Bibliometric Analysis of Teacher Competency and Pedagogical Models for Digital Technology Integration in School Physical Education

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ABSTRACT

This bibliometric analysis maps research on teacher competency and pedagogical models for digital technology integration in school physical education (PE), with the aim of clarifying growth patterns, knowledge structures, and thematic priorities. A Scopus search was executed using a structured TITLE-ABS-KEY strategy and reported through a PRISMA-aligned screening flow. The search retrieved 708 records, followed by staged screening and eligibility checks that yielded a final dataset of 79 documents. The dataset spans 2012 to February 4, 2026 and shows sustained scholarly activity across 15 citable years, involving 321 contributing authors. Impact indicators show 912 total citations, 11.54 citations per paper, 65.14 citations per year, and a strong h-core concentration of 863 citations, alongside an h-index of 18, g-index of 27, and m-index of 1.200. To reveal the conceptual structure, keyword co-occurrence mapping identified six clusters linking teacher training and professional development with technology integration, teacher perceptions and self-efficacy, assessment and school implementation, and movement-based PE priorities including meaningful PE, with COVID-19 appearing as a marker of accelerated discourse during remote teaching periods. These findings position the field as an intersection of competency frameworks and pedagogical model scholarship, with clear pathways for future research focused on stronger alignment between digital tool use, pedagogical model fidelity, and evidence of learning outcomes in movement-based contexts.

INTRODUCTION

Digital technology reshapes teaching and assessment in schools. PE adds added demands because learning happens through movement, space use, and rapid feedback. Teachers need strong competency and clear pedagogical choices to align digital tools with lesson goals. Recent studies report uneven perceived digital competence among PE teachers and persistent barriers linked to access, confidence, and classroom enactment (Martínez-Rico et al., 2022; Irwahand et al., 2022).

Technology use in school PE now appears across face to face, online, and blended formats. Research on online PE links health perceptions with teacher effectiveness and shows shifts in instructional routines under digital delivery (Ben Amotz et al., 2025). Hybrid flexible instruction studies describe practical adaptations made by PE teachers and point to a need for models of teaching that fit blended conditions (Tanucan et al., 2025). School intervention studies also show relationships between information and communication technology programmes and teaching and learning processes in PE, which places pedagogy at the centre of technology work (Koh et al., 2025).

Studies on teacher and student perceptions of ICT in PE report perceived benefits, classroom uses, and expectations for future practice (Pérez et al., 2024). Research on reflective practice connects teacher learning with purposeful lesson refinement (Adank et al., 2026). Evidence on self-efficacy links confidence beliefs with achievement goals in PE systems, which positions psychological readiness as part of competency (Kusmiyati et

al., 2024). Other work links digital empowerment and information technology application with innovative teaching practices, including mechanisms that shape classroom decisions (Zhao et al., 2025). Professional development research also evaluates a digital teacher learning tool aimed at strengthening motivational climate in secondary school PE (Weeldenburg et al., 2024). Studies across diverse contexts, including teacher education, reinforce this multi strand evidence base (Tomura et al., 2025; Scanlon et al., 2025).

Despite growing research on digital technology in school PE, prior studies remain fragmented across teacher competency, tool use, professional development, and teaching models. No bibliometric study maps the combined knowledge base that links teacher competency with pedagogical models for digital technology integration in school PE. This study addresses this gap by conducting a Scopus based bibliometric analysis from 2012 to February 4, 2026 to identify publication trends, influential sources, leading contributors, and thematic structures in this field.

LITERATURE REVIEW

Digital technology integration in school physical education (PE) influences lesson design, assessment routines, and student engagement. The literature clusters around four strands which are adoption barriers and school conditions, perceived digital competence, professional learning and competency frameworks and pedagogical approaches for movement learning. Evidence across these strands indicates that knowledge development remains unevenly connected with limited integration between teacher competency and pedagogical models in movement-based lessons.

Barrier and School Conditions

Barrier focused research explains uneven technology integration in movement-based settings. Core issues include access constraints, implementation challenges, and contextual limits within PE spaces and routines (Irwahand et al., 2022). Evidence from disruption period online PE adds structural pressures, with greater emphasis on task design, management, and participation structures under home based conditions (Ben Amotz et al., 2025; Pérez et al., 2024). Hybrid flexible teaching accounts further indicate tensions between curriculum goals and technology use when alignment guidance between tools and instructional intent appears limited (Tanucan et al., 2025). Collectively, this strand indicates that school level conditions and delivery settings shape the feasibility and quality of integration.

Perceived Digital Competence

Perceived competence evidence complements barrier studies by showing uneven readiness across planning, teaching, and evaluation in school contexts (Martínez-Rico et al., 2022). Synthesis with barrier findings suggests two linked pressures. Structural conditions shape opportunity to adopt tools. Competence perceptions shape willingness to act within those conditions. This strand frames perceived readiness as a proximal factor influencing technology related teaching actions within existing school constraints.

Professional Learning and Competency Frameworks

Professional development research addresses teacher learning conditions, though emphases differ across studies. Evaluation of a digital professional development tool highlights programme design, sustained support, and workplace alignment as determinants of teaching change (Weeldenburg et al., 2024). Digital empowerment research links capability building with instructional goals and classroom decision making (Zhao et al., 2025). Self-efficacy findings show confidence related differences in sustained engagement with technology supported practice in physical education contexts (Kusmiyati et al., 2024). Competency frameworks add theoretical structure. TPACK grounded research conceptualises competency as integrated knowledge domains shaping planning and instructional choices with technology (Doğru, 2024). Studies that focused on teacher decision making explain how roles, beliefs, and school expectations shape classroom action during technology integration (Tomura et al., 2025). Teacher education research highlights uneven opportunities to develop technology related pedagogical skill within preparation pathways (Scanlon et al., 2025). Across this strand, effective professional

learning aligns tool selection with lesson aims, strengthens decision making during instruction, and supports competence development within authentic school contexts.

Pedagogical Approaches for Movement Learning

This strand links technology use with pedagogical approaches that target movement learning outcomes. Intervention research reports measurable changes in outcomes tied to physical activity and learning processes, shifting attention toward instructional design rather than tool adoption alone (Koh et al., 2025). Movement based teaching research broadens pedagogical relevance by foregrounding embodied learning and creative movement tasks (Cappello et al., 2025). Comparative synthesis with adoption and competence strands indicates limited integration between competency frameworks and explicit pedagogical model selection, enactment, and assessment routines within movement-based lessons.

Previous Study on Bibliometric Analysis

Bibliometric studies map intellectual structure, thematic trajectories, and collaboration patterns in digital technology research. Within physical education, bibliometric work frequently prioritises growth trends, keyword co-occurrence, collaboration networks, and topic bursts. Zhou (2023) mapped online education research in sport and physical education and reported growth with shifting keyword clusters. Chai et al. (2025) analysed digital transformation in physical education and identified hotspots and future directions using CiteSpace. In contrast, teacher digital competence bibliometric research often foregrounds intellectual foundations through co citation structures and influential sources. Aydin and Yildirim (2022) used Web of Science and VOSviewer to identify key journals, scholars, and foundational works. Ma and Ismail (2025) integrated bibliometric mapping with content analysis to synthesise dominant themes across education. Li and Tinmaz (2025) mapped teacher digital competence research in China using CiteSpace. Comparison across these streams shows methodological overlap in database driven mapping and keyword analysis, paired with differences in analytic depth and conceptual focus. Physical education technology mapping highlights topical development. Teacher digital competence mapping clarifies intellectual foundations. Links around pedagogical models in school physical education remain under specified within both streams.

Research Questions

This paper presents a bibliometric analysis of teacher competency and pedagogical models for digital technology integration in school physical education by focusing on six main research questions (RQs):

RQ 1: What is the current landscape of teacher competency and pedagogical models for digital technology integration research in the school physical education?

RQ 2: What emerging trends are observable in publication on teacher competency and pedagogical models for digital technology integration in school physical education?

RQ 3: Which journals and publications serve as epicentres for high impact studies on teacher competency and pedagogical models for digital technology integration in school physical education?

RQ 4: What landmark papers have shaped the discourse and direction of teacher competency and pedagogical model research for digital technology integration in school physical education?

RQ 5: Which key players, authors, institutions, and countries are driving advances in teacher competency and pedagogical models for digital technology integration in school physical education?

RQ 6: What key research themes underspin the development and growth of teacher competency and pedagogical models for digital technology integration in school physical education?

The comprehensive nature of this study offers an opportunity to understand the scope of research on teacher competency and pedagogical models for digital technology integration in school physical education. By applying bibliometric and network analysis techniques, this study develops a detailed view of the scholarly landscape,

core themes, and thematic clusters within this domain. The insights support decisions on teacher development and instructional design in physical education. They also support alignment with evolving technology and curriculum expectations. This study aims to map the field from its early foundations to current directions. Through systematic analysis, it provides an overview of the field's historical, present state and sets a basis for future research. The work targets improved teaching quality and stronger innovation in school physical education through purposeful digital technology integration.

METHOD

This study employed data sourced from the Scopus database as of February 4, 2026. The collected data covered document types, source types, languages, subject areas, publication trends, average authorship per document, institutional contributions, publication distribution by country, and prominent keywords, along with related indicators. Many prior bibliometric studies on digital technology integration in school physical education have relied on a single database source, such as Scopus, which narrows coverage of the literature. This study recognises the value of integrating multiple databases, including Web of Science and Google Scholar, in future research to widen coverage and strengthen the overall analysis.

Search Strategy

This review followed modified PRISMA guidance to structure the systematic assessment and reporting of studies. The review design aligned with established PRISMA reporting principles for transparent selection and screening. (Haddaway et al., 2022; Moher et al., 2009). The search query as below was used in Scopus database followed by the application of subject specific filters:

TITLE-ABS-KEY ("physical education" AND (school* OR "secondary school" OR "primary school" OR "K-12") AND (teacher* OR educator* OR "physical education teacher*" OR PETE OR "teacher education" OR preservice OR "pre-service" OR "in-service") AND ("digital competence" OR "digital competency" OR TPACK OR "pedagogical content knowledge" OR PCK OR "teacher competence" OR "teacher competency" OR "professional development" OR training OR "teacher training" OR CPD) AND (teach* OR teaching OR pedagog* OR instruction* OR curriculum OR "pedagogical model*" OR "models-based practice" OR "instructional model*" OR "teaching strateg*" OR "instructional design") AND (technolog* OR digital OR ICT OR "technology integration" OR "digital technolog*" OR "educational technolog*" OR "digital tool*" OR video OR "video-based" OR app* OR LMS OR "learning management system" OR "online learning" OR e-learning OR "blended learning" OR "flipped classroom" OR gamif* OR exergam* OR "virtual reality" OR VR OR "augmented reality" OR AR OR wearable* OR sensor* OR assessment OR evaluat* OR rubric* OR feedback OR "digital assessment" OR "digital feedback" OR "formative assessment" OR "mobile learning" OR m-learning OR smartphone* OR tablet*) AND (attitude OR belief* OR "self-efficacy" OR perception* OR acceptance OR intention OR barrier* OR challenge* OR constraint* OR TAM OR UTAUT)) AND NOT TITLE-ABS-KEY (elite OR athlete* OR "high performance" OR "sport performance" OR biomechanic* OR physiolog*).

The study's scope and selection criteria included search field, time frame, source type, and document type to support the exclusion of non-relevant studies. Based on the PRISMA flow (Figure 1), the search identified 708 records from Scopus. Before screening, 0 duplicate records were removed, and 300 records were marked as ineligible by automation tools due to subject classification outside Social Sciences. Next, 408 records were screened and 36 records were excluded by automation tools because they were not Article or Proceeding. Reports sought for retrieval totalled 372, with 169 reports not retrieved due to access limits. A total of 203 reports were assessed for eligibility. Reports were excluded for the following reasons, not in English (n = 55), not in final publication stage (n = 14), and not in physical education (n = 55). Following this screening, the final dataset retained 79 documents related to teacher competency and pedagogical models for digital technology integration in school physical education.

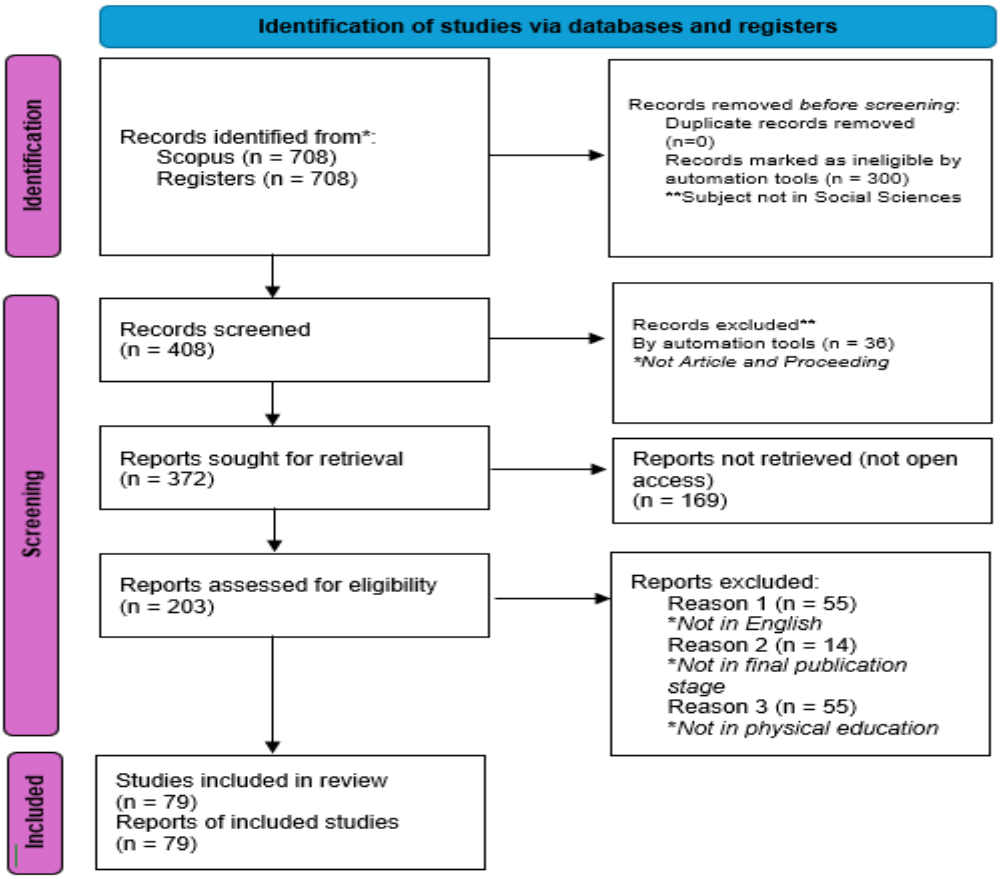

Figure 1 Flow diagram of the search strategy

Data Cleaning and Harmonisation

Data cleaning and harmonisation support accuracy and reliability in bibliometric analysis. This study used OpenRefine and the bibliometrix toolkit in R to refine and align inconsistent records. The focus was on author names, affiliations, keywords, and core bibliographic fields. These tools supported higher precision and stronger consistency across the dataset, given variation in indexing and author reporting. The process began with exporting Scopus records in CSV format, then selecting key columns for standardisation. Keyword fields, author names, and affiliation strings were cleaned through clustering, merging, and rule-based transformations. Duplicates were checked through title, DOI, and source comparisons. Missing values were flagged and completed through manual verification, where records contained sufficient metadata to support correction. Advanced bibliometric indicators were computed after cleaning. These indicators included Total Publications (TP), Number of Contributing Authors (NCA), Number of Cited Publications (NCP), Total Citations (TC), Citations per Publication (C/P), Citations per Cited Publication (C/CP), Citations per Author (C/A), Authors per Publication (A/P), Citations per Year (C/Y), Citable Years, and index measures such as h-index, g-index, and m-index. Outputs were summarised across publication year, source titles, authors, institutions, and countries. Overall, data harmonisation and cleaning improved dataset clarity and strengthened the foundation for mapping teacher competency and pedagogical models for digital technology integration in school physical education.

Data Analysis

The data analysis was structured to address the research questions. The approach mapped the current landscape of teacher competency and pedagogical models for digital technology integration in school physical education. The analysis focused on document types, source categories, languages, subject areas, and citation patterns. Findings were reported across key indicators such as annual publication volume, contributions from leading authors, prominent institutions, key countries, and influential source titles. This reporting supported identification of major contributors and field level trends. To assess impact and influence, bibliometric indicators

were calculated, including total publications, number of cited papers, total citations, citations per publication, citations per cited publication, authors per publication, and index metrics such as h-index, g-index, and m-index. The analysis also summarised citation performance across the h-core. To identify dominant themes and conceptual structure, network-based techniques were applied. These included co-occurrence analysis of author keywords, thematic mapping to position themes by centrality and development, and factorial methods such as correspondence analysis to visualise keyword relationships. These outputs supported detection of topic clusters, pattern recognition across subfields, and mapping of connections between teacher competency constructs, pedagogical models, and digital technology integration practices in school physical education.

Tools

The study utilized a range of tools to perform a comprehensive bibliometric analysis of teacher competency and pedagogical models for digital technology integration in school physical education. Microsoft Excel was used for initial data cleaning and organization, while biblioMagika® streamlined the cleaning, harmonization, and standardization of data on authors' affiliations and countries. OpenRefine was applied specifically to harmonize and clean data for authors' keywords. Once the data was prepared, VOSviewer generated informative visual representations of the research findings, with Mendeley serving as the reference manager. This combination of tools and techniques enabled a thorough and rigorous examination of the research landscape on teacher competency and pedagogical models for digital technology integration in school physical education.

FINDINGS

In this section, the authors present an in-depth examination of the research landscape for teacher competency and pedagogical models for digital technology integration in school physical education. This detailed analysis addresses the research questions (RQs), yielding a deep understanding of the field. Through this focused analysis, the authors are committed to delivering a detailed and insightful overview of teacher competency and pedagogical models for digital technology integration in school physical education, contributing valuable knowledge for scholars, practitioners, and decision makers.

RQ1: Landscape of Research on Teacher Competency and Pedagogical Models for Digital Technology Integration in School Physical Education

To address the initial research question, which aims to map the current state of teacher competency and pedagogical models for digital technology integration research in school physical education, the authors analyse the distribution of publications across multiple factors, including document type, source type, languages, and subject areas. Additionally, citation metrics assessed to gauge the impact and significance of these contributions within the field of teacher competency and pedagogical models for digital technology integration in school physical education. The data were first organised by document type, encompassing formats such as articles, conference papers, book chapters, and review articles. Conference papers often present research findings shared at scholarly conferences, with some subsequently published in proceedings or as book chapters.

Through an extensive analysis covering the period from 2012 to 2026, a comprehensive dataset in Table 1 highlights significant academic contributions, totalling 79 publications and indicating a sustained research trajectory over 15 citable years. This body of work involves a network of 321 contributing authors, showing strong collaboration across the field. The count of 79 cited papers reflects broad uptake of the published outputs within the scholarly community. A total of 912 citations further indicates field level influence across the study period. This research collection recorded an average of 11.54 citations per paper. For cited papers, the average citations per cited paper is also 11.54. Citation impact across time is reflected in 65.14 citations per year. Authorship patterns show 4.06 authors per paper, with 2.84 citations per author, supporting an overview of productivity and influence at author level. Impact concentration is shown by a citation sum within the h-core of 863, alongside an h-index of 18, a g-index of 27, and an m-index of 1.200. These indicators describe both the scale of publication output and the influence of this literature, providing a structured view of the academic footprint for this research area.

Table 1 Citation metric

Main Information	Data
Publication Years	2012 - 2026
Total Publications	79
Citable Year	15
Number of Contributing Authors	321
Number of Cited Papers	79
Total Citations	912
Citation per Paper	11.54
Citation per Cited Paper	11.54
Citation per Year	65.14
Citation per Author	2.84
Author per Paper	4.06
Citation sum within h-Core	863
h-index	18
g-index	27
m-index	1.200

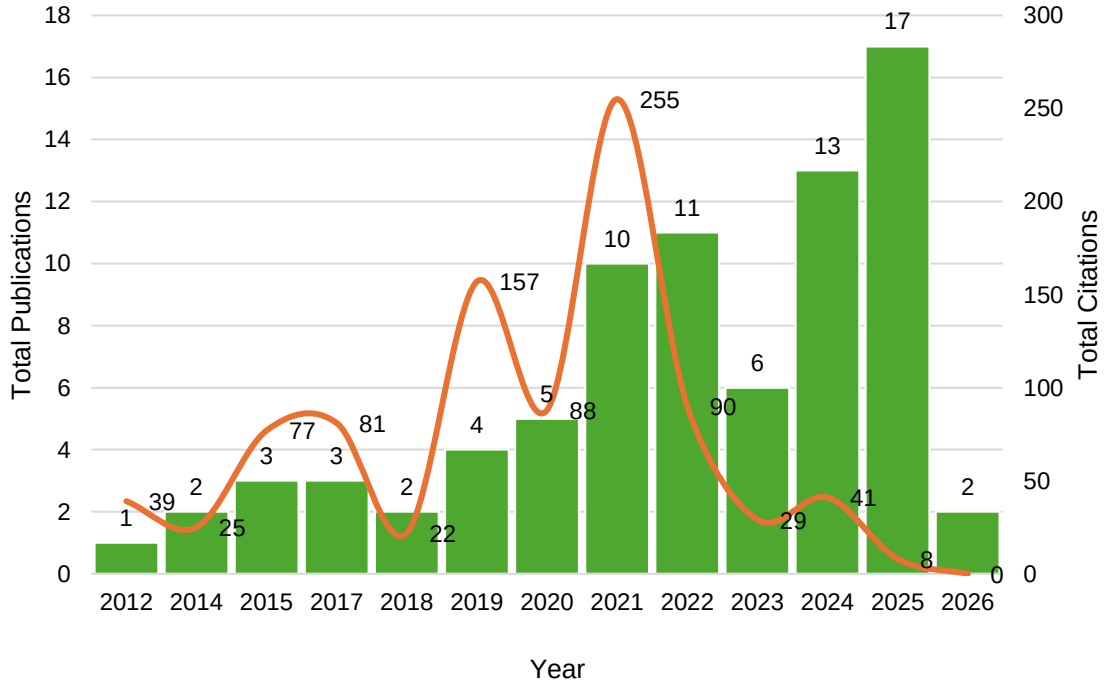

Figure 2 Total publications and citations by year (as data is only available up to February 4, 2026)

RQ2: Publication Trends and Emerging Directions in Teacher Competency and Pedagogical Models for Digital Technology Integration in School Physical Education

To address the second research question, the authors traced the developmental trajectory of this growing field. The earliest recorded publication in 2012 marks the beginning of research on teacher competency and pedagogical models for digital technology integration in school physical education, which has increased over time. By 2025, there were 17 publications with 8 total citations, indicating continued growth in publication output, as shown in Table 2. The visualisation of total publications and citations shows a clear rise in annual publications, with notable citation spikes. A major spike appears in 2021, where 255 citations were recorded alongside 10 publications. These peak signals a period of heightened scholarly attention and stronger citation visibility for work published within this topic area. In contrast, later years show lower citation totals, which aligns with recency effects for newly published studies.

Concurrent with the rise in total publications, there has also been a marked increase in the Number of Contributing Authors (NCA), reaching 85 in 2025. This pattern reflects an expanding and collaborative research community. The observed growth supports the view that the field draws on multiple knowledge bases, linking teacher competency frameworks, pedagogical models in physical education, and digital technology integration in school contexts. The increase in author participation indicates wider academic engagement and stronger cross institutional activity, which positions this topic as a growing area within physical education and education technology research.

In terms of impact, the h-index and g-index values shown in Table 2 reflect the influence of this field. The h-index reached 18, while the g-index stood at 27, indicating the presence of frequently cited papers alongside broader citation accumulation. The m-index shows fluctuations over the years, peaking at 1.500 in 2021, which signals a high rate of influential publications during that period. The m-index remained high in 2024 at 1.333 and in 2022 at 1.200, before dropping in 2025 and reaching 0.000 in 2026. These metrics support a pattern of uneven citation impact across years. The variability suggests differences in topic visibility, publication venues, and citation behaviour, alongside time lag effects. Further investigation is needed to explain these fluctuations, especially by examining highly cited documents, keyword shifts, and collaboration patterns that coincide with the 2021 citation peak.

Table 2 Publication by year

Year	**TP**	**NCA**	**NCP**	**TC**	**C/P**	**C/CP**	***h***	***g***	***m***
2012	1	11	1	39	39.00	39.00	1	1	0.067
2014	2	4	2	25	12.50	12.50	2	2	0.154
2015	3	6	3	77	25.67	25.67	3	3	0.250
2017	3	5	3	81	27.00	27.00	3	3	0.300
2018	2	11	2	22	11.00	11.00	2	2	0.222
2019	4	13	4	157	39.25	39.25	3	4	0.375
2020	5	16	5	88	17.60	17.60	5	5	0.714
2021	10	51	10	255	25.50	25.50	9	10	1.500
2022	11	37	11	90	8.18	8.18	6	9	1.200
2023	6	23	6	29	4.83	4.83	3	5	0.750

2024	13	51	13	41	3.15	3.15	4	5	1.333
2025	17	85	17	8	0.47	0.47	1	2	0.500
2026	2	8	2	0	0.00	0.00	0	0	0.000
Total	79	321	79	912	11.54	11.54	18	27	1.200

Note: TP=total number of publications; NCA=number of contributing authors; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index; m=m-index.* Publication data is only up until February 4, 2026.

RQ3: Core Journals and High Impact Publication Outlets in Teacher Competency and Pedagogical Models for Digital Technology Integration in School Physical Education

Table 3 identifies the leading source titles actively contributing to teacher competency and pedagogical models for digital technology integration in school physical education, focusing on outlets with two or more publications. Sustainability (Switzerland) leads in productivity with a total publication count (TP) of 10 and a total citation count (TC) of 113, indicating strong and consistent contributions. Sport, Education and Society also shows a central role with TP of 8 and TC of 134, supported by a high citations per publication (C/P) of 16.75. Its h-index of 7 reflects a sustained presence of frequently cited papers within this topic area.

European Physical Education Review stands out for citation impact. Although it has a TP of 4, it records the highest TC of 192 and a C/P of 48.00, showing concentrated influence per article. Retos contributes with TP of 6 and TC of 61, indicating steady visibility across its outputs. Frontiers in Sports and Active Living adds TP of 5 with TC of 26, reflecting moderate citation reach. Journal of School Health records TP of 3 with TC of 58 and a C/P of 19.33, showing strong citation return relative to its publication count. International Journal of Human Movement and Sports Sciences also shows meaningful influence with TP of 2 and TC of 39, alongside a C/P of 19.50.

The g-index and m-index values provide added insight into influence patterns across these outlets. For example, Sustainability (Switzerland) records a g-index of 10 and an m-index of 0.778, indicating broad citation accumulation across its publications. Sport, Education and Society shows a g-index of 8 and an m-index of 0.583, supporting consistent citation activity. Retos reports a g-index of 3 and an m-index of 0.500, while Journal of School Health reports a g-index of 3 and an m-index of 0.333. These patterns indicate a mix of high output outlets and high impact outlets, which together shape the publication landscape for this research domain.

Table 3 Most productive source title

Source Title	**TP**	**NCA**	**NCP**	**TC**	**C/P**	**C/CP**	***h***	***g***	***m***
Sustainability (Switzerland)	10	48	10	113	11.30	11.30	7	10	0.778
Sport, Education and Society	8	17	8	134	16.75	16.75	7	8	0.583
Retos	6	27	6	61	10.17	10.17	3	6	0.500
Frontiers in Sports and Active Living	5	24	5	26	5.20	5.20	2	5	0.333
European Physical Education Review	4	17	4	192	48.00	48.00	4	4	0.333
Education Sciences	4	26	4	9	2.25	2.25	1	3	0.200

Frontiers in Education	3	8	3	12	4.00	4.00	2	3	0.400
Cogent Education	3	15	3	34	11.33	11.33	1	3	0.100
Journal of School Health	3	13	3	58	19.33	19.33	2	3	0.333
International Journal of Human Movement and Sports Sciences	2	5	2	39	19.50	19.50	1	2	0.143

Note: TP=total number of publications; NCA=number of contributing authors; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index; m=m-index.

RQ4: Landmark Papers Shaping Teacher Competency and Pedagogical Model Research for Digital Technology Integration in School Physical Education

Table 4 highlights the top five highly cited articles in the field of teacher competency and pedagogical models for digital technology integration in school physical education. These works show influential contributions that shaped research focus, methods, and school-based practice discussions. Leading the list is González-Víllora et al. (2019), whose systematic review on hybridizing pedagogical models has received 116 citations, with an average of 14.50 citations per year. This study positions hybrid models as a central direction for teaching design in physical education, and it provides a key reference point for linking pedagogical approaches with classroom implementation.

Following this is the article by Vilchez et al. (2021), which examines teachers and school health leaders' perspectives on distance learning in physical education during the COVID-19 pandemic. The study has garnered 55 citations with an average of 9.17 citations per year, indicating strong uptake in research discussing teacher capacity, school readiness, and delivery constraints during remote physical education. Another influential work by Hortigüela-Alcalá et al. (2021) focuses on physical education in the COVID-19 context through teachers across educational stages. With 42 citations and 7.00 citations per year, this article highlights teacher challenges and adaptation efforts during a major shift in instructional conditions.

Other highly cited studies include Morley et al. (2021), which addresses inclusion of pupils with special educational needs and or disabilities in mainstream secondary physical education. This paper received 41 citations with 6.83 citations per year, showing sustained interest in inclusive pedagogical decision making. Mokmin (2020) contributes evidence on a personalized virtual fitness trainer in physical education, reporting 39 citations and 5.57 citations per year, which reflects growing attention to digital systems that support instruction, feedback, and learner engagement. Together, these articles indicate that the most cited works in this field cluster around hybrid pedagogical models, teacher perspectives during distance learning, pandemic driven instructional change, inclusive practice, and digital tools for fitness and teaching support.

Table 4 Top five (5) highly cited articles

No	Authors	Title	TC	C/Y
1	Gonzalez-Villora et al., (2019)	Hybridizing pedagogical models: A systematic review.	116	14.50
2	Vilchez et al., (2021)	Teachers and school health leaders' perspectives on distance learning physical education during the COVID-19 pandemic	55	9.17
3	Hortigüela-Alcalá et al., (2021)	Physical Education in the COVID-19 context. A tale from teachers of different educational stages	42	7.00

4	Morley et al., (2021	Including pupils with special educational needs and/or disabilities in mainstream secondary physical education: A revisit study.	41	6.83
5	Mokmin (2020)	The effectiveness of a personalized virtual fitness trainer in teaching physical education by applying the artificial intelligent algorithm	39	5.57

RQ5: Leading Contributors, Authors, Institutions, and Countries in Teacher Competency and Pedagogical Models for Digital Technology Integration in School Physical Education

Table 5 presents the most productive authors in the field of teacher competency and pedagogical models for digital technology integration in school physical education, highlighting contributors within the current dataset. The highest publication output in this table is two publications. Vos, Steven B. from Fontys University of Applied Sciences, Netherlands, recorded 2 publications and 1 cited publication, resulting in 6 total citations. This output corresponds to 3.00 citations per publication and 6.00 citations per cited publication, with an h-index of 1, g-index of 2, and m-index of 0.333. Another key contributor is Lynch, Timothy Joseph from Monash University, Australia, with 2 publications and 2 cited publications, producing 52 total citations. Lynch's work shows strong citation concentration, with 26.00 citations per publication and 26.00 citations per cited publication, supported by an h-index of 2, g-index of 2, and m-index of 0.200. Kwok, Ng W. from Lithuanian Sports University, Lithuania, also recorded 2 publications and 1 cited publication, with 20 total citations. This equals 10.00 citations per publication and 20.00 citations per cited publication, with an h-index of 1, g-index of 2, and m-index of 0.167.

Several authors in the table contributed one publication each, with varying citation impact across institutions and countries. González-García, Rómulo Jacobo from Universidad Católica de Valencia San Vicente Mártir, Spain, recorded 1 publication and 15 citations, producing 15.00 citations per publication, with an h-index of 1, g-index of 1, and m-index of 0.200. Gonzalez-Jurado, Jose Antonio from Universidad Pablo de Olavide, Spain, recorded 1 publication and 12 citations, with 12.00 citations per publication and an m-index of 0.077. Zeveloff, Abigail D. from a School of Nursing in the United States recorded 1 publication with 39 total citations, producing 39.00 citations per publication and 39.00 citations per cited publication, with an h-index of 1, g-index of 1, and m-index of 0.067. Quennerstedt, Mikael from Swedish School of Sport and Health Sciences, Sweden, recorded 1 publication with 11 citations, resulting in 11.00 citations per publication and an m-index of 0.333. Stuart, J. from Edge Hill University, United Kingdom, recorded 1 publication with 7 citations, giving 7.00 citations per publication and an m-index of 0.250. Contreras, Luis Díaz from Universidad Bernardo O'Higgins, Chile, recorded 1 publication with 2 citations, producing 2.00 citations per publication and an m-index of 0.333.

Collectively, these authors show an international spread across Europe, Australia, and the United States, with visible contributions from the Netherlands, Australia, Lithuania, Spain, Sweden, the United Kingdom, Chile, the United States, and Malaysia. The pattern also suggests uneven citation concentration, where a smaller number of publications accounts for higher citation totals, as shown by Lynch (Australia) and Zeveloff (United States). This distribution reflects a field where influence is shaped by a limited set of highly cited outputs, alongside a broader base of single publication contributors across multiple countries and institutions.

Table 5 Most productive authors

Full Name	**Current Affiliation**	**Country**	**TP**	**NCP**	**TC**	**C/P**	**C/CP**	***h***	***g***	***m***
Vos, Steven B.	Fontys University of Applied Sciences	Netherlands	2	1	6	3.00	6.00	1	2	0.333

Lynch, Timothy Joseph	Monash University	Australia	2	2	52	26.00	26.00	2	2	0.200
Kwok, Ng W.	Lithuanian Sports University	Lithuania	2	1	20	10.00	20.00	1	2	0.167
González-García, Rómulo Jacobo	Universidad Católica de Valencia San Vicente Mártir	Spain	1	1	15	15.00	15.00	1	1	0.200
Contreras, Luis Díaz	Universidad Bernardo O'Higgins	Chile	1	1	2	2.00	2.00	1	1	0.333
Gonzalez-Jurado, Jose Antonio	Universidad Pablo de Olavide	Spain	1	1	12	12.00	12.00	1	1	0.077
Zeveloff, Abigail D.	School of Nursing	United States	1	1	39	39.00	39.00	1	1	0.067
Quennerstedt, Mikael	Swedish School of Sport and Health Sciences	Sweden	1	1	11	11.00	11.00	1	1	0.333
Ayob, Adenan	UCSI University	Malaysia	1	0	0	0.00	0.00	0	0	0.000
Fairclough, Stuart J.	Edge Hill University	United Kingdom	1	1	7	7.00	7.00	1	1	0.250

Note: TP=total number of publications; NCA=number of contributing authors; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index; m=m-index.

Other than that, Table 6 presents the most productive institutions in the field of teacher competency and pedagogical models for digital technology integration in school physical education, listing those with at least six publications. Leading the table is Fontys University of Applied Sciences in the Netherlands, with a total of 9 publications. The institution records 30 total citations, averaging 3.33 citations per publication, with an h-index of 5, a g-index of 5, and a high m-index of 1.667, indicating sustained influence relative to the active publication period. Idris Universiti Pendidikan Sultan in Malaysia follows closely with 8 publications and 48 total citations, achieving 6.00 citations per publication and 8.00 citations per cited publication. Its h-index of 6 and g-index of 6 reflect a strong and consistent contribution within the dataset.

Several institutions share similar productivity levels of 7 publications. Universidad Bernardo O'Higgins in Chile records 7 publications with 14 total citations, with an h-index of 2 and a g-index of 3, indicating modest citation reach. Universitas Negeri Semarang in Indonesia also reports 7 publications, with 9 total citations and an h-index and g-index of 3, showing steady output with lower citation density. The University of Western Australia records 7 publications and 28 total citations, but with only 1 cited publication and a citations per cited publication value of 28.00, indicating citation concentration in a smaller set of outputs. Universidad de Oviedo in Spain stands out strongly for impact. With 7 publications, it records 170 total citations and an average of 24.29 citations per publication, supported by an h-index of 7 and a g-index of 7, signalling a highly influential institutional contribution.

Institutions with 6 publications also show meaningful impact differences. University of Idaho in the United States records 6 publications and 6 total citations, indicating limited citation reach. Universidad de Valladolid in Spain records 6 publications with 86 total citations, averaging 14.33 citations per publication and 17.20 citations per cited publication, with an h-index of 5 and a g-index of 6. These values suggest strong citation performance across its outputs. Overall, the citation metrics, including h-index and g-index, show that institutional influence in this field is shaped by both productivity and citation intensity, with Universidad de Oviedo and Universidad de Valladolid in Spain, and Idris Universiti Pendidikan Sultan in Malaysia, emerging as key institutional drivers within the research landscape.

Table 6 Most productive institutions

Institution Name	**Country**	**TP**	**NCP**	**TC**	**C/P**	**C/CP**	***h***	***g***	***m***
Fontys University of Applied Sciences	Netherlands	9	5	30	3.33	6.00	5	5	1.667
Universiti Pendidikan Sultan Idris	Malaysia	8	6	48	6.00	8.00	6	6	1.200
Universidad Bernardo O'Higgins	Chile	7	7	14	2.00	2.00	2	3	0.667
Universitas Negeri Semarang	Indonesia	7	3	9	1.29	3.00	3	3	1.000
The University of Western Australia	Australia	7	1	28	4.00	28.00	1	5	0.083
Universidad de Oviedo	Spain	7	7	170	24.29	24.29	7	7	0.778
University of Idaho	United States	6	6	6	1.00	1.00	1	2	0.250
Universidad de Valladolid	Spain	6	5	86	14.33	17.20	5	6	0.714
Levinsky-Wingate Academic College	Israel	5	5	40	8.00	8.00	5	5	0.714
The University of Newcastle	Australia	5	5	25	5.00	5.00	4	5	1.333

Note: TP=total number of publications; NCA=number of contributing authors; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index; m=m-index.

Finally, Figure 3 and Table 7 provide an overview of the global research contributions in teacher competency and pedagogical models for digital technology integration in school physical education, focusing on countries that have contributed eleven or more publications. Spain leads the field with 47 publications, and a total citation count of 965, showing strong impact with an h-index of 14 and an average of 20.53 citations per publication. Spain also records a g-index of 31 and an m-index of 1.077, which indicates sustained influence across the publication period. The United States follows with 35 publications and 855 total citations. The United States shows strong citation performance, with an average of 24.43 citations per publication and 25.91 citations per cited publication, supported by an h-index of 19, a g-index of 29, and an m-index of 1.267. These values reflect both high output and strong citation visibility.

The United Kingdom also contributes substantially, with 33 publications and a total of 562 citations. The United Kingdom records an average of 17.03 citations per publication and an h-index of 13, with a g-index of 23 and an m-index of 1.000, reflecting consistent influence within the field. Australia contributes 22 publications with 128 citations, with lower citation density at 5.82 citations per publication, alongside an h-index of 6 and an m-index of 0.500. Malaysia and Indonesia each record 16 publications but differ in citation impact. Malaysia

accumulates 91 citations, averaging 5.69 citations per publication, with an h-index of 7 and an m-index of 1.000. Indonesia records 34 citations, averaging 2.13 citations per publication, with an h-index of 4 and an m-index of 0.800. These patterns suggest similar publication activity but different citation reach and uptake.

Other contributing countries include Israel with 13 publications and 40 citations, the Netherlands with 12 publications and 43 citations, Chile with 12 publications and 27 citations, and Poland with 11 publications and 132 citations. Poland shows comparatively strong impact, with 12.00 citations per publication and an h-index of 7. The Netherlands records an m-index of 2.000, which indicates strong influence relative to the active time window for its publications. Overall, the data in Figure 3 and Table 7, including h-index, g-index, and m-index values, show a wide international research base, with high output and high impact concentrated in Spain, the United States, and the United Kingdom, alongside expanding contributions from multiple regions.

Table 7 Most productive countries

Country	**TP**	**NCP**	**TC**	**C/P**	**C/CP**	***h***	***g***	***m***
Spain	47	46	965	20.53	20.98	14	31	1.077
United States	35	33	855	24.43	25.91	19	29	1.267
United Kingdom	33	28	562	17.03	20.07	13	23	1.000
Australia	22	11	128	5.82	11.64	6	11	0.500
Malaysia	16	8	91	5.69	11.38	7	9	1.000
Indonesia	16	10	34	2.13	3.40	4	5	0.800
Israel	13	5	40	3.08	8.00	5	6	0.714
Chile	12	8	27	2.25	3.38	2	5	0.222
Netherlands	12	8	43	3.58	5.38	6	6	2.000
Poland	11	8	132	12.00	16.50	7	11	1.167

Note: TP=total number of publications; NCA=number of contributing authors; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index; m=m-index.

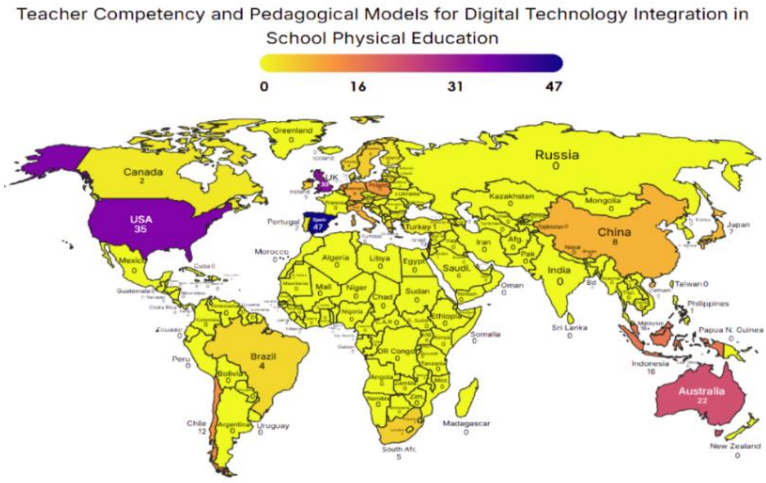

Figure 3 Visualization of global distribution of teacher competency and pedagogical models for digital technology integration in school physical education research

RQ6: Key Research Themes and Thematic Clusters in Teacher Competency and Pedagogical Models for Digital Technology Integration in School Physical Education

The keyword co-occurrence analysis offers a clear overview of the thematic structure and research directions in teacher competency and pedagogical models for digital technology integration in school physical education. The analysis aligns overlapping terms, then maps co-occurrence patterns to identify keyword groups that appear together. The output highlights the main conceptual core, alongside lines of work on pedagogy, teacher training, and technology implementation in school settings.

Figure 4 summarises six major keyword clusters derived from the analysis. Each cluster represents a distinct strand that links with other strands in this research domain. Cluster 1 (Green) showed physical education, education, interdisciplinary, sport, continuing professional development, South Africa. Cluster 2 (Red) focused on technology integration, information technologies, communication, ICT, teachers' perceptions, self-efficacy, covid-19. Meanwhile, Cluster 3 (Blue) showed teacher education, physical activity, meaningful physical education. Next, Cluster 4 (Orange) represented for teachers, elementary school, assessment, professional development. Cluster 5 (Purple) for schools, health, implementation, pedagogical approach. Finally, Cluster 6 (Yellow and Turquoise) stated that teacher training, novice teachers, emotions, primary school, teaching, China.

Cluster 1 positions the field core, with physical education as the largest and most central node. Strong links with education, interdisciplinary, and sport indicate cross-disciplinary scholarship across education and sport. The presence of continuing professional development signals attention to strengthening teacher competency through sustained learning. The keyword South Africa appears as a marker of an active geographic context in this literature.

Cluster 2 focuses on technology integration and teacher-related psychological factors. Technology integration, ICT, and information technologies point to the use of digital tools and digital infrastructure in physical education teaching and learning. Teachers' perceptions and self-efficacy reflect work that examines beliefs, confidence, and acceptance related to technology. Covid-19 signals growth in technology-related discussions during periods of remote teaching and pedagogical adjustment.

Cluster 3 shows the link between teacher education and movement-based learning goals. Teacher education connects closely with physical activity and meaningful physical education. This pattern supports a theme on pedagogical competency for planning safe, engaging, and impactful learning through physical activity. This cluster also supports discussion on pedagogical models that match the dynamic nature of physical education lessons.

Cluster 4 highlights classroom practice and assessment as key concerns. Teachers and professional development indicate a strong focus on strengthening capacity through training and support. Assessment links teacher competency with ways to evaluate learning, including skill assessment and feedback processes. The presence of elementary school indicates coverage of primary-level contexts, aligned with foundational movement skills and developmentally appropriate pedagogy.

Cluster 5 focuses on school context, health, and implementation. Schools and implementation point to institutional-level issues such as organisational support, policy, and resourcing. Health reinforces the connection between physical education and student wellbeing goals. Pedagogical approach indicates attention to teaching approaches that shape how digital technology aligns with pedagogical strategies.

Cluster 6 stands out as a more specific strand related to teacher development. Teacher training and novice teachers reflect attention to pre-service preparation and early-career support. Emotions suggests attention to affective factors such as stress, anxiety, or motivation during technology integration. Primary school, teaching, and China indicate teaching contexts and a contributing national context that shape theme variation.

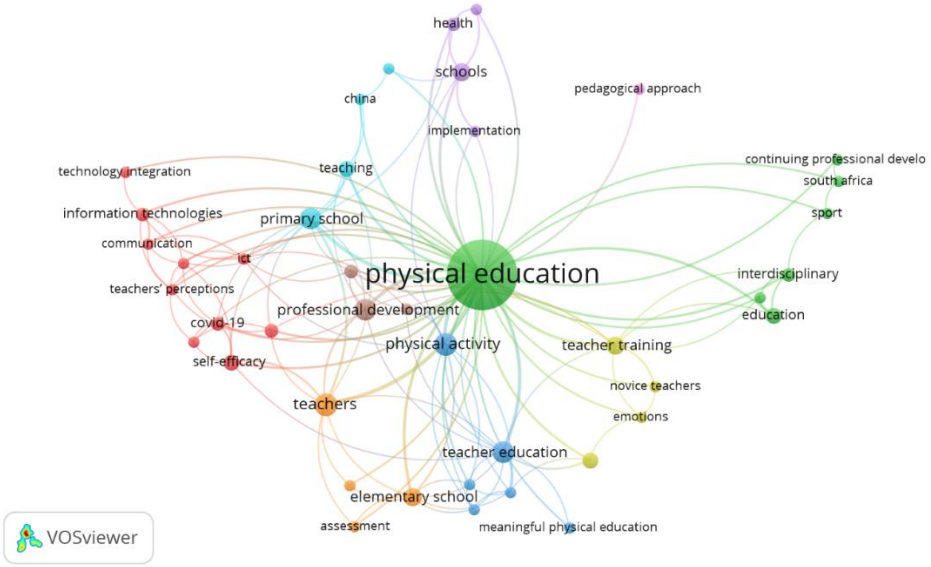

Figure 4 Co-occurrence network of the author's keywords

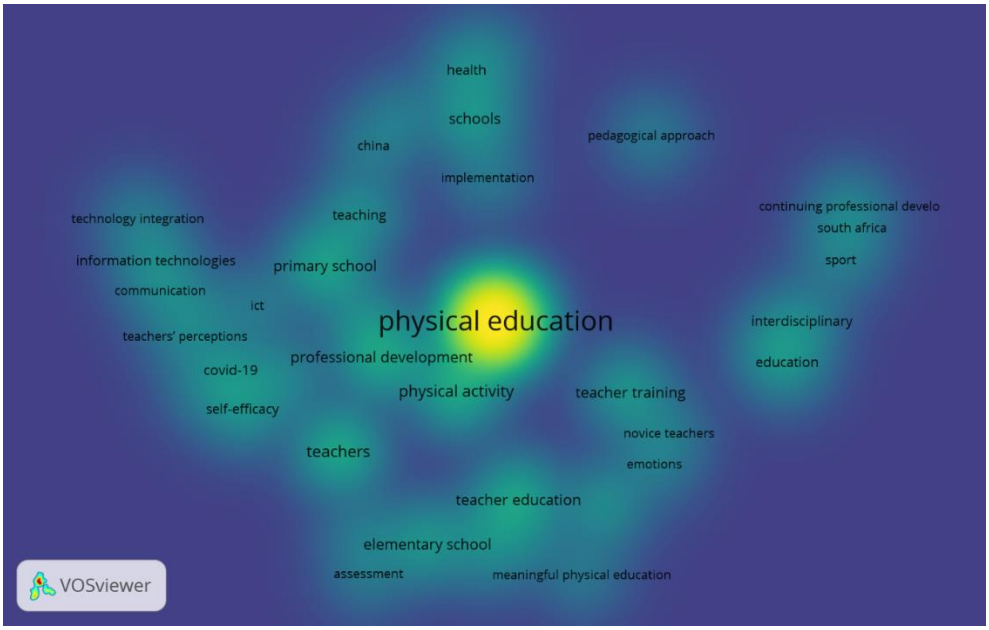

Figure 5 Co-occurrence network of the author's keywords density

DISCUSSION

The mapping results show a field organised around several partially connected strands rather than a single coherent line of inquiry. Keyword co-occurrence places physical education as the anchor and then separates attention across professional development and teacher education, technology integration and teacher beliefs, assessment and classroom practice, and school implementation conditions. This structure signals compartmentalisation between research on teacher capability and research on models of teaching for movement learning.

The cluster centred on technology integration, ICT, teachers' perceptions, self-efficacy, and COVID-19 reflects a dominant adoption and acceptance orientation in the literature. This aligns with empirical work that positions perceived competence, confidence, and practical constraints as key drivers of technology use in physical education settings (Martínez-Rico et al., 2022; Irwahand et al., 2022; Kusmiyati et al., 2024). Theoretical integration through self-efficacy clarifies why perception-oriented studies accumulate strongly in the network. Belief structures act as proximal determinants of sustained engagement with technology supported practice. Yet

the cluster pattern also indicates that psychological variables are often examined without explicit linkage to pedagogical model decisions in movement-based lessons.

TPACK provides a stronger bridge between technology use and instructional design because it frames competence as integrated knowledge guiding planning and enactment with digital tools (Doğru, 2024). The co-occurrence structure suggests that this bridge remains under-developed at field level. Competence terms appear strongly with training and professional development, while pedagogical approach and movement learning terms appear weaker integrated into the technology adoption core. This separation implies that many studies describe readiness and uptake, yet fewer specify how technology use supports model-based design choices across lesson phases, including task progression, feedback loops, and assessment routines for psychomotor learning.

Agency and positioning research strengthens interpretation of the implementation clusters because it explains how institutional expectations, roles, and context shape enacted practice, beyond individual knowledge and beliefs (Tomura et al., 2025). The cluster linking schools, health, implementation, and pedagogical approach indicates that organisational conditions and curriculum purposes remain central constraints in physical education settings. Evidence from online and hybrid contexts reinforces this point by showing that lesson routines shift toward management, task design, and participation structures, which raises the demand for explicit pedagogical structures that fit movement learning under varied conditions (Ben Amotz et al., 2025; Pérez et al., 2024; Tanucan et al., 2025).

Professional learning appears as a recurring connector across clusters, which supports the view that teacher learning pathways remain a primary lever in this research domain. Intervention and programme evaluation studies emphasise sustained support and workplace alignment as conditions for change in teaching practice (Weeldenburg et al., 2024). Digital empowerment research similarly links capability building with instructional goals and decision making in practice (Zhao et al., 2025). Yet the current structure also signals a gap between professional learning discourse and evidence of pedagogical model fidelity in real lessons. Studies often report training activity, perceptions, or competence indicators, while fewer track how teachers enact specific models of teaching with technology across time and contexts.

Overall, the bibliometric profile depicts a field with increasing scholarly attention and clear practical relevance yet marked by thematic compartmentalisation. The results suggest that progress in the domain depends on stronger integration of teacher competency frameworks with explicit pedagogical model design and enactment, alongside research that accounts for school implementation conditions and context variation across countries.

CONCLUSION

This study maps the intellectual structure of research on teacher competency and pedagogical models for digital technology integration in school physical education. The main contribution lies in clarifying how the field has developed across partially connected strands, with teacher competency and professional learning often discussed separately from explicit pedagogical model design for movement learning. By bringing these strands into one combined bibliometric mapping, the study offers a clearer view of where the literature converges and where it remains disconnected. This synthesis strengthens conceptual grounding for future empirical work that aims to connect competence development with model-based teaching in movement contexts.

The novelty of the study is the integrated focus on teacher competency and pedagogical models within school physical education, rather than treating them as separate literatures. The mapping identifies a consistent gap. Many studies examine adoption conditions, beliefs, or competence indicators, yet fewer specify how competence frameworks guide pedagogical model selection, enactment, and assessment routines during movement-based lessons. This gap limits translation into practice and constrains cumulative theory building.

Future research should prioritise three areas. First, develop integrated empirical models that link TPACK domains with explicit pedagogical models, while testing belief and agency mechanisms that shape classroom enactment. Second, shift outcome focus from adoption to enactment by measuring model fidelity and documenting how digital tools function across lesson phases, including feedback and assessment for psychomotor learning. Third, strengthen evidence through longitudinal and practice embedded designs that

examine how professional learning translates into sustained pedagogical change across different school conditions.

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