Celik, I. [30]	2023	Finland	AI	Development of a scale for measuring teachers' AI knowledge by extending the TPACK model to include ethical aspects
7	Chiu, T. K. F., Ahmad, Z., Çoban, M. [45]	2024	China	AI	Scale development for measuring teachers' self-assessment of their AI competence (TAICS) in schools (K–12). Development of six dimensions: AI knowledge, AI didactics, AI assessment, AI ethics, human-centred education, professional development.
8	Delcker, J., Heil, J., Ifenthaler, D. [55]	2025	Germany	AI	A study involving 480 vocational schoolteachers examined requirements based on a six-dimensional competence model. The result: competencies vary greatly – there is a need for further training for teachers in education and the workplace.
9	Education and Training Foundation [80]	2023	England, GB	Digital	The DTPF is a revised competence model for digital teaching that combines pedagogical practice with technology and maps three competence levels.
10	Ergül, D. Y., Tasar, M. F. [81]	2023	Greece	Digital	The study develops TDiCoS, a valid and reliable scale for self-assessment of teachers' digital competences, based on international standards.
11	Falloon, G. [82]	2020	Australia	Digital	Expanding digital teaching skills beyond purely technical abilities to a holistic, interdisciplinary understanding that aims at ethical and safe participation in digital environments.
12	Herzig, B., Martin, A. In: Ladel, S., Knopf, J., Weinberger, A. (eds.) [51]	2018	Germany	Media	Competence structure model with three parts: media didactics, media education and media-related structural development, whereby beliefs, self-efficacy expectations and technical knowledge are aspects of media education.
13	Huwer, J., Becker-Genschow, S., Thyssen, C., Thoms, L.-J., von Kotzebue, L., Finger, A., Kremser, E., Berber, S., Brückner, M., Maurer, N., Bruckermann, T., Meier, M. In: Huwer, J., Becker-Genschow, S., Thyssen, C., Thoms, L.-J., Finger, A., von Kotzebue, L., Kremser, E., Meier, M., Bruckermann, T. (eds.) [28]	2024	Switzerland	AI	The DiKoLAN^KI competence model operationalises AI competence in science teaching as eight systematically structured areas of competence, which build on existing digital competence models in terms of content and have been specifically expanded to include AI-specific requirements.
14	Huwer, J., Irion, T., Kuntze, S., Schaal, S., Thyssen, C. [49]	2019	Switzerland	Digital	Extension of the TPaCK model to the DPaCK model, which considers not only technical knowledge but also pedagogical-didactic and subject-specific didactic competencies.

Nr.	Author	Year	Country	Area	Focus
15	INTEF [83]	2017	Spain	Digital	The CDCFT consists of five competence areas with a total of twenty-one competencies. Each competence is assigned six competence levels based on the dimensions of knowledge, skills, and attitude. The five competence areas are information and data competence, communication and collaboration, digital content creation, safety and problem solving.
16	Jiang, L., Yu, N. [47]	2024	China	Digital	The TDCM is a comprehensive, theory-based, and empirically validated competence model for teachers at Chinese secondary schools. It integrates ethical, pedagogical, and developmental perspectives and explicitly highlights the promotion of students' digital competence as one of its six core dimensions.
17	Joshi, D. R., Neupane, U., Joshi, P. R. [84]	2021	Nepal	Digital	DEPSWALIC is a competence model that systematically maps the digital competencies of teachers at all levels of education. The model is divided into six competence areas, supplemented by two fundamental cross-cutting dimensions – ethical sensitivity and policy awareness.
18	Lameras, P., Arnab, S. [85]	2021	England, GB	Digital	Development of a competence model for teachers' digital skills; generated from expert interviews with six competence dimensions.
19	Lan, G., Feng, X., Du, S., Song, F., Xiao, Q. [62]	2025	China	AI	Development of the GenAI-TPACK model, which combines technical, pedagogical, and ethical knowledge for the use of generative AI by university lecturers.
20	Laupichler, M. C., Aster, A., Haverkamp, N., Raupach, T. [46]	2023	Germany	AI	Development of SNAIL, a scale for non-AI-experts with the dimensions Technical Understanding, critical appraisal, and practical usage
21	Long, D., Magerko, B. [17]	2020	USA	AI	Structuring AI competence into five subject areas, each of which contains specific competence goals and design principles. This is a literature-based, conceptual framework model that does not contain any psychometrically validated dimensions.
22	Lorenz, U., Romeike, R. In: Pellet, J.-P., Parriaux, G. (eds.) [56]	2023	Germany	AI	Expansion of DPaCK to AI-PACK with new AI-related requirements to support the design of holistic education and study programmes for teaching in the digitally networked 'AI world,' which give equal weight to user-oriented, technological, and socio-cultural perspectives.
23	Ng, D. T. K., Leung, J. K. L., Chu, S. K. W., Qiao, M. S. [13]	2021	China	AI	Exploratory review to conceptualise, define, teach, and evaluate the emerging concept of 'AI competence'.
24	Ng, D. T. K., Leung, J. K. L., Su, J., Ng, R. C. W., Chu, S. K. W. [50]	2023	China	AI	Creation of a framework with key areas of expertise: teacher professional engagement, instructional design, content choice and learning competencies.
25	Ning, Y., Zhang, C., Xu, B., Zhou, Y., Wijaya, T. T. [72]	2024	China	AI	To construct a framework for integrating AI technology education content knowledge, which aims to clarify the complex interrelationships and synergy effects of AI technology, educational methods, and subject-specific content in the field of education.
26	Pérez-Escoda, A., García-Ruiz, R., Aguaded, I. [86]	2019	Spain	Digital	Development of an integrative competence model for digital competence based on the analysis of five international reference models. The model comprises four developmental dimensions with six overarching competence areas: information management, digital communication, content creation, digital identity, critical thinking, and problem solving.
27	Raffaghelli, J. E. In: Gómez Chova, L., López Martínez,	2019	Spain	Information	Development of a competence model for teachers' data and information competence that ties in with the increasing datafication in

Nr.	Author	Year	Country	Area	Focus
	A., Candel Torres, I. (eds.) [53]				the education sector. It consists of six dimensions, ranging from professional data practice to data-based teaching and learning, performance assessment and individual support, to the explicit teaching of data competence to students.
28	Reddy, P., Chaudhary, K., Sharma, B., Hussein, S. [87]	2023	Fiji	Digital	The competence model comprises six dimensions of digital competence: information competence, media competence, communication competence, visual competence, technology competence and computer competence. Each of these dimensions has been operationalised through specific skills.
29	Redecker, C. [19]	2017	Luxembourg	Digital	Development of a Europe-wide competence framework (DigCompEdu) for teachers' digital competences with the aim of promoting professional digital competences in all relevant areas.
30	Rozali, M. Z., Hong, G. C., Samshul, S. N., Ismail, A., Zakaria, A. F. [88]	2014	Malaysia	Digital	Validation of a digital competence framework ('DIGIGLO') for design and technology teachers in primary schools with the aim of assessing digital competences, identifying further training needs, and providing targeted teacher training.
31	Rubach, C., Lazarides, R. [54]	2021	USA	Information	Identification of six dimensions of teachers' fundamental beliefs about information competence.
32	Schmidt, J. M.-C. [64]	2024	Germany	AI	Development of a structural model for AI-related competence facets of (prospective) teachers in vocational education (dissertation)
33	Schultz-Pernice, F., von Kotzebue, L. von, Franke, U., Ascherl, C., Hirner, C., Neuhaus, B. J., Ballis, A., Hauck-Thum, U., Aufleger, M., Romeike, R., Frederking, V., Krommer, A., Haider, M., Schworm, S., Kuhbandner, C., Fischer, F. [52]	2017	Germany	Media	The article presents a framework model for media-related core competencies of teachers, which aims at professional lesson planning in a digitalised world. The model distinguishes between teachers' own media competencies and media-related teaching competencies, each of which is divided into a knowledge component and an action component.
34	Tang, L., Gu, J., Xu, J. [89]	2022	China	Digital	Creation of a reliable self-evaluation framework for the DC of teachers in service during online teaching; collection of data from 1,342 teachers with experience in online teaching; results: the constructed evaluation framework is consistent with the collected data.
35	Tondeur, J., Howard, S., van Zanten, M., Gorissen, P., van der Neut, I., Uerz, D., Kral, M. [73]	2023	Belgium	Digital	Development and validation of a framework for digital competences for teachers in higher education; The new framework covers four dimensions of teachers' digital competences: teaching practice, empowering students for a digital society, teachers' digital competence and teachers' professional development.
36	UNESCO [41]	2018	France	Digital	Definition of core digital competencies for teachers worldwide; combines digital technologies with pedagogical practice, aims at professional development and teaching improvement, and is aligned with global educational goals.
37	UNESCO [70]	2024	France	AI	First global AI competence framework for teachers introduced by UNESCO: defines which AI competencies are necessary for ethical, effective use in teaching, learning and assessment.
38	Vogel, S., Yadav, A., Phelps, D., Patel, A. [74]	2024	USA	Digital	The EnCITE framework model for integrating computer science and digital technologies into teacher training addresses technological, pedagogical, ideological, political, and developmental challenges.
39	Wang, B., Rau, P.-L. P., Yuan, T. [34]	2023	China	AI	Development of a quantitative scale to obtain accurate data on the AI competence of normal users by identifying primary core constructs of AI competence, including awareness, use, evaluation, and ethics.

Nr.	Author	Year	Country	Area	Focus
40	Williams, R. [38]	2024	England, GB	AI	Investigation into how AI can be used in secondary education. The aim is to teach pupils AI skills at an early stage in order to promote participation, ethical awareness, and social engagement.
41	Wu, D. In: Ma, W. W. K., Chen, L., Fan, C. W., U, L. H., Lu, A. (eds.) [39]	2024	China	Digital	Development of a digital competence model for teachers. The model comprises five dimensions: digital awareness, technological knowledge and skills, digital application in teaching, digital social responsibility, and professional development through digital learning and innovation.
42	Yue, M., Jong, M. S.-Y., Dai, Y., Lau, W. W.-F. [40]	2025	China	AI	Development of a competence model for students (SAIL), whereby AI knowledge, skills, ethics, and attitudes are regarded as basic competencies that are strengthened through an iterative process of design and research.

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Biography

Luca Mikula is a researcher at the University of Bayreuth, Department of Computer Science. He completed his Master of Education at the University of Bayreuth in 2024. His research focuses on teacher education and professional development, with a particular emphasis on AI-related competences, digital competence models, and the pedagogical implications of artificial intelligence in education. His work combines systematic literature reviews, qualitative content analysis, and design-oriented educational research to support the development of theoretically grounded and practice-relevant competence frameworks for teachers.

Research Field

Luca Mikula: AI-related competences, teacher education, qualitative content analysis, design-oriented educational research, media education competences