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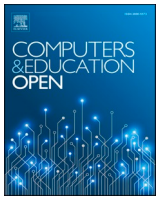

A review of reviews on TPACK research: is there any focus?

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ABSTRACT

The TPACK framework describes what knowledge educators need to effectively integrate technology into teaching specific content. This integrated knowledge is specific to the domains that TPACK combines, i.e. to the content that is taught, the pedagogical approaches chosen and the technology used. Given that there is a substantial body of research literature on TPACK, it seems useful to focus review-studies on one domain. For example, a review might summarize what is known about teachers' TPACK using a specific technology, comparing and combining the literature across content domains or pedagogical approaches. Inversely a review could also focus on specific content or on a specific pedagogical approach. In this review of reviews we investigate to what extent review research on TPACK focuses on specific domains (technology, pedagogy or content) or their related knowledge components in the TPACK-framework. Based on a systematic literature review of 32 review studies we find that few reviews focus their research questions, selection criteria or results on specific domains or knowledge components. This could be due to a lack of clarity regarding the interpretation of the model (analytic or holistic), about which only six reviews were explicit. We call on the field to clarify the interpretation of TPACK and to decide on which research would be needed to test the model. We argue that focused review studies could be one way to significantly advance the TPACK research field.

1. Introduction and background

Mishra and Koehler [1] introduced the Technological Pedagogical Content Knowledge (TPACK) framework, which identifies the knowledge educators need to effectively integrate technology into teaching [2]. TPACK is widely recognized in educational technology as a robust model [3]. Compared to other frameworks, such as TAM [4,5], and the "Will, Skill, Tool" model [6,7], Harris et al. [8] highlighted TPACK's unique strength in emphasizing both content and pedagogical knowledge. Unlike other models, which assume that the professional knowledge required for technology integration is uniform across teaching disciplines, TPACK acknowledges the diversity of disciplinary knowledge and the distinct pedagogical strategies suited to teaching specific content [8]. Furthermore, many educational technology models overlook the impact of shifting classroom and school contexts, which influence both teaching practices and student outcomes [9]. By addressing these limitations, TPACK stands out as a relevant and adaptable framework for educators [8].

TPACK [1] builds upon earlier models and concepts, with Shulman's [10] Pedagogical Content Knowledge (PCK) often cited as its foundation (Schmid et al., 2024; [11,12]). Shulman [10] challenged the assumption that effective teaching requires only strong content knowledge and pedagogical skills, arguing instead for the integration of the two into a distinct form of knowledge he termed PCK. This integration enables teachers to understand the factors that facilitate or hinder learning specific subjects [10]. PCK equips educators to blend subject knowledge with appropriate teaching strategies, ensuring that learners can effectively grasp the material [12]. Pierson [13] argued that the success of technology integration depends on pedagogical expertise and introduced Technological Knowledge (TK) as an addition to Shulman's [10] PCK model. TK, which goes beyond basic technological skills, involves understanding how specific technologies can enhance teaching and learning [13]. This led to the development of TPCK, which integrates TK, Pedagogical Knowledge (PK), and Content Knowledge (CK) to guide effective technology use in education. Koehler and Mishra [11] further expanded this concept, emphasizing the dynamic, interconnected nature

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of these knowledge domains. In 2007, the term TPCK was updated to TPACK, reflecting a view of the three types of knowledge as an integrated whole [14].In sum, the TPACK model [15] identifies seven domains of teacher knowledge, see Fig. 1. These include three core domains: TK, PK and CK. TK involves understanding the characteristics, capabilities, and uses of technology, while PK and CK align with Shulman's foundational knowledge bases. The model also includes three interactional domains: Pedagogical Content Knowledge (PCK), which blends PK and CK, Technological Content Knowledge (TCK), which focuses on using technology to represent and explore subject matter (e.g., virtual reality for historical events), and Technological Pedagogical Knowledge (TPK), which emphasizes how technology facilitates teaching strategies (e.g., online forums for peer feedback). At the intersection of these domains is TPACK, which integrates content, pedagogy, and technology for effective teaching, addressing the representation of concepts, student challenges, and new or existing epistemologies [15].

However, questions arise regarding the exact constitution and interrelation of its seven knowledge domains. Scholars continue to debate whether these domains are integrative or transformative [16]. In line with this debate, there are authors that approach TPACK as consisting of seven distinct knowledge bases (e.g., [17]), while others argue that the TPACK domains are difficult to separate (e.g., [18]). This conceptual distinction has methodological implications. In this work, we understand a holistic approach to TPACK as one that considers the framework as an integrated whole without isolating its individual components. And, we understand an analytic approach as one that explicitly focuses on one or more of the separate knowledge domains within the TPACK framework. This distinction is relevant because the way in which TPACK is conceptualized (either holistically or analytically) can influence how authors from review papers interpret the findings of the original papers. Reviews that approach TPACK holistically typically investigate it as an integrated, inseparable construct, often still recognizing the existence of its components. On the other hand, analytic reviews examine the individual domains and their intersections more explicitly. This brings us to the purpose of this paper.

2. Problem statement and goal of the study

The TPACK-framework by Mishra and Koehler (2005) has achieved significant prominence, with over 5000 citations on Scopus. Despite this, persistent theoretical and methodological issues remain. Schmid et al. (2024) highlighted these challenges in a meta-review of 21 studies, citing unclear definitions and limited practical applicability as key concerns [19]. Central debates revolve around the constitution and interrelation of TPACK's seven domains, whether integrative or transformative, and the tension between holistic and analytical perspectives. This raises the question about how review studies address these tensions.

Additionally, similar to PCK, TPACK inherently describes knowledge that is specific to a certain domain, technology or pedagogical approach. For example, the TPACK of a secondary education mathematics teacher using an interactive white board is different to the TPACK of a developer of an educational app to introduce a second language to adults using AI. However, one could expect that insights within a domain, a technology or pedagogical approach (and public) could be shared. For example, research on teachers' knowledge of the affordances of different technologies can perhaps be synthesized across educational contexts or content domains. This raises the question to what extent review research in the TPACK community has focused on one domain, technology or pedagogical approach.

This review of reviews critically evaluates TPACK-research, focusing on:

1. which TPACK components are predominantly investigated,
2. the focus of reviews on specific content domains, technologies, or pedagogical approaches, and
3. the adoption of holistic versus analytical perspectives.

By synthesizing findings and through suggestions for future research directions in reviewing TPACK research, this study aims to advance TPACK's methodologically and, ultimately its theoretical foundations and practical implications.

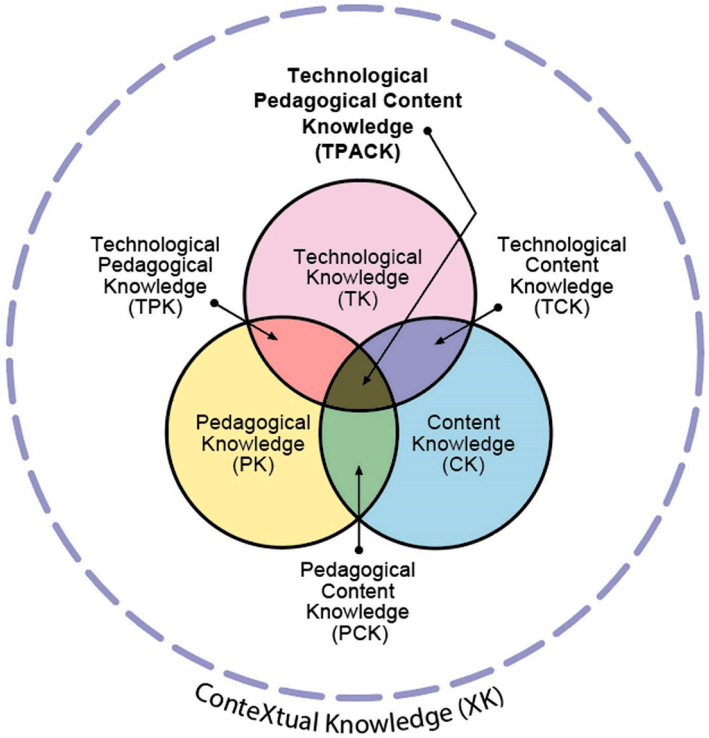

Fig. 1. TPACK model (adopted from Mishra, [67]).

3. Methodology

To answer these research questions, we conducted a systematic literature review of existing review articles on TPACK. We did not opt for a meta-review, given that the reviews that were selected (see further) did not allow us to the statistical analyses typically used in meta-reviews.

A systematic search strategy was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [20]. Search strings and associated inclusion and exclusion criteria were established. Prior to the selection, through title and abstract screening, of articles based on the inclusion and exclusion criteria, a sample ($n = 15$) of titles and abstracts of articles was screened independently by two of the authors until a Cohen's kappa (κ) > 0.7 was obtained. After two rounds, in between which disagreements were discussed and the coding scheme was adjusted accordingly, κ was 0.87, indicating near perfect agreement. After this, the articles were further screened via CADIMA (a free web tool for systematic reviews) by the first author [21]. The remaining articles were thoroughly read and screened by the first author based on the same inclusion criteria. Once the final set of articles were selected, an excel sheet was created to facilitate data extraction and data analysis in order to synthesize results.

Three electronic databases, Education Resources Information Center (ERIC), Scopus and Web of Science (WoS), were searched for articles. The specific search strings used, the number of results that were found without duplicates and with duplicates can be found in Table 1.

To ensure a consistent level of quality while retaining a sufficient number of reviews, specific inclusion and exclusion criteria were applied, acknowledging that stricter quality thresholds would have excluded many relevant reviews. First, articles had to be written in English or Dutch. Second, the articles had to investigate TPACK. Articles were excluded when they utilized TPACK solely as a theoretical framework or to contextualize results. Third, the articles had to be review studies. We define a review as an overview and evaluation of the existing peer-reviewed literature on a specific topic, in this case TPACK. Articles were excluded if they were not primarily reviews (e.g., when they reviewed the literature in the theoretical background of an otherwise empirical paper) or if the reviews was written in a contemplatively manner and lacking a clear methodology. Fourth, the articles had to be journal articles. Proceedings, conference papers, editorials, colloquia, books or chapters from books were excluded from this review of reviews. Fifth, articles had to be freely accessible and fully available. Articles that required payment or could not be found in its complete form online were excluded. Lastly, articles had to be of sufficient transparency. A review was included if they were peer-reviewed and if the reported methodology gave enough detail to repeat the reported search ('quality'-code in Fig. 2). This excluded narrative reviews [22], but included systematic and bibliographic reviews. We deliberately chose not to apply other quality assessments, as this would have greatly reduced the number of eligible reviews. As such, the forth and sixth criterium served to ensure a minimum level of quality was present. All inclusion criteria are listed in Table 2.

Fig. 2 shows the number of articles included in each PRISMA step. A total of 307 records were retrieved from ERIC, Scopus and WoS. After the duplicates were manually removed from the original records, 201 records were screened based on title and abstract. This resulted in 79 reports that were sought for retrieval. Afterwards, 70 reports were assessed for their eligibility to this review of reviews based on the inclusion criteria. Based on a full text screening 38 reports were excluded from this review of reviews. In total 32 reviews were included in this work [23] did two reviews in their research, we only included the data from the first review concerning instruments to measure pre-service or in-service science teachers' enacted TPACK in lessons. All data surrounding the second review (about the use of student-generated explainer videos or animations (SGEVA) in science education) was left out since it does not meet the inclusion criteria.

Table 1
Search Strings Used in ERIC, Scopus and WoS Databases and The Corresponding Number of Results Including and Excluding Duplicates.

Database	Search string	Number of results with duplicates	Number of results without duplicates
ERIC	(title:((TPACK OR "technological pedagogical content knowledge" OR TPCK) AND review)) OR (abstract: ((TPACK OR "technological pedagogical content knowledge" OR TPCK) AND review))	62	60
Scopus	(TITLE ((TPACK OR "technological pedagogical content knowledge" OR TPCK) AND review)) OR (ABS((TPACK OR "technological pedagogical content knowledge" OR TPCK) AND review))	136	84
WoS	(TI=((TPACK OR "technological pedagogical content knowledge" OR TPCK) AND review)) OR (AB=((TPACK OR "technological pedagogical content knowledge" OR TPCK) AND review))	109	57

3.1. Data analysis

The remaining 32 articles were fully read several times and coded. We coded the search strings, inclusion and exclusion criteria as one way that authors could focus their review on specific knowledge-components of TPACK or on a specific content domain, technology or pedagogical approach. Also, if present, the focus on a specific teacher population is extracted from the included reviews. For teacher populations that were also an indicator of a specific discipline (e.g., Ishartono et al. [24] refers to "Pre[-]service mathematics teachers"), these codes are shared in the reported column on the teacher population and the content focus.

The research questions/aims are another way that authors can focus their review. Given the richness of the research questions/aims, these were coded inductively and subsequently thematically analyzed. Finally, all selected reviews were also coded for their holistic or analytic approach to TPACK by abstracting elements from the introduction, methods, results and discussion sections of the reviews.An article was coded as 'holistic' when it explicitly mentioned the use of a holistic approach, an article was coded as 'analytic' when it explicitly mentioned the use of an analytical approach or when it investigated one or more knowledge components of TPACK. However, many reviews did not provide such explicit labels. For these cases, we applied an inductive coding approach to derive their categorization. This distinction between explicit and induced categorization is important, as it reflects both the clarity of reporting in the review literature and the conceptual stance taken by the authors. An 'induced' code was given to reviews that were not explicit. An article was classified under 'induced holistic' when it investigated TPACK in its entirety and discussed the dynamic or interactive processes among the various components of TPACK. An article was classified under 'induced analytic' when its operationalization was classified according to the different TPACK components or when the article was structured according to the components of TPACK. Note that these codes are not exclusive, a review can be 'holistic' and 'induced analytic'.

For all codes, if there was no obvious indication of one of the components of interest, we interpreted the text as well as we could. This will be clearly indicated in the results below. All coding was done by the first author, but were discussed with the last author.

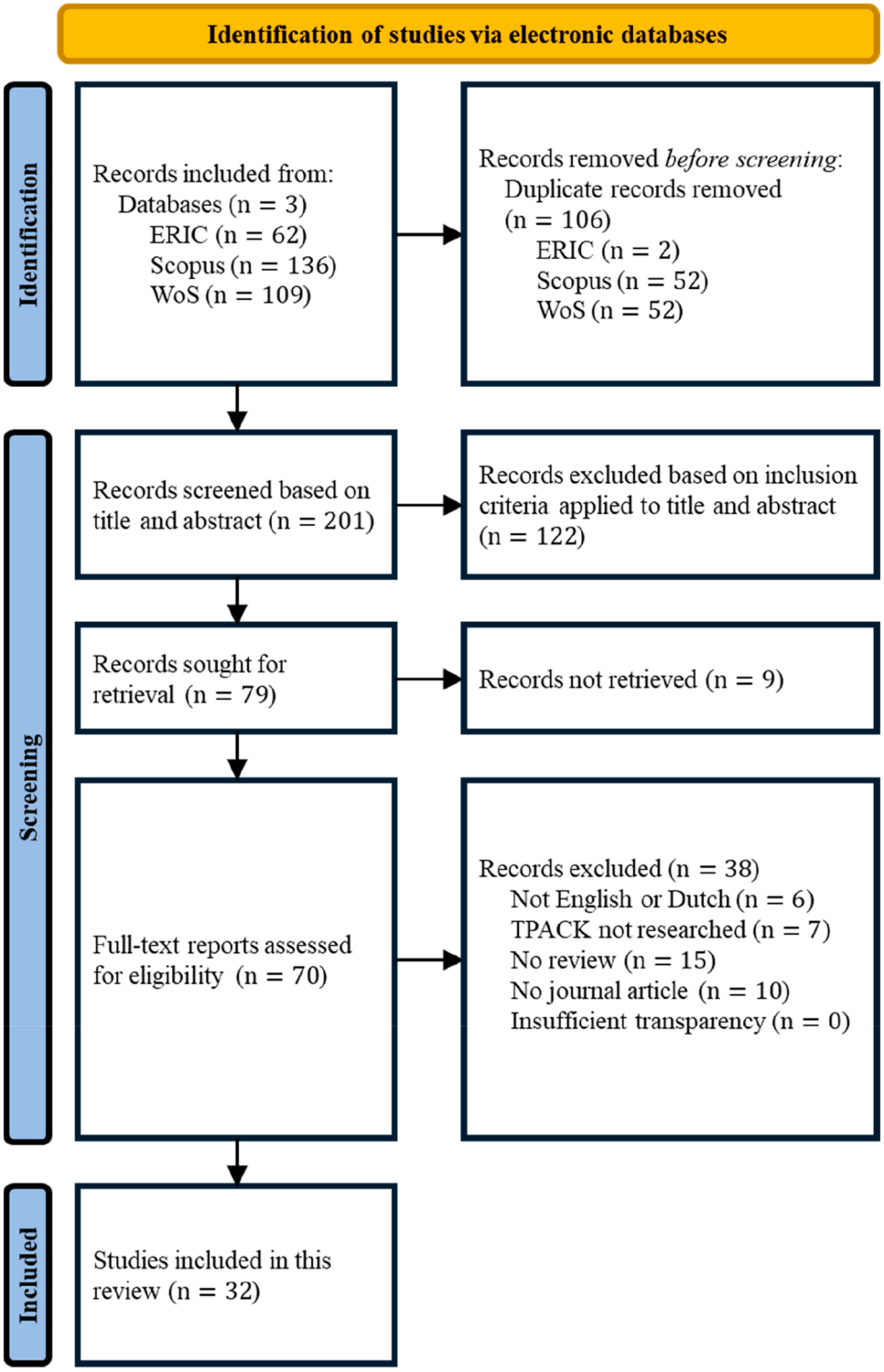

Fig. 2. PRISMA Flow Diagram.

4. Results

4.1. Focus on T, P or C in the search strings and inclusion/exclusion criteria

Tables 3 and 4 give an overview of the presence of TPACK knowledge components and specific content domains, technologies and pedagogical concepts present in the search strings and inclusion/exclusion criteria for the selected reviews. Combined there are five reviews that explicitly mention a knowledge component [25] added 'context* knowledge' (and variations) in the search string as well as added XK in the inclusion criteria. While there is discussion in the literature on the inclusion of *context* as additional knowledge component [26,27], we do not consider it as part of the original conception of TPACK and was thus not coded in Tables 3 and 4.

Thirteen papers explicitly mention a content domain in their search strings or inclusion/exclusion criteria, where mathematics and languages were the most common focuses. For example, Kholid et al., [28]

Table 2
Inclusion criteria and details.

Inclusion criteria	
Language	English or Dutch
Content	TPACK
Methodology	Review
Document type	Peer reviewed journal articles (i.e. excluding conference proceedings, book chapters, editorials,…)
Accessibility	Open access or accessible via the universities' library
Transparency	The reported methodology gives enough detail to repeat the reported search.
Date	No date restrictions were applied

included "Mathematics Education", "Mathematics Learning", and "Mathematics Teaching" in their search string, which was coded as 'mentions a content domain in their search string'. Fourteen reviews focus their search on a population, three papers refer to specific technologies, seven focus on specific pedagogical concepts. However, these focusing search strings or inclusion/exclusion criteria can be very broad (e.g., "teachers" in Lou & Zou (2022); "ICT" in Gür & Karamete [29]; "teaching" in Handayani et al. [30]).

Finally, Tables 3 and 4 report the teacher population if they were explicitly present in the search strings (Table 3) or inclusion criteria (Table 4). Note that "preservice mathematics teachers" spans both the teacher population and the content columns. Respectively six and twelve reviews specify teacher populations of which eight focus on pre-service teachers.

Summarizing, we find in the selected reviews only some focus their search strings and inclusion/exclusion criteria on a content domain or a population and that most review research does not explicitly focus on a specific technology or pedagogical concept. Additionally, while some reviews are very specific, most are very broad.

4.2. Focus on T, P or C in the research questions/aims

Table 5 gives an overview of the elements present in the research questions and aims. The thematic analysis revealed eight categories across the different research questions of the reviews: TPACK (19.12 %, $N = 26$), Measuring (6.62 %, $N = 9$), Content (8.09 %, $N = 11$), Technology (1.47 %, $N = 2$), Bibliographic (19.85 %, $N = 27$), Research (25 %, $N = 34$), Population (13.24 %, $N = 18$) and Educational level (6.62 %, $N = 9$). The subcodes for these categories can be found as a note to Table 5.

We find that there are four papers that include a focus on (a specific) technology (Te) in their research questions/aims, more than half refer to a specific population in their RQ/aims (P1–3), ten papers include a specific content in their RQs/aims, two include a specific pedagogical approach in their RQs/aims (lesson studies in [31] and collaborative discourse in [32]). Only two reviews that ask questions on specific elements in the TPACK framework (T5) where only one paper (Njiku, 2020) explicitly focused their RQs on the different knowledge-domains in the TPACK model. The other [30] was less clear about its aim and thus required interpretation. It should be noted here that there were four reviews that referred to contextual knowledge (XK) in their research questions/aims. Finally, quite common are RQs/aims on bibliographic RQs (13 reviews), research (21), and the TPACK model (20).

Summarizing, analogous to the search strings and inclusion/exclusion criteria, the research questions or aims of the selected reviews focus mostly a population or content domain and most do not explicitly focus

Table 3
Overview of the knowledge components or focus on a domain, technology or pedagogical approach in the TPACK reviews based on the search strings.

	TK, CK, PK	PCK, TCK or TPK	Teacher population	Content domain	Technology specified	Pedagogical concept
[50]						
[46]			Health professionals	Nurs* OR Medical OR Health		
[51]						
[23]				Science, Biology	Application	
[25]						
[52]						
[48]				English as a second language, ESL, EFL, TESOL, English language		Dispositions
[29]					ICT	
[30]						Teaching
[53]						
[24]			"Pre[-]service mathematics teachers"			
[28]				Mathematics		
[54]					Online, Internet, Mobile	Flipped, Blended, E-learning, Web-based, Inverted
[55]						
[56]				Chemistry		
[57]				Social science, "science technology",		
[58]			Higher education, K-12 teachers, Professional development, Pre-service teachers, Online instructors			
[59]						
[60]						
[47]		PCK		Science		
[49]						
[66]						
[31]						Lesson study
[61]			Pre[-]service teacher*			
[36]			Vocational school			
[62]				English language, ESL, EFL, literacy		
[12]						
[63]						
[19]						
[64]						
[32]						
[65]	"elements of TPACK"		"pre-service mathematics teachers' education"			

Table 4
Overview of the knowledge components or focus on a domain, technology or pedagogical approach in the TPACK reviews based on inclusion/exclusion criteria.

	TK, CK, PK	PCK, TCK or TPK	Teacher population	Content domain	Technology specified	Pedagogical concept
[50]	"components of the TPACK framework"		Preservice teacher			
[46]				Health profession		
[51]				English as foreign language		
[23]			Pre- or in-service teachers	Science		Lesson planning, observation and/or reflection
[25]						
[52]						
[48]			Pre- or in-service teachers	English language education (TESOL, ESL, EFL)		
[29]						
[30]						
[53]						
[24]			Pre-service mathematics teachers			
[28]				Mathematics		
[54]			Teachers	Humanities		
[55]						
[56]						
[57]						
[58]			K-12 or higher education, including pre-service teachers			Online learning
[59]	"seven TPACK domains"					
[60]			"Schools and primary education"	Social sciences		
[47]						
[49]						
[66]						
[31]						Lesson study
[61]						
[36]			Vocational education and training (NOT industrial technical education)			
[62]						
[12]			"(student-)teachers"			
[63]			Preservice teachers			
[19]						
[64]						
[32]			Teachers			Collaborative discourse
[65]			Preservice mathematics teachers			

on a specific technology or pedagogical concept.

4.3. Holistic or analytic approach to TPACK

Table 6 gives an overview of which reviews adopt a holistic or analytic approach. There are very few reviews available that explicitly take on a 'Holistic' (6.25 %, $N = 2$), 'Analytic' (6.25 %, $N = 2$) or both 'Holistic and analytic' (6.25 %, $N = 2$) perspective. The other papers were not explicit, but could be coded as holistic and/or analytic based on (the structure of) the text, were marked as 'induced' in Table 6. It was inductively coded as holistic if the review investigated TPACK in its entirety and discussed the dynamic or interactive processes among the various components of TPACK. An article was inductively classified as analytic if (it was not explicitly mentioned in the text and) the operationalization in the review was classified according to the different TPACK components or when the article was structured according to the components of TPACK. Fourteen articles are induced holistic, six are induced analytic and five are a combination. For example, Kholid et al. [28] was coded induced holistic, although they do not explicitly label TPACK as a holistic construct, they describe the knowledge components as a dynamic interaction "Nonetheless, instead of considering them as separate, the focus of this model is on the complex interactions of these three bodies of knowledge" (Kholid et al., 2013, p.3). Marlina (2023) could not be classified as it was a purely bibliographic review.

Summarizing, most authors were not explicit in how they approached the TPACK model. Based on how we interpret the review papers, most authors approach TPACK in a holistic way.

5. Discussion

5.1. Focus on specific technologies, content domains or pedagogical concepts

Fig. 3, that summarizes parts of Tables 3, 4 and 5, shows that, while some reviews on TPACK focus on a content domain, most review research does not explicitly focus on a specific technology or pedagogical concept. We note that the reviews did mention content domains, technologies and pedagogical concepts more often in the results and discussion of the articles. For example, two-thirds of review articles mention a type of technology. Of course, mentioning does not constitute a focus. Moreover, while some reviews refer to specific technologies (e.g., [28] refers to "interactive whiteboards (IWBs) (Gonzales & Gonzales, 2021), GeoGebra (Alizadeh-Jamal et al., 2018; Gonzales & Gonzales, 2021; Ishartono et al., 2022; Kholid et al., 2022) and Adobe Flash (Yan et al., 2018)" (p. 10)), the reported technologies were often very broad terms (e.g., ICT, computer and mobile technologies, world wide web, etc.). Likewise pedagogical concepts mentioned in the results or discussion-sections of the reviews are also often not specific (e.g., blended learning, constructivist oriented teaching, argumentation).

This may indicate a trend where TPACK is studied in a global way that is not bound to specific content, technology or pedagogy. However, the knowledge needed to implement specific content in the classroom should be specific to all three domains [33]. To be clear, this specificity does not only apply to the content but also extends to both pedagogical approaches and the use of technology. In other words, teachers must know how to select the appropriate pedagogy and technology for a given content. This requires knowledge in all three domains as well as

Table 5
Extended Thematic Classification of the Research Questions or Aims of the Reviews.

		T1	T2	T3	T4	T5	T6	M1	M2	M3	C1	C2	C3	C4	C5	C6	Te	Pe	B1	B2	B3	B4	B5	B6	B7	R1	R2	R3	R4	R5	R6	P1	P2	P3	E1	E2	E3	E4
[50]	Aim1									X																					X			X				X
[46]	Aim 1			X											X															X								
[51]	RQ1							X																														
	RQ2								X																													
[23]	Aim 1							X																														
	Aim 2									X																								X				X
[25]	RQ1																									X												
	RQ2						X																															
[52]	RQ1																									X			X									
	RQ2																							X														
	RQ3			X																							X											
	RQ4																					X																
[48]	RQ1				X							X																					X					
	RQ2						X					X																										
	RQ3						X																										X					
[29]	RQ1																			X																		
	RQ2																												X									
	RQ3																												X									
	RQ4																														X							
[30]	Aim 1					X																																
	Aim 2																		X						X													
[53]	RQ1																			X						X												
	RQ2																			X						X												
	RQ3																			X		X						X										
	RQ4																			X							X											
	RQ5																			X	X	X																
	RQ6																			X		X		X		X												
	RQ7																			X		X																
[24]	RQ1							X						X																					X				X
	RQ2									X							X										X								X				X
	RQ3	X																																				
[28]	RQ1																			X	X											X						
	RQ2																X																					
	RQ3													X			X															X						
	RQ4		X	X																																		
[54]	RQ1															X	X			X		X				X		X					X					
	RQ2																												X									
	RQ3			X																																		
[55]	RQ1		X																														X					
	RQ2		X																												X		X					
[56]	Aim 1			X									X						X																			
[57]	Aim 1	X																																				
[58]	Aim 1																X													X		X					X
	Aim 2																X													X		X					X
[59]	RQ1					X		X			X																										
	RQ2					X					X																											
[60]	RQ1																																X		X			
	RQ2																											X					X		X			

(*continued on next page*)

Table 5 (*continued*)

		T1	T2	T3	T4	T5	T6	M1	M2	M3	C1	C2	C3	C4	C5	C6	Te	Pe	B1	B2	B3	B4	B5	B6	B7	R1	R2	R3	R4	R5	R6	P1	P2	P3	E1	E2	E3	E4
	RQ3																												X	X		X			X			
	RQ4																												X									
[47]	RQ1												X							X				X														
	RQ2												X							X	X						X											
	RQ3												X							X							X											
	RQ4												X							X					X													
[49]	RQ1						X																															
	RQ2																															X						
[66]	Aim 1			X				X																														
[31]	RQ1																	X			X																	
	RQ2										X							X																	X			
	RQ3																	X													X							
	RQ4		X															X									X			X								
	RQ5																	X																				
	RQ6		X	X														X																				
	RQ7		X															X																				
[61]	RQ1																			X						X								X				
	RQ2																				X	X	X											X				
	RQ3																										X							X				
	RQ4		X	X																														X				
	RQ5																								X									X				
[36]	RQ1				X																												X			X		
	RQ2																				X								X							X		
[62]	RQ1											X															X						X					
	RQ2																												X									
[12]	Aim 1																														X							
[63]	Aim 1		X																															X				X
[19]	RQ1																		X																			
	RQ2																											X					X					
[64]	Aim 1																		X																			
	Aim 2																										X											
	Aim 3																		X								X											
[32]	RQ1																	X															X					
	RQ2																	X										X					X					
	RQ3		X															X												X			X					
[65]	RQ1		X											X																				X				X
	RQ2		X											X																	X			X				X
Total RQs/aims	85	2	11	8	2	3	4	5	1	3	3	3	5	4	1	1	6	10	5	15	6	7	1	3	3	7	9	6	6	4	9	4	16	12	1	3	2	9
Total reviews	32	2	7	8	2	2	3	5	1	3	2	2	2	2	1	1	2	2	4	6	6	4	1	3	3	5	7	6	5	3	8	3	9	6	1	1	1	6

Note. The category 'TPACK' consists of: T1 = Development of the model, T2 = Development of TPACK by participants, T3 = Challenges, T4 = Characteristics, T5 = Specific element and T6 = Operationalization. The category 'Measuring' consists of: M1 = Instrument/measuring general, M2 = Quality and M3 = Instrument development. The category 'Content' consists of: C1 = Content general, C2 = Languages, C3 = Sciences, C4 = Mathematics, C5 = Health and C6 = Humanities. The category 'Technology' is abbreviated by Te, 'pedagogical approach' is abbreviated to Pe. The category 'Bibliographic' consists of: B1 = Bibliographic/bibliometric general, B2 = Time, B3 = Location, B4 = Journals, B5 = Institutions/funding agencies, B6 = Cited articles and B7 = Keywords/databases. The category 'Research' consists of: R1 = Research trend, R2 = Researchers/authors, R3 = How researched, R4 = Research area, R5 = Contribution to research/further research and R6 = Contribution to teaching practice (also including professional development). The category 'Population' consists of: P1 = Population general, P2 = In-service teachers and P3 = Pre-service teachers. The category 'Educational level' consists of: E1 = Educational level general, E2 = Primary, E3 = Secondary and E4 = Tertiary.

Table 6
Overview of the perspective taken in the reviews on TPACK.

	explicit	induced
Holistic	[48]	[46]
	[54]	[55]
		[64]
		[52]
		[57,65]
		[29]
		[58]
		[53]
		[47]
		[24]
		[31]
		[28]
		[61]
Analytic	[25]	[51]
	[36]	[30]
		[59]
		[66]
		[12]
		[19]
Holistic and Analytic	[62]	[50];
	[32]	[23]
		[60]
		[49]
		[63]
NA		[56]

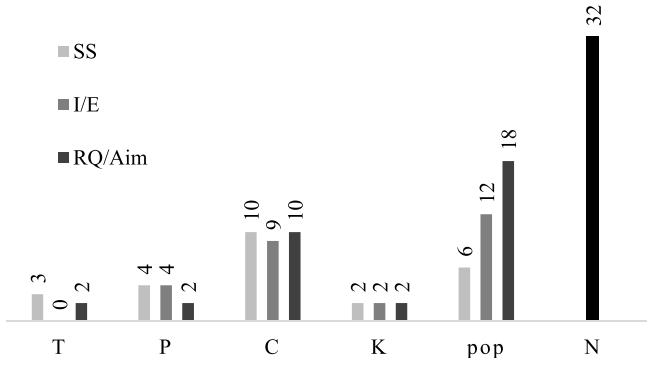

Fig. 3. Overview of the presence of technology (T), pedagogical approach (P), content domain (C), specific knowledge elements in the TPACK framework (K) including PCK but excluding TPACK and population (pop) in the Search Strings (SS), In- or Exclusion criteria (I/E) and Research Questions or Aims (RQ/Aim). For reference the number of included reviews ($N = 32$) is shown on the right.

integrated knowledge. Moreover, even when a particular content, pedagogy or technology is imposed (e.g. mandatory inquiry-based learning or having to use interactive whiteboards) teachers still need specific (integrated) knowledge to incorporate it effectively into their teaching [34]. In this respect, Kadluba et al. [35] state that reviews do not consider content-specific domains for TPACK. They argue that this is problematic because the TPACK construct is by nature content-specific and that the benefits of technology differ between content domains. In their review, the focus was on TPACK assessment in mathematics.

As such we were surprised to find that TPACK review research is only to a limited extent domain specific and almost not technologically or pedagogically specific. Recently, Petko et al. [27] suggested that contextual knowledge (XK) is also a knowledge domain (in addition to being an external influence), thus adding another knowledge domain to the TPACK model. If this is widely adopted, we suggest that future review research also tries to summarize findings on TPACK within a specific context (e.g., German dual system vocational schools like Torggler et al. [36]).

Of course, as could be expected, reviews that do not focus on specific T, C or P, typically have other priorities. There are several studies that focus on scientometrics and bibliographics, general TPACK (assessment, evolution of the model) or the role of context in TPACK. There are, however, also seven reviews that do not seem to have any particular focus. Still, we think that reviews should be explicit in the choices they make regarding the technology, content domain and pedagogical concepts included.

5.2. Holistic or analytic approach to TPACK

Tables 3, 4, 5 (code T5) and 6 all show that reviews on TPACK very often do not explicitly focus the peripheral knowledge domains (PK, CK, TK, PCK, TPK, TCK). Instead, the results in Table 6 suggest that most review research takes on a holistic approach to TPACK. This is not surprising given the limited focus on specific technologies, content domains or pedagogical concepts. It is, however, surprising given how TPACK is constructed.

The TPACK-framework consists of seven distinct knowledge bases. We recognize that these knowledge bases interact and are thus not completely independent (e.g., knowing how to use a technology to teach (TPK) requires knowledge about the technology (TK)). However, it seems relevant to at least also consider them as separate knowledge bases. After all, the inverse (knowing the technology (TK) does not mean you also know how to use it for teaching (TPK)) is obviously true.

Moreover, empirical research (e.g., Angeli & Valides, 2009) showed that TPACK knowledge base (not the model as a whole) is a unique body of knowledge, and that growth in its separately contributing knowledge bases does not lead to growth in TPACK itself. This puts pressure on the holistic view of TPACK as it was originally theorized [11]. As such, we suggest to focus in future review research on the various components of TPACK. A detailed understanding of how different authors report on and use the components of TPACK and their interaction can contribute to clarify the TPACK framework. Indeed, it has been argued that the definition of TPACK and its components may not be fully developed and clear [18,37,19].

5.3. Systematicity of the reviews

Only systematic and bibliometric reviews are included in this review of reviews. However, we were not very stringent regarding the clarity of the reported review-methodology. We found that the search protocols were very different in the selected reviews. Moreover, only a third of the selected reviews uses an established methodology to search for and select articles (e.g. Prisma, Starlite). This reduces the transparency and can perhaps even question the validity and reliability of the reviews (keeping in mind that the peer-review process is not a perfect system [38]). As such, in line with Schmid et al. (2024), we find methodological issues with the selected review articles.

While not unique to TPACK research, the lack methodological rigor is concerning and should be addressed in future review research. It may be helpful to look at other disciplines that have different research standards, also regarding meta-reviews [39]. For example, the biomedical sciences benefit from interdisciplinary research with advanced tools and methods in statistics and informatics, and has best practice and reporting guidelines for various types of research [39,40]. In contrast, the field of pedagogy and other human sciences has not yet developed a similarly advanced use of meta-research (including systematic reviews, review of reviews and meta-reviews). Given that TPACK is a research area that is quickly expanding, it is imperative that review articles are of high quality. We suggest using validated methodologies (e.g., PRISMA or Starlite). We should note that in this review of reviews, we also did not use the statistical analyses typically used in meta-reviews in bio-medical sciences. As such we opted to refer to this work as a "review of reviews", acknowledging that this work is not as methodologically sound as meta-reviews in the field of biomedical sciences typically are.

5.4. Limitations

We included only reviews written in English or Dutch, but recognize that language restrictions in reviews can lead to language bias [41–43]. While the bias due to English is expected to be less than other language restrictions, it is not yet certain that this completely resolves the language bias [44,45].

Likewise, we only included systematic (including bibliographic) review studies. As such, we excluded narrative reviews. We recognize that this may have excluded review papers that could have provided valuable insights.

We examined the search strings, the inclusion/exclusion criteria, the research questions/aims and the results. It can be expected that these are aligned. Indeed, this is typically the case. For example, Ali et al. [46] includes their focus on health education in their search strings, the inclusion/exclusion criteria, the research questions and the reported results. As such, it could be argued that there is perhaps not much added value in triangulating these, expectedly aligned, data. However, we do not find this alignment everywhere. For example, Putri et al. [47] included "science" in the search string, but no in the inclusion/exclusion criteria nor in the research questions. The reported results are, though focused on science.

The coding and analysis in this review of reviews was mainly done by the first author. We acknowledge that this is a limitation and that this may have led to certain biases or errors. However, this review of reviews still followed qualitative guidelines. There was ample discussion between the authors and the coding was done after agreement was reached (confirmed by a sufficiently high Cohen's kappa).

We chose not to include contextual knowledge (XK) as part of our review of reviews because it is not yet widely accepted within the TPACK framework and was not part of its original conceptualization. However, several prominent authors have argued for the inclusion of XK in the TPACK model [26,27,67], including authors whose work is covered in this review [25,48,49]. We acknowledge that this is a limitation of the study, however we think that incorporating XK into our analysis would not substantially alter the main conclusions of our work. Future research will also need to specifically focus on XK and on how it is integrated in the TPACK framework.

Finally, in this review of reviews we only considered the focus of the selected reviews themselves. However, as suggested by a reviewer, future research could conduct an analysis of the outcomes of the included reviews, potentially even comparing reviews with content, pedagogical or technological (or no) focus.

5.5. Suggestions for future review research

Education is inherently situated, and so is education research. To effectively study constructs such as TPACK, we have to be acutely aware of its situatedness. Teaching involves the delivery of specific content to a specific group of students in a specific class, school, city and country, using specific tools and pedagogical approaches, at a specific moment in time. Education researchers might want to develop insights and frameworks that not only capture parts of this complexity but can also serve as guides for practitioners in education, who will have to interpret these insights into their own dynamic complex context.

TPACK research, for instance, attempts to uncover the specific knowledge teachers have to use to make informed teaching decisions, and how this specific knowledge builds on their specific knowledge of content, pedagogy and technology. Despite a substantial body of primary education research on TPACK, still many open questions remain regarding the knowledge components, their interrelations and how they contribute to TPACK as a whole. Here we think focused review research can progress the field. Concretely, we think it is worthwhile for future review studies to focus on specific technologies, content or pedagogical approaches. At the very least, future review studies should be explicit about which technological, content or pedagogical domains they include or exclude. For example, by reviewing and condensing TPACK research available that share a specific technology (e.g., interactive whiteboards) across subjects, age groups and pedagogical approaches, it is possible to gain insights in the knowledge that is specific to that technology. Such focused analyses can also identify unresolved questions pertinent to that technology. Conducting this research for several technologies, and compiling these reviews, might give the possibility to gain general insights into TK and how it is connected to TPK, TCK and TPACK. Of course, analogously insights into the other domains can be distilled from the existing literature. Finally, based on these reviews-of-reviews the whole TPACK framework can be evaluated. This is a huge research endeavor, which we think is needed to truly assess a broad framework like TPACK. It is, of course, imperative that these reviews are themselves of sufficient methodological quality and critically assess the quality of the primary research they include.

6. Conclusion

The aim of this work was to summarize the review research about TPACK. Specifically, this review of reviews aims to summarize which knowledge domains of TPACK are primarily researched, to which extent reviews focus on particular content domains, pedagogical approaches or technologies, and whether a holistic or analytic stance is taken. By conducting a systematic review, following the PRISMA guidelines, we find that reviews often do not focus on a specific content domain, teacher population, technology and/or a pedagogical concept. TPACK is a growing field, and reviews are thus needed.

AI-statement

During the preparation of this work the author(s) used no AI-tool.

CRediT authorship contribution statement

Febe Fontyn: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Jo Tondeur:** Writing – review & editing. **Jan Sermeus:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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