JSSER
www.jsser.org

Journal of Social Studies Education Research
Sosyal Bilgiler Eğitimi Araştırmaları Dergisi

2025:16 (4),109-144

Communities of Practice and Teacher Education in the Era of Artificial Intelligence: A Review

Cindy Yomaira Medina Vargas [1], Andrés Chiappe[2] & Felipe Sepúlveda[3]

Abstract

The integration of artificial intelligence (AI) in education increases the need to transform teacher training, aligning with the principles of Education 4.0, which emphasize flexible and personalized learning environments supported by emerging technologies. This article presents a scoping review of 62 Scopus-indexed studies examining the use of Communities of Practice (CoPs) in teacher education. Following the PRISMA statement protocol, the findings were organized into seven dimensions: Interaction, Learning, Teaching, Psycho-emotional, Technology, Research, and Evaluation. Results indicate that CoPs effectively foster professional collaboration (30.46% of positive aspects) and teacher learning (24.87%), encouraging knowledge sharing, pedagogical reflection, and identity formation. Technological tools such as virtual platforms and social networks enhance accessibility and continuous development. However, challenges persist. The primary limitation is low sustained participation (36.67% of negative aspects), often due to time constraints, lack of institutional support, unequal engagement, and resistance to change. This is followed by technological barriers (16.11%), including poor connectivity and limited digital competence, while psycho-emotional tensions—such as hierarchical dynamics and lack of motivation—also hinder effectiveness. Within the framework of Education 4.0 and the rise of AI, CoPs are positioned as crucial spaces for promoting digital literacy and collaboratively integrating new technologies. To maximize their potential, it is essential to reinforce research components, employ inclusive methodologies, and ensure that technological tools respond to teachers' real needs. This review offers actionable insights for educational institutions and policymakers aiming to implement CoPs effectively in teacher training programs, especially in the face of ongoing digital transformation.

Keywords: *Communities of practice, Teacher education, Education 4.0, professional development, Educational Technology.*

Introduction

The 21st century has witnessed a rapid technological evolution that is reshaping how people live, work, and learn in virtually all spheres of life, including education (Tarman, 2016). According to Masood et al. (2024), the Fourth Industrial Revolution, or Industry 4.0, has introduced advanced technologies such as artificial intelligence (AI), robotics, and data-driven automation that are

[1] *Doctorate candidate, Universidad de La Sabana, Colombia; medinaciyo@unisabana.edu.co*
[2] *Assoc. Prof., Universidad de La Sabana, Colombia; andres.chiappe@unisabana.edu.co, (corresponding author)*
[3] *Assoc. Prof., Universidad Católica de la Santísima Concepción, Chile; fsepulveda@ucsc.cl*

fundamentally transforming professional practices and production systems. These innovations have prompted education systems to reconsider their aims, structures, and pedagogies, considering rapidly changing technological landscapes and labour market demands (Ayanwale 2023; Bonfield et al., 2020; Lekhu, 2023; Lubinga et al., 2023). In response, Education 4.0 has emerged as a paradigm that seeks to align teaching and learning with these transformations, emphasizing flexible and personalized learning environments, competency-based curricula, and the integration of digital tools into pedagogical practice (Cabrita et al., 2020; Hussin, 2018; Kgosi et al., 2023; Mlangeni et al., 2024; Vargas et al., 2024).

Within this broader transformation, teacher education and professional development occupy a particularly critical position (Baas & Tsotetsi, 2023; Mashiane-Nkabinde et al., 2023; Nhlumayo, 2024). Teacher education programs are expected to prepare pre-service and in-service teachers to teach with and about advanced technologies, to design learning experiences that leverage digital resources and data, and to support students' development of higher-order thinking and socio-emotional skills in increasingly complex environments. According to González-Pérez and Ramírez-Montoya (2022), Education 4.0 demands teachers to become designers of learning experiences that incorporate digital tools, active methodologies, and collaborative knowledge-building. However, many teacher education systems still struggle to keep up with the speed and depth of change associated with Education 4.0. Structural constraints, fragmented professional development initiatives, and limited opportunities for sustained collaborative inquiry mean that teachers often encounter advanced technologies, including AI, in isolated workshops rather than as part of a coherent, practice-embedded learning trajectory (Bonfield et al., 2020; Cabrita et al., 2020).

In this context, communities of practice (CoPs) have been increasingly proposed as a promising mechanism for supporting teacher learning in the era of Education 4.0. In the early 90´s, Lave and Wenger (1991) presented communities of practice as groups of practitioners who engage in a joint enterprise, develop mutual engagement, and cultivate a shared repertoire of practices, tools, and meanings over time. Building on this perspective, Wenger (2010) highlights how such communities can function as key sites for identity formation, professional learning, and the negotiation of meaning in organizational settings. In this review, we focus specifically on professional communities of practice among teachers—including communities labelled as CoPs, professional learning communities, networks, or similar constructs—that: (a) are intentionally

organized around ongoing collaboration on pedagogical problems; (b) bring together pre-service and/or in-service teachers and teacher educators; and (c) are situated in formal teacher education and professional development settings, whether face-to-face, online, or hybrid. Rather than addressing informal student communities or short, one-off events, the review concentrates on structured, sustained communities in which teachers collectively negotiate meanings and practices related to their professional work (Noble, 2021).

Despite the growing advocacy for such communities in policy and increased research debates on Education 4.0, the evidence on how CoPs are actually designed, enacted, and sustained in teacher education remains fragmented. Existing studies often report local initiatives that differ in their goals, membership, facilitation, use of digital infrastructures, and links to institutional programs. As a result, it is still unclear what kinds of outcomes and mechanisms CoPs tend to generate across key dimensions of teacher education—such as interaction patterns, professional knowledge building, psycho-emotional support, technological appropriation, engagement with research, and feedback practices—and what constraints and vulnerabilities limit their effectiveness and sustainability (De Carvalho-Filho et al., 2020; Truscott & Barker, 2020). This lack of synthesis is particularly salient in relation to social studies teacher education, where discipline-specific goals, epistemologies, and classroom practices may shape how CoPs are organized and what kinds of benefits and tensions they produce.

Moreover, the rapid diffusion of AI and related technologies in education intensifies the urgency of understanding how teacher communities are functioning and evolving. AI-supported tools, analytics dashboards, conversational agents, and platform-based environments are beginning to reconfigure how teachers access resources, receive feedback, and collaborate across institutional and geographical boundaries (Masood et al., 2024). At the same time, these developments amplify concerns about workload, ethics, equity, and the depth of professional judgment required in a context marked by volatility, uncertainty, increasing digital interconnection, and expanding uses of AI (González-Pérez & Ramírez-Montoya, 2022). In this scenario, professional CoPs for teachers—whether digitally mediated or supported by AI—can no longer be treated as peripheral add-ons; they have become central arenas where teachers make sense of technological change, negotiate new pedagogical roles, and collectively test and stabilize emerging practices (Noble, 2021).

To address these intertwined issues, this review systematically maps and synthesizes empirical studies on CoPs in teacher education to examine their outcomes, challenges, and technological mediations within the broader agenda of Education 4.0 and AI-related innovation. Guided by this aim, three research questions were formulated to structure the search, screening, and synthesis procedures:

RQ1. What outcomes and mechanisms do CoPs generate across seven dimensions (Interaction; Learning; Teaching; Psycho-emotional; Technology; Evaluation & Feedback; Research design and use), especially amongst social studies teacher education where reported?

RQ2. What challenges and constraints limiting CoP effectiveness and sustainability are documented across these dimensions?

RQ3. How do digital and AI-mediated tools, together with facilitation roles, contribute to these outcomes and constraints, and under what design features are stronger or weaker impacts observed?

Thus, considering the potential results synthesized for these questions, the review seeks to report on the design of teacher education and professional development initiatives that harness communities of practice as a key mechanism for navigating Education 4.0, connecting local professional learning with responsible uses of data and AI, and aligning technological innovation with discipline-specific pedagogical goals.

Literature Review

Education 4.0 and Its Relation to Teacher Training

The transition to this new educational model has not been without challenges. One of the main obstacles relates to the low efficacy of teacher training processes related to the incorporation of technologies into educational practices (Indrajit et al., 2021). According to Tiwari et al. (2022), one of the major issues with these processes is the low transfer rate of teachers' learning to their classrooms, which poses significant barriers to the effective and sustained transformation of the education system. According to Azevedo and Almeida (2021), this phenomenon has multiple causes, including a lack of resources, resistance to change, and insufficient and irrelevant continuous training for teachers. From this perspective, educational policies must focus on providing adequate support and resources for teacher training, thus ensuring the successful implementation of Education 4.0. Considering this, it is important to mention that following this

path involves rethinking the traditional goals of teacher training and, among other things, adopting new methodologies that integrate emerging technologies. This change is crucial to prepare educators to develop the necessary competencies for the 21st century in their students, such as innovation, creativity, collaboration, and the resolution of complex problems through a holistic approach that combines technical knowledge with soft skills like effective communication and emotional intelligence. According to Salmon (2019), these competencies are essential in an increasingly digital and interconnected world. Additionally, it is crucial that teachers feel comfortable using technologies from the fourth industrial revolution within their professional practices.

Communities of Practice: Concept and Relevance

Now, within the framework of teacher training, it is highlighted that communities of practice (CoPs) have emerged as a powerful tool for developing a wide range of capacities in teachers of all levels and areas of knowledge. This concept, introduced by Jean Lave and Etienne Wenger in the early 1990s, is based on the idea that learning is a social process that occurs through regular interaction among individuals with common interests (Mercieca & McDonald, 2021). In this regard, Hass et al. (2021), Koatz et al. (2024) and Sahn and Riesen (2024) refer to CoPs as a group of engaged people who share a concern or passion for something they do and learn to do it better through regular interaction. Viewed from this perspective, CoPs facilitate collaborative learning and the construction of shared knowledge, which is essential for the continuous professional development of teachers (Bagerius & Ekström, 2024). This learning is structured around three key dimensions: the joint enterprise, which refers to the commitment to a common goal; mutual engagement, which involves active interaction and collaboration among members; and the shared repertoire, which includes tools, symbols, and practices that members develop and use together (Godinho Soares et al., 2023). These dimensions not only foster a sense of belonging and collaboration but also facilitate the exchange of knowledge and experiences, which is crucial for improving pedagogical practices.

From a research perspective, Figure 1 shows that the use of communities of practice in teacher training processes is a growing, albeit still emerging topic, given the minimal amount of research published in indexed journals on this topic compared to research on teacher training in general and teacher training mediated by digital technologies.

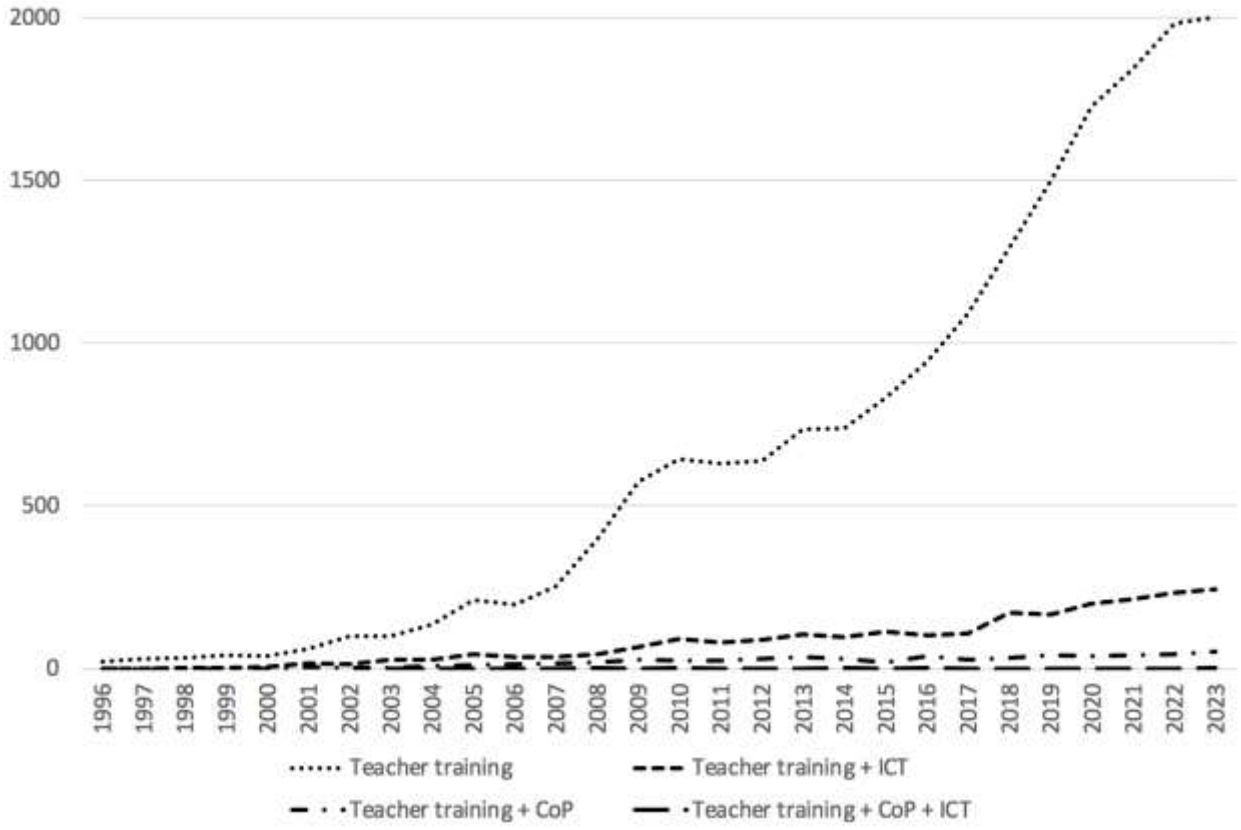

Figure 1. Published research on Teacher training, CoP and ICT

Source: own elaboration based on Scopus data.

These data indicate that there is much to be explored regarding the articulation of the use of communities of practice, the use of digital technologies (including those of the fourth industrial revolution), and teacher training processes, which together form a highly relevant triad for addressing the preparation of the teaching staff to adequately respond to the challenges imposed by the era change in which we currently live.

Applications and Benefits in Teacher Training

In the field of teacher training, CoPs provide a platform for metacognitive reflection and the development of new teaching strategies, supported by emerging technologies such as learning management platforms, virtual learning environments, and social networks (López et al., 2023). In this way, CoPs not only support the professional development of teachers but also promote a culture of innovation and continuous improvement in education. In teacher training, communities of practice have proven to be an invaluable resource for fostering professional development and

improving pedagogical practices, as they offer a space where teachers can share experiences, exchange knowledge, and collaborate in solving common problems (Murtagh & Rushton, 2023). This interaction facilitates the creation of a "shared repertoire" of resources and practices that enrich teaching and learning (Falkner & Larsson, 2020). Additionally, CoPs allow teachers to develop a collective professional identity, which reinforces their commitment to continuous improvement and educational innovation. In the context of Education 4.0, CoPs seem especially valuable due to the accelerated pace of technological change, a matter that will need to be explored in depth.

This topic opens a set of questions about the relevance and effects the use of emerging and disruptive technologies such as AI, and their potential to facilitate or enhance learning management, collaboration, and knowledge exchange in an efficient and accessible manner, and, in general, the enrichment of teachers' learning. In this regard, the literature indicates that the benefits of CoPs are not limited to improving individual teachers' competencies but also contribute to creating a culture of organizational learning within educational institutions, promoting collaboration and the exchange of best practices (Duryan, 2023).

On the Sense of Urgency

Considering the above, the implementation of communities of practice in teacher training represents a significant opportunity to improve the quality and effectiveness of education in the context of the fourth industrial revolution. However, despite the demonstrated benefits, the adoption of CoPs is not without challenges and limitations. Therefore, it is crucial to conduct a comprehensive review of the existing literature to assess the positive and negative aspects of using these communities in teacher training. Such a review will allow for the identification of effective practices, as well as areas that require improvement, providing a solid foundation for future research and educational innovation processes.

Moreover, in a world where artificial intelligence and other emerging technologies are rapidly transforming the educational landscape, it is essential to evaluate how CoPs can be effectively integrated into this new ecosystem. The urgency of this task should not be underestimated, as the speed of technological change requires educational systems to be agile and adaptable and to transform in sync with these changes. In this sense, the purpose of the literature review proposed here aims not only to allow a better understanding of CoPs but also to identify strategies to

maximize their positive impact on teacher training in a context of constant change, uncertainty, increasing digital interconnection and use of AI.

Now, to address these and other relevant issues in this field, we conducted a scope literature review aimed at identifying: (1) the outcomes and mechanisms through which communities of practice (CoP) support teacher development in Education 4.0 contexts, (2) the challenges that constrain their effectiveness and sustainability, and (3) the roles of digital—including AI-mediated—tools and facilitation conditions in shaping CoP processes and results.

Education 4.0, AI and teacher communities of practice

Education 4.0 frames the expectations placed on teachers and teacher education programs as they respond to the demands of the fourth industrial revolution, characterized by data-intensive, networked and AI-rich learning environments. According to González-Pérez and Ramírez-Montoya (2022), Education 4.0 requires the development of complex 21st-century skills through active, technology-mediated pedagogies rather than through traditional transmissive approaches. Recent reviews emphasize that Education 4.0 combines personalized learning, advanced digital technologies and flexible learning ecologies to align educational provision with rapidly changing social and economic demands (de Souza & Debs, 2024). In higher education, this paradigm is increasingly used as a lens to redesign curricula, assessment and teacher development, so they become more responsive to emerging technologies, including AI (Bonfield et al., 2020).

From a sociocultural perspective, teacher learning is understood as a situated, relational and collective process that unfolds within communities engaged in shared practice. According to Wenger (2010), communities of practice (CoPs) are characterized by mutual engagement, joint enterprise and shared repertoires that make possible the negotiation of meaning about professional problems. Subsequent work has shown that CoPs provide a powerful structure for teacher professional learning, particularly when teachers work on authentic problems of practice over time (Patton & Parker, 2017). Recent conceptualizations of professional learning highlight that such communities create practice architectures that shape what and how teachers can learn in, from and for their everyday practice (Salo et al., 2024).

In this review, we are interested in a specific type of community of practice: teacher education CoPs oriented towards Education 4.0 and AI integration. These communities are composed of pre-service, in-service or teacher educators who systematically explore how to redesign teaching, curricula and assessment considering Education 4.0 demands. According to Patton and Parker

(2017), teacher education CoPs can move beyond a culture of mere collaboration to become spaces for critical inquiry into pedagogy and identity. More recent empirical studies report that CoPs which intentionally integrate digital technologies and innovation agendas can foster sustained changes in teachers' beliefs and practices, as well as contribute to more equitable and future-oriented forms of schooling (Mahlo et al., 2024; Vičič Krabonja et al., 2024).

The analytical framework used in this review connects the structural features of such CoPs with their learning and change outcomes for teachers. We mobilize the idea that professional learning must be understood simultaneously at the level of individual trajectories, collective practices and wider institutional conditions (Salo et al., 2024). In line with recent reviews of continuing professional development, effective CoP-based initiatives tend to articulate clear learning trajectories, scaffold participation over time and align collaborative work with meaningful problems of practice (Merino et al., 2025). At the same time, research addressing online and hybrid communities of practice shows that the specific configurations of roles, tools and interaction spaces influence the depth of collaboration and knowledge building (Nguyen et al., 2024).

AI intensifies these dynamics by transforming both the content and the modalities of teacher professional learning. According to Celik (2023), AI tools can support teachers by automating routine tasks, providing data-driven insights and opening new possibilities for formative assessment, while also introducing new forms of workload, opacity and ethical tension. Systematic reviews of AI in education indicate that AI-mediated environments are increasingly used to personalize learning pathways and to support feedback, tutoring and predictive analytics, which in turn require new competences and forms of professional judgement from teachers (Wang et al., 2025). Recent work also stresses that AI-enabled learning environments reconfigure collaboration patterns, making it necessary to rethink how communities of practice orchestrate human and non-human actors in teaching and learning (Mariyono & Nur Alif Hd, 2025).

Building on these strands of literature, our conceptual model positions teacher communities of practice for Education 4.0 as a key mediating structure between systemic demands (e.g., AI adoption, digital transformation agendas) and teachers' individual and collective learning. According to Li et al. (2025), generative AI can become a powerful resource for teachers' self-directed professional development when it is embedded in coherent learning ecologies rather than used as an isolated tool. In this review, we therefore examine how CoPs are designed, facilitated and sustained to help teachers interpret Education 4.0 discourses, experiment with AI-enhanced

pedagogies and negotiate the tensions that arise. In doing so, we use the theoretical framework outlined above as a lens to analyse the kinds of CoPs that are emerging, the practices they enable and the professional learning outcomes they are reported to generate.

Method

Research Design

There are a wide variety of methods to conduct a literature review (Kosztyán et al., 2021). This study employed a scoping review and configurative evidence synthesis to map and interpret empirical research on teacher communities of practice (CoPs) in the context of Education 4.0 and emerging uses of AI. The review followed the PRISMA guidelines for transparent reporting of identification, screening, eligibility and inclusion procedures, while adopting a theory-informed and descriptive approach to synthesis (Okoli, 2015; Page et al., 2021). Rather than testing predefined hypotheses, the design aimed to systematically characterize how CoPs are conceptualized, how they are designed and enacted in teacher education and professional development, and what outcomes, challenges and technological mediations they are reported to generate. To achieve this, we combined bibliometric and descriptive analyses with directed content analysis and the subsequent quantification of codes, treating quantitative and qualitative information as complementary strands within a single configurative review rather than as separate "mixed-methods" components. The steps and details of how this method was executed are presented in Figure 2.

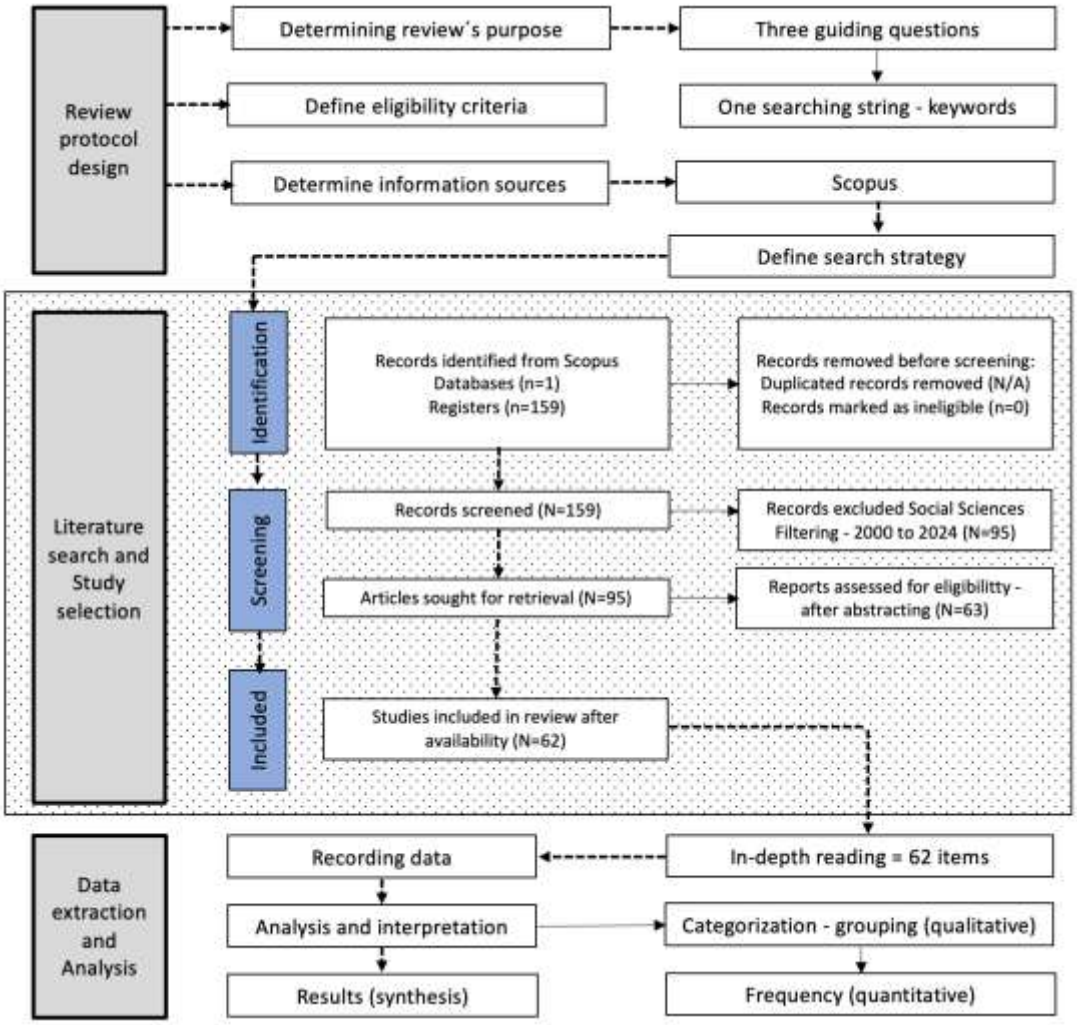

Figure 2. Flowchart of the literature review method

Source: Own elaboration

Review Protocol Design

Determining the Review's Purpose

Guided by the research questions, this review aims to generate a cumulative and practice-relevant account of how communities of practice (CoPs) are designed, enacted, and sustained in teacher education—particularly within social studies and in AI-powered Education. Specifically, the purpose is to: (a) systematize evidence on CoP outcomes and the mechanisms by which they are produced across interactional, learning, instructional, psycho-emotional, technological, and evaluative dimensions; (b) delineate the organizational, temporal, facilitation-related, and

technological constraints that limit effectiveness and sustainability; (c) examine the roles of digital and AI-mediated tools and the design features associated with stronger or weaker impacts; and (d) surface methodological gaps, equity considerations, and reporting practices that shape the current evidence base.

Eligibility Criteria

Eligibility was operationalized using Population–Phenomenon–Context–Design–Outcome (PPCDO) elements.

- Population. Pre-service and in-service teachers and/or teacher educators in formal education systems (early childhood to upper-secondary) or teacher-education programs in higher education. Studies focused exclusively on K-12 students or administrators without teacher learning outcomes were excluded.
- Phenomenon. Communities of practice (CoPs), professional learning communities (PLCs), or analogous collaborative teacher groups explicitly grounded in CoP/PLCs or aligned constructs (e.g., shared repertoire, joint enterprise, mutual engagement). Initiatives branded as "communities" but functioning solely as one-off workshops were excluded.
- Context. Teacher education and professional development settings, including school-based PD, university coursework, induction/mentoring programs, and hybrid/online CoPs. No geographical restrictions were applied.
- Design. Empirical primary studies employing qualitative, quantitative, or mixed methods (e.g., case studies, quasi-experimental, survey/correlational, design-based research). Non-empirical articles (editorials, theoretical essays), conference abstracts without full articles, and dissertations were excluded.
- Outcomes. Studies reporting data on teacher learning, practice, collaboration/interaction, identity/agency, psycho-emotional variables, or implementation/technology processes. Purely descriptive reports without empirical data were excluded.
- Time window and language. Searches covered 2000 to 2024. We included studies in English and Spanish; languages outside this set were excluded at full-text if translation was not feasible within project resources.

Availability. Full-text availability was required after reasonable retrieval attempts (institutional subscriptions, author contact when appropriate).

Information Sources

The primary information source was Scopus, selected a priori for its suitability to the review's scope and for reproducibility reasons. According to (Chaparro et al., 2016), Scopus offers broad, multidisciplinary indexing across education, social sciences, and computing/engineering, which is essential to capture work on communities of practice (CoPs) that sit at the intersection of teacher education and technology-mediated/AI-mediated professional learning typical of Education 4.0. In addition to education journals, Scopus indexes many outlets in educational technology and learning analytics where CoP studies are frequently reported, thereby reducing the risk of disciplinary silos.

Metadata quality and search functionality

Field-restricted queries and standardized metadata (document type, author and affiliation disambiguation, DOIs, reference lists, cited-by counts, author and index keywords) enable precise, transparent, and reproducible searches; they also facilitate efficient de-duplication and downstream screening at scale. Regarding citation navigation, built-in cited-by and reference linking supports systematic forward/backward citation chasing, which we used to surface seminal and recent records that keyword searches alone might miss. Also, considering feasibility and auditability, relying on a single, well-specified database simplifies full-record export with stable identifiers, allows versioning of query strings and result counts, and improves the audit trail for independent verification.

We acknowledge that single-database retrieval can miss items uniquely indexed in other sources (e.g., ERIC or Web of Science), regional outlets, or grey literature. To mitigate this risk, we: (a) piloted strings against a seed set and refined terms iteratively, (b) complemented Scopus retrieval with backward/forward citation chasing from included studies, and (c) documented the limitation explicitly in the Discussion, recommending future multi-database and grey-literature searches. Given our focus on peer-reviewed empirical studies in teacher education, we limited results to the article document type and the languages specified below; this increased comparability for quality appraisal and synthesis while maintaining relevance to the Education audience.

Search Strategy

Once the guiding questions of the review were defined, we designed a search strategy to identify empirical studies on teacher communities of practice in teacher education and professional development. The primary search was conducted in Scopus, given its broad coverage of peer-

reviewed journals in education and the social sciences. The core search string combined terms referring to communities of practice and professional learning communities with terms related to teachers and teacher education, using Boolean operators and wildcards. The final query took the following general form: ("community of practice" OR "communities of practice" OR "professional learning community" OR "professional learning communities" OR "teacher community" OR "teacher learning community" OR "teacher network") AND (teacher OR "teacher education" OR "teacher professional development").

No geographical restrictions were applied, and the search was limited to peer-reviewed journal articles and conference papers written in English. The time span reflected the period in which CoPs began to be reported systematically in teacher education research and extended to the date of the search.

In addition to this primary query, and to probe the robustness of the findings related to AI (RQ3) more specifically, we conducted a complementary search in Scopus that incorporated AI-related descriptors. This supplementary query kept the same CoP and teacher education terms but added the clause ("artificial intelligence" OR "AI") to the search string. The complementary search was run using the same document-type and language filters as the primary search and followed the same screening and eligibility procedures. Its purpose was not to construct a separate corpus, but to verify whether AI-specific CoP studies were being systematically missed by the original query. After title-and-abstract screening and full-text assessment, the results of this complementary search were consistent with those of the primary search and did not require substantive changes to the set of included studies or to the patterns reported in the Results section.

Finally, the database searches were complemented by backward- and forward-citation chasing of all studies that passed full-text screening. Reference lists and citing articles were scanned to identify additional empirical work on teacher CoPs that met the PPCDO eligibility criteria but might not have been retrieved by the keyword strategy. This iterative process helped to reduce the risk of omitting relevant studies while maintaining a clear and auditable trail of inclusion decisions.

Literature Search and Study Selection

Identification

The Scopus strategy described above initially returned n=159 records. Search results were exported with complete metadata (including DOIs and cited-by fields) and archived. To align the

corpus with the aims of this review and the target outlet, we then applied Scopus filters in the following order: first, Subject Area = Social Sciences; second, Document Type = Article. After applying both filters, the retrieval set comprised n=95 peer-reviewed journal articles. No additional records were identified through other databases at this stage; however, we planned backward/forward citation chasing during eligibility to surface potentially relevant items not captured by the keyword strategy.

Screening (title/abstract)

All n=95 records were imported into the MSExcel screening tool and de-duplicated (exact and fuzzy matching), yielding the same n=95 unique records given the single-database source. Reviewers independently assessed titles and abstracts against the a priori eligibility criteria (Population, Phenomenon, Context, Design, Outcomes). Records were excluded when at least one non-negotiable criterion was not met (e.g., not a teacher/teacher-educator population; not a CoP/PLC phenomenon; not empirical; outside education). This stage reduced the set to n=63 candidate studies for full-text assessment. Inter-rater agreement was monitored across the review; disagreements were collaboratively conciliated, triggering minor refinements to decision notes in the codebook.

Eligibility (full text)

Full texts were sought through institutional subscriptions, open-access links, and (when necessary) author contact. Of the n=63 records entering this stage, n= 62 full texts were successfully retrieved; one article could not be obtained despite reasonable efforts, and was therefore excluded with the reason coded as "Full text unavailable". Each full text was independently assessed against all eligibility criteria, with justifications recorded. Reasons for exclusion at this stage were coded using the following categories: (1) population/design/phenomenon mismatch; (2) not empirical or insufficient primary data; (3) intervention not aligned with CoP/PLC constructs (one-off workshop or community label without CoP features); (4) outcomes outside scope (no teacher-learning/practice/interactional or psycho-emotional indicators); (5) language outside inclusion set; (6) duplicate publication; and (7) full text unavailable.

Data Extraction

We developed and piloted a structured extraction matrix capturing bibliographic metadata and other relevant information regarding research questions and categories of analysis.

To support synthesis, we applied a theory-informed codebook across seven analytic dimensions: (1) Interaction & collaboration; (2) Teacher learning; (3) Instructional practice; (4) Psycho-emotional; (5) Technology & infrastructures; (6) Research design & context; and (7) Evaluation & evidence quality. The codebook includes operational definitions, inclusion/exclusion rules, and coding examples. Extracted data were managed in a MS Excel spreadsheet, with tables linking connecting claims to specific studies, quotations, and quantitative indicators.

Analytic dimensions and review variables

To structure the synthesis, we defined a set of analytic dimensions and review variables that translate the theoretical framework on communities of practice and Education 4.0 into operational categories for coding. At the study level, the extraction matrix captured descriptive variables such as country or region, educational level (e.g., pre-service, in-service, mixed), institutional setting (university-based, school-based, partnership arrangements), subject area (including the presence or absence of an explicit social studies focus), type of community (e.g., CoP, professional learning community, network), sample characteristics, research design, data collection methods and main analytical approaches. These variables were used to map the field and to examine how CoP configurations varied across contexts and study designs.

At the level of findings, we adopted seven analytic dimensions that specify how teacher CoPs operate and what they appear to generate for their members in Education 4.0 contexts. The Interaction dimension captures participation structures, conversational patterns and the distribution of voice within communities, including indications of marginalisation or dominance. The Learning dimension refers to the development of professional knowledge, skills and dispositions, paying particular attention to how teachers make sense of disciplinary content and pedagogical approaches in social studies and related fields. The Teaching dimension focuses on changes in classroom practice, instructional design and the enactment of innovations that are attributed—explicitly or implicitly—to CoP participation. The Psycho-emotional dimension encompasses emotions, motivation, sense of belonging, professional identity and wellbeing. The Technology dimension concerns how digital infrastructures, platforms and, where present, AI-related tools mediate participation, access to resources and collaborative work. The Evaluation and Feedback dimension examines how assessment practices, data use and feedback flows (peer, mentor, student or system-generated) support or constrain learning within the community. Finally, the Research design and

use dimension captures the role of inquiry and research-informed practice, including how CoPs engage with evidence, practitioner research or design-based approaches.

During data extraction, each relevant finding reported in the included studies was coded into one or more of these dimensions and assigned a polarity label (positive or negative) when the study described the aspect as a strength, benefit or enabling mechanism, or conversely as a challenge, constraint or adverse outcome. This polarity-sensitive coding allowed us to construct a nuanced map of the mechanisms and outcomes associated with CoP participation across studies, and to quantify the distribution of positive and negative evidence within and across the seven dimensions, while preserving the qualitative richness of the original accounts.

Data Analysis

Data analysis followed a three-stage strategy that combined descriptive statistics with directed qualitative content analysis and subsequent quantification of codes. The goal was to preserve the richness of the qualitative evidence while producing an integrated, transparent synthesis across the corpus of studies. Rather than constituting a separate mixed-methods design, these stages were conceived as complementary components within a single configurative review.

Stage 1 – Bibliometric and descriptive analyses (quantitative). In the first stage, we conducted bibliometric and descriptive analyses of the extracted study-level variables. This included counts and cross-tabulations of publications over time, outlet types, geographical distribution, subject areas, CoP configurations, research designs and data collection methods. Where available, we also examined co-occurrence of keywords and author-provided descriptors to identify salient thematic clusters related to CoPs, Education 4.0 and technology use.

Stage 2 – Directed qualitative content analysis with polarity. In the second stage, we undertook a directed content analysis of the findings sections of the included studies, using the seven previously described analytic dimensions as a guiding framework. Segments of text reporting outcomes, mechanisms or challenges were coded to one or more dimensions and assigned a positive or negative polarity label. Coding was iterative and reflexive, with regular checks to ensure consistency in the application of the codebook and to refine dimension boundaries when necessary. This process generated a structured, polarity-sensitive map of how CoPs were reported to influence interaction, learning, teaching, psycho-emotional aspects, technology use, evaluation and feedback, and research engagement.

Stage 3 – Comparative descriptive analyses (quantitative). In the third stage, we converted the coded qualitative data into frequency tables and simple comparative displays. We calculated the number of positive and negative instances per dimension and examined how these distributions varied across key study-level variables such as educational level, institutional setting, subject area and CoP type. These comparative analyses were used to address the research questions and to identify patterns and tensions in the evidence base, while avoiding over-interpretation of small sub-groups or under-reported combinations. The results of the complementary AI-focused search were incorporated into this stage using the same coding framework, and confirmed that the patterns reported for AI-related aspects of CoPs were consistent with those observed in the broader corpus.

Synthesis methods

Given conceptual and methodological heterogeneity, we adopted a convergent integrated synthesis. Quantitative indicators were textually transformed and integrated with qualitative thematic findings across the seven dimensions. We avoided vote-counting by direction alone; instead, we linked claims to evidence matrices and reported the number and design types of contributing studies for each synthesized assertion.

Results

In the following section, the results are presented based on the question: What are the positive and negative aspects of using communities of practice in teacher training? To answer this question, data collection was carried out through the three phases, which will be presented below.

Relevant concepts associated with CoPs.

Within the reviewed articles, the occurrence of a group of words was observed, as shown in Figure 3.

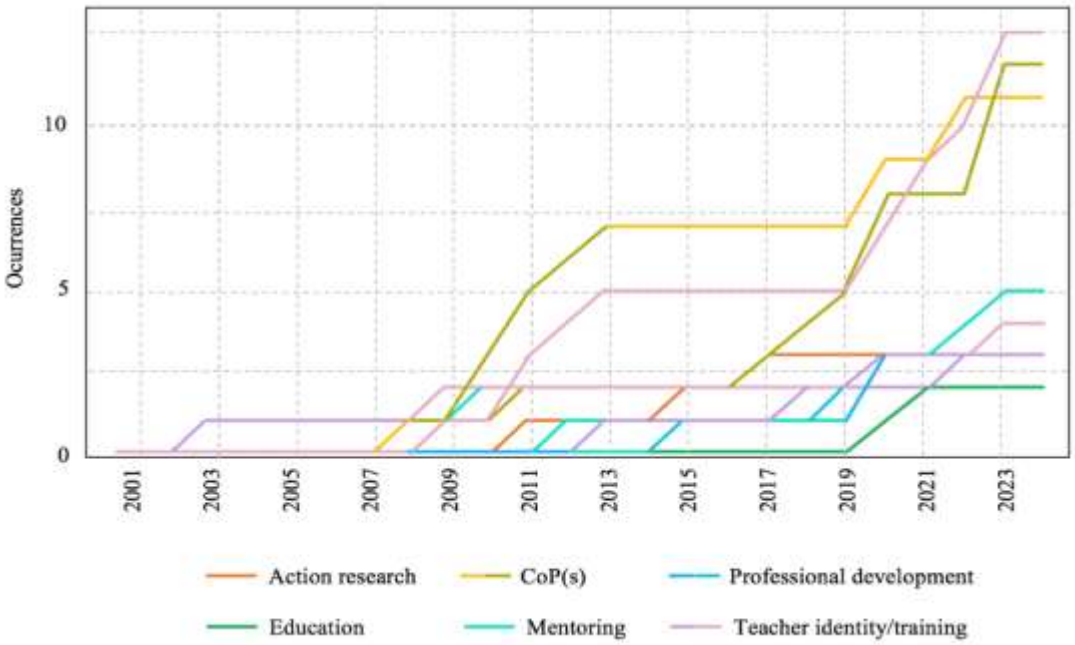

Figure 3. Main concepts related to CoPs over time

Source: Own elaboration

The graph shows that in the year 2000, the identified terms were scarcely mentioned in the literature, suggesting that before this period, these concepts were either infrequently discussed in specialized literature or considered less relevant within the context of teacher training research. However, beginning in 2009, there is a notable increase in the use of terms such as "Communities of Practice" and "Professional Development," indicating a growing interest within the academic community to explore these areas further.

Additionally, it is important to highlight the presence of Mentoring as part of the purposes associated with the use of CoPs in teacher education experiences, and Action Research as the main approach through which researchers have sought to understand and strengthen daily teaching practice through training processes.

Results regarding positive aspects of CoP use.

The analysis of the extracted data generated 7 distinct categories of positive aspects, as shown in Figure 4.

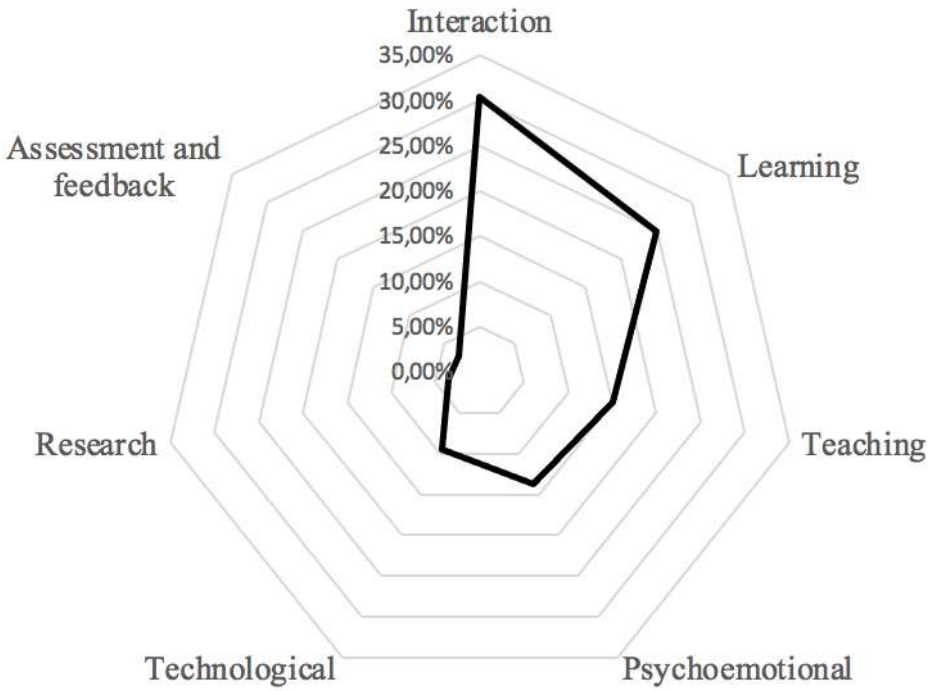

Figure 4. Categories of positive aspects of CoP use in teacher training

Source: Own elaboration

In this regard, Bergmark (2023), Lee et al. (2020), Allela et al. (2020), Falkner & Larsson (2020), Summers & Turner (2011), and Gorozidis et al. (2020) agree that there are a significant number of positive aspects to using communities of practice in teacher training. CoPs are considered a valuable tool for fostering collaborative learning, the professional development of teachers, and the professionalization of teaching and learning in the classroom.

Regarding the Interaction category (n=180; 30.46%), the positive aspects involve enhancing relationships through collaboration and teamwork, enabling the exchange of knowledge, resources, and practices, fostering participation and active dialogue, and strengthening communication and networks. Summers & Turner (2011), Bergmark (2023), Yandell & Turvey (2007), and Lee et al. (2020) agree that CoPs promote collaboration among their members through joint work on projects or activities of shared interest, such as action-research projects, where teachers and external researchers collaborate to improve educational practices. Summers & Turner

(2011) further state that interaction through collaboration among community members contributes to its construction and sustainability, helping to overcome individual barriers and promoting collective work toward a common goal.

Communities of Practice not only enable collaboration among their members, but also facilitate the exchange of knowledge, resources, and practices, which promotes meaningful learning. Bergmark (2023) highlights that sharing elements related to pedagogical practice enriches collective knowledge and allows these practices to be transferred to the classroom. Moreover, CoPs encourage participation in events, forums, and seminars on pedagogical discussions, which, according to Da Costa (2019), strengthens the construction of both individual and collective teacher identity. This interaction helps teachers establish networks of professional support and exchange, as seen in the "aeioTU" Network, a platform that facilitates peer collaboration (López et al., 2023).

Among the most notable aspects of CoPs is the impact on learning, a category representing almost a quarter of the positive results (24.87%). Collaborative learning, personalized learning, problem-solving, and innovation in teaching techniques are key subcategories (Bergmark, 2023; Falkner & Larsson, 2020; Summers & Turner, 2011). This type of collaboration enriches teacher training by fostering spaces for the exchange of knowledge and reflections on pedagogical practice. A relevant example is the service-learning project described by Petersen & Henning (2018), where students established ties with their peers and community members, generating a reciprocal exchange of learning and pedagogical solutions.

Noble (2021), drawing on Lave and Wenger's situated learning framework, notes that knowledge is generated through shared participation and interaction, reinforcing the role of CoPs as facilitators of meaningful learning. Interactions within CoPs allow pre-service teachers to collectively construct knowledge, promoting both professional and pedagogical development (Summers & Turner, 2011). Through this exchange, teachers gain access to diverse perspectives and resources, applying new pedagogical approaches in the classroom and fostering innovation, self-reflection, and autonomous learning.

Teaching, another prominent category (15.06%), shows a close relationship with learning, given that the way one learns directly influences how one teaches. Reflection on pedagogical practices is a central subcategory, as CoPs engage teachers in collaborative action-research processes where they share experiences and develop new perspectives on classroom issues (González Alfaya et al.,

2017), while allowing experimentation and constructive feedback, encouraging critical reflection on pedagogical practices.

Additionally, González Alfaya et al. (2017) highlight that CoPs enable teachers to critically analyze both their performance and their colleagues', generating more effective teaching strategies. In this regard, Allela et al. (2020) show how interaction within CoPs helped pre-service teachers rethink their pedagogical strategies, while Falkner & Larsson (2020) emphasize that access to new technologies and approaches in CoPs directly impacts the improvement of their classes, providing a safe environment for pedagogical experimentation.

The categories of Psychoemotional, Technology, Research, and Assessment and Feedback, although less frequent in studies on Communities of Practice, present relevant aspects of 21st-century teacher training processes. The Fourth Industrial Revolution has brought new technologies into teaching and learning, allowing CoPs to become safe spaces where teachers can innovate and experiment with new pedagogical techniques. Thus, Falkner & Larsson (2020) argue that these environments stimulate creativity, teamwork, and the acquisition of new teaching strategies.

In the field of research and assessment, CoPs not only allow the transfer of knowledge but also encourage the creation of new pedagogical practices that shape teachers' professional identity (Falkner & Larsson, 2020). These interaction spaces facilitate the comprehensive development of learning and peer feedback, reinforcing both personal and professional growth. Psychological aspects also play an important role, as CoPs foster emotional and professional bonds that strengthen the sense of camaraderie and commitment among participants.

Within the Psychoemotional category, four subcategories stand out: relationship building, motivation and emotional support, identity and autonomy development, and the role of the tutor and mentor. According to Gorozidis et al. (2020), Bergmark (2023), and Coles & Brown (2001), CoPs encourage the development of collaborative relationships among colleagues, where the exchange of knowledge and reflections enriches pedagogical practice. Furthermore, mutual support within these communities helps pre-service teachers feel supported, especially in situations of uncertainty or professional stress. This emotional support improves teachers' psychological and personal well-being, shielding them from social isolation and fostering a sense of belonging.

On the other hand, Da Costa (2019) notes that CoPs allow teachers to develop a more autonomous professional identity by making pedagogical decisions based on reflection on their practice. This contributes to greater autonomy in their work, promoting the strengthening of their identity as

'teacher-author.' These dynamics allow teachers to assume greater responsibility for their educational work.

The Technology category, representing 9.48% of mentions, includes subcategories such as accessibility and flexibility, communication and collaboration, and the use of digital tools in education. Gorozidis et al. (2020) and Allela et al. (2020) highlight that CoPs promote the use of technological platforms such as WhatsApp, Facebook, and Moodle for teacher training, enhancing communication among colleagues and improving collaborative learning processes. These technologies not only facilitate access to educational resources but also permit autonomous interaction between teachers, boosting motivation and peer feedback. For instance, Allela et al. (2020) note that the use of mobile technologies, such as WhatsApp, enables real-time communication, fostering socialization and collaboration in flexible and accessible environments. Furthermore, Murtagh & Rushton (2023) introduce the concept of Virtual Communities of Practice (VCoPs), where platforms like blogs, social networks, and online forums facilitate the constant exchange of pedagogical ideas and knowledge. These virtual communities strengthen the individual and collective growth of teachers, which is later reflected in the improvement of educational practices in the classroom.

Technology has also enabled the incorporation of tools for critical reflection and self-assessment of teaching practices. Stevenson (2015) presents the 'video-stimulated recall' (VSR) technique, where teachers record their classroom practices and then reflect on them with colleagues and experts, creating feedback spaces that allow for the improvement of teaching methods.

The Research (3.55%) and Assessment and Feedback (2.88%) categories are related to the development of pedagogical research and its implementation in the educational environment. Bergmark (2023) argues that CoPs allow for the integration of research projects in the classroom, creating connections between professional development and the teachers' working environment. This research-focused approach promotes pedagogical reflection, the exchange of knowledge, and the development of new educational strategies adapted to the specific contexts of classrooms. Moreover, CoPs facilitate the sharing of findings and advancements in educational research, encouraging teachers' participation in new projects (Nielsen et al., 2023).

Finally, within the category of Evaluation and Feedback, Fraser (2018) highlights the importance of formative assessment in pedagogical processes. This type of evaluation, which focuses not only on the content learned but also on how learning is acquired, is both motivating and comprehensive.

Additionally, it encourages self-assessment as well as recognition of individual and collective dynamics. Peer feedback, a crucial element within CoPs, not only strengthens the sense of belonging and cohesion among members but also fosters critical reflection on pedagogical practices. This process promotes commitment to learning and mutual support among participants, as noted by Lee et al. (2020).

The role of the tutor or mentor in CoPs is also highly relevant in feedback and evaluation processes. Their intervention directly impacts the professional development of pre-service teachers. According to Fraser (2018), tutors are seen as feedback providers, counsellors, and role models whose contributions not only improve teaching practices but also influence the construction of teachers' professional identities. Both Lee et al. (2020) and Fraser (2018) agree that tutors should guide critical reflection and support teachers in adapting to new educational challenges.

Results Regarding the Negative Aspects of CoP Use

This subsection presents the negative aspects identified in the literature review related to the use of Communities of Practice (CoPs) in teacher education. The same categories as in the previous section were used, as shown in Figure 5.

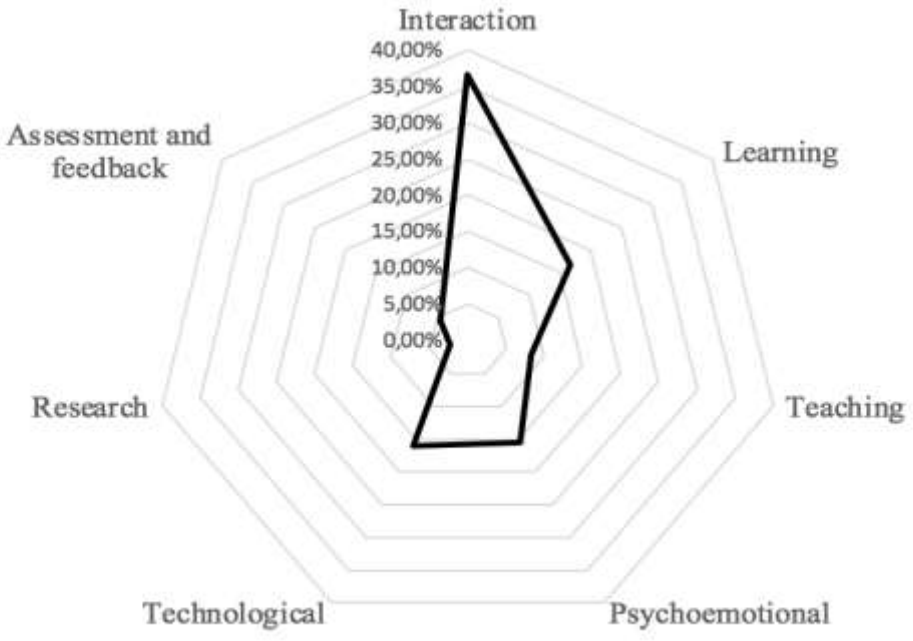

Figure 5. Categories of negative aspects of CoP use in teacher education.

Source: Own elaboration

Although CoPs are recognized for their ability to foster collaboration and experience sharing in teacher education, the literature review shows that they also present several limitations that affect their dynamics and effectiveness. Authors such as Bergmark (2023), Gorozidis et al. (2020), and López et al. (2023) have identified recurring issues in the implementation of these communities. One of the main challenges is the lack of available time for members to actively participate in proposed activities and discussions, which reduces commitment and limits the adoption of new ideas and practices.

Within the Interaction category (n=66; 36.67%), problems related to lack of participation and commitment, administrative and organizational difficulties, communication and collaboration issues, and power dynamics were identified. According to García-Monge et al. (2019) and Summers & Turner (2011), differences in experience, knowledge, or authority within CoPs can create inequalities in participation, with some members dominating discussions while others take on more passive roles. Stevenson (2015) adds that in multicultural contexts, cultural and linguistic barriers further complicate interaction.

Besides the above, the lack of time has been identified as a critical factor affecting participation in CoPs. Backhouse (2022), Milara et al. (2020), and Lee et al. (2020) agree that the daily responsibilities of teachers limit their availability to participate actively in CoP activities, which negatively impacts planning and motivation to contribute. Furthermore, Cesareni et al. (2011) mention that organizational difficulties, such as the lack of resources and limited institutional support, can generate frustration and disinterest, jeopardizing the sustainability of CoPs. Resistance to change is another identified obstacle. Defise (2013) and Perumal (2013) point out that this resistance may be related to the lack of connection between teachers and the new methodologies being proposed.

In the Learning category (n=30; 16.67%), four subcategories of problems have been identified: challenges of collaboration and support, difficulties in designing learning strategies, cognitive and psychological barriers, and participation limitations. Defise (2013) and Perumal (2013) agree that the lack of alignment between the theories discussed in CoPs and the real needs of teachers diminishes their motivation to actively participate. On the other hand, García-Monge et al. (2019) add that fears and insecurities arising from a lack of experience or knowledge in certain subjects also limit participation. López et al. (2023) warn that some members participate only to obtain information without contributing meaningfully to collective learning.

The Technology category (n=29; 16.11%) indicates that access and connectivity limitations, along with a lack of technological skills, represent significant barriers to participation in CoPs. López et al. (2023) and Gorozidis et al. (2020) emphasize that in rural areas, the lack of internet access is a key factor that hinders continuous participation. Additionally, the digital platforms used in many CoPs present usability issues and are not always suitable for facilitating in-depth discussions. Tyrer (2019) notes that although platforms like WhatsApp are popular, their structure does not allow for meaningful interaction or proper organization of debates and information.

In the Psycho-emotional category (n=28; 15.56%), several issues have been identified, such as power dynamics, negative emotions, lack of motivation, exclusion, and social conflicts. Although CoPs are designed to promote socialization and mutual support, authors like Tyrer (2019), Bergmark (2023), and García-Monge et al. (2019) warn that stress and anxiety can arise when members feel that their contributions are not sufficiently valued. Furthermore, the pressure to actively participate in CoPs, combined with work responsibilities, can lead to emotional burnout. Feelings of inferiority and exclusion also emerge when there is no adequate integration into the community's dynamics, which can result in member attrition, as noted by Bergmark (2023).

Regarding teaching (n=15; 8.33%), García-Monge et al. (2019) identify that teachers face difficulties in adopting new methodologies when these conflict with their traditional beliefs, which leads to resistance to change and tensions among CoP members. These tensions are heightened when there is a disparity in levels of experience and knowledge, affecting pedagogical discussions and the implementation of new practices.

The category of evaluation and feedback (n=8; 4.44%) indicates that peer feedback within CoPs tends to be superficial, as participants avoid critical comments in order not to make others uncomfortable. López et al. (2023) point out that hierarchical feedback from tutors can create dependence, reducing the autonomy of members. Additionally, there is a disconnection between theory and practice in feedback, which makes it difficult to apply recommendations in the classroom.

Lastly, in the Research category (n=4; 2.22%), Bergmark (2023) mentions that the lack of familiarity with research processes within CoPs generates insecurity among members, hindering collaborative research efforts. Furthermore, the disconnection between theory and practice is an obstacle to the effective implementation of research in the classroom, as teachers struggle to critically reflect on their pedagogical practices

Discussion

The findings of this review paint a very positive picture of teacher communities of practice across most of the analytic dimensions, particularly in relation to interaction, learning and teaching. Positive mechanisms linked to interaction account for roughly one third of all positive instances, highlighting how CoPs create structured opportunities for collegial exchange, shared problem-solving and mutual support that are often missing in more individualised professional development formats. In line with situated learning perspectives (Lave & Wenger, 1991; Wenger, 2010), these communities appear to operate as social infrastructures that make it possible for teachers to negotiate meanings about their practice, to appropriate new pedagogical tools and to construct shared repertoires that respond to concrete classroom challenges (López et al., 2023; Noble, 2021). The learning and the teaching dimensions further reinforce this picture. Across the corpus, CoP participation is associated with the development of new pedagogical strategies, greater confidence in implementing innovative approaches and a closer alignment between professional development activities and classroom enactment (Bergmark, 2023; González Alfaya et al., 2017; Nielsen et al., 2023). Several studies report that when communities are sustained over time and supported by mentors or facilitators, they contribute to deeper forms of reflection on practice and to more robust links between educational theory, disciplinary content and classroom experimentation, including in social studies where issues of citizenship, critical thinking and social justice are central. In this sense, the results suggest that CoPs can function as a key mechanism for bridging the persistent gap between formal teacher education and the complex realities of teaching in rapidly changing educational environments.

At the same time, the review documents a substantial set of negative aspects and constraints that temper this optimistic picture. Time pressure, workload and precarious working conditions recurrently limit teachers' ability to participate fully in communities, even when they value the experience. Problems related to participation asymmetries, conflict and lack of continuity indicate that CoPs can reproduce existing hierarchies and inequalities if they are not carefully designed and facilitated (Bergmark, 2023; García-Monge et al., 2019). In the technological dimension, the co-existence of positive and negative instances points to a tension: while digital platforms and tools can expand opportunities for collaboration and feedback, they also introduce access issues, usability problems and new forms of fragmentation when infrastructures are unstable or when

teachers receive little support to integrate them meaningfully into their professional learning (Murtagh & Rushton, 2023).

The complementary AI-focused search conducted for this review confirms that, despite increasing policy and research attention, there are still relatively few empirical studies that place artificial intelligence at the centre of teacher communities of practice. Most of the evidence analysed concerns more general forms of digital mediation or early-stage AI-related initiatives, rather than mature, AI-intensive CoP designs. As a result, the claims made in this article about AI should be read primarily as implications grounded in the broader technology-related evidence, rather than as direct evaluations of AI-mediated CoPs. This does not diminish the relevance of AI for the future of teacher professional learning; rather, it underscores a gap between conceptual and policy expectations around AI and the current state of empirical research. The synthesis therefore points to CoPs as a promising, but still under-explored, structure for supporting teachers as they confront the opportunities and risks associated with AI in Education 4.0 contexts.

Study limitations

Several limitations of this review warrant consideration when interpreting its findings. The exclusive use of Scopus as the primary database may have omitted relevant studies indexed elsewhere, potentially limiting the comprehensiveness of the findings. Furthermore, the review's timeframe may not fully capture the most recent developments in AI and education, given the rapid pace of technological change. The categorization of positive and negative aspects, while necessary for analysis, may oversimplify the complex interplay between various factors affecting CoPs' effectiveness. Additionally, the review's methodology may not have captured all relevant studies about technology integration in CoPs, particularly those focused on emerging AI applications in education.

Directions for future research

Looking ahead, the patterns identified in this review suggest several avenues for future research that are directly grounded in the evidence. First, there is a clear need for empirical studies that examine AI-mediated CoPs in teacher education in a systematic way. Despite the complementary AI-focused search, explicit cases in which AI tools—such as analytics dashboards, conversational agents or generative AI systems—play a central role in the community's work remain scarce.

Future research should therefore design and document CoPs in which AI is intentionally integrated into interaction, feedback and knowledge-building processes, and examine how such designs influence the seven analytic dimensions identified in this review, including interaction patterns, learning outcomes, teaching practices and psycho-emotional aspects, particularly in social studies teacher education.

Second, the findings highlight the importance of investigating the conditions under which CoPs are sustainable and equitable over time. Negative evidence related to workload, participation asymmetries, emotional strain and uneven access to technology suggests that the benefits of CoPs are contingent on robust institutional support, careful facilitation and attention to issues of power and inclusion. Longitudinal and comparative studies across institutional types, regions and resource conditions would help clarify how different configurations of support, leadership and technological infrastructure contribute to or hinder the durability and impact of CoPs, including in contexts where access to AI and advanced digital tools is limited or uneven. Such research could also shed light on how CoPs mediate the distribution of professional agency and responsibility among teachers facing the pressures of digital transformation.

Finally, future research should explore multi-level connections between CoP participation, teacher learning and student outcomes, moving beyond self-reported changes and short-term perceptions. Mixed-methods designs that combine ethnographic or design-based studies of community practices with systematic analyses of teaching artefacts, classroom observations and, where appropriate, student learning indicators could provide a more fine-grained understanding of how CoP-generated innovations travel into everyday teaching and how they affect learners. In social studies education, this might involve examining how CoPs support teachers in addressing controversial issues related to AI, datafication and democracy, or in fostering students' critical and ethical engagement with digital technologies. By articulating these multi-level links, future work can help consolidate CoPs—not only as spaces of collegial support—but as strategic infrastructures for navigating Education 4.0 and for shaping more just and reflective uses of AI in education.

Acknowledgements

We thank Universidad de La Sabana (Technologies for Academia - Proventus Research Group (EDUPHD-20-2022 Project)), for the support received for the preparation of this article.

References

Allela, M. A., Ogange, B. O., Junaid, M. I., & Charles, P. B. (2020). Effectiveness of Multimodal Microlearning for In-service Teacher Training. *Journal of Learning for Development*, *7*(3), 384–398. https://doi.org/10.56059/jl4d.v7i3.387

Ayanwale, M. (2023). Can Experience Determine the Adoption of Industrial Revolution 4.0 Skills in 21st Century Mathematics Education?. *Research in Social Sciences and Technology, 8*(1), 74-91. https://doi.org/10.46303/ressat.2023.6

Azevedo, A., & Almeida, A. (2021). Grasp the Challenge of Digital Transition in SMEs—A Training Course Geared towards Decision-Makers. *Education Sciences*, *11*(4), 151. https://doi.org/10.3390/educsci11040151

Baas, N., & Tsotetsi, C. (2023). "I Mainly Rely on the Textbook:" A Call for Teacher Enhancement in Agricultural Sciences. *Research in Educational Policy and Management, 5*(3), 58-74. https://doi.org/10.46303/repam.2023.21

Backhouse, A. (2022). 'Stepping on the teacher's toes': Student teachers' experience of a one-year postgraduate teacher training programme. *European Journal of Teacher Education*, *45*(5), 707–726. https://doi.org/10.1080/02619768.2020.1860005

Bagerius, H., & Ekström, P. (2024). Jointly with others: Learning to collaborate in higher education teacher training. *Hogre Utbildning*, *14*(2), 42–55. Scopus. https://doi.org/10.23865/hu.v14.5968

Bergmark, U. (2023). Teachers' professional learning when building a research-based education: Context-specific, collaborative and teacher-driven professional development. *Professional Development in Education*, *49*(2), 210–224. https://doi.org/10.1080/19415257.2020.1827011

Bonfield, C. A., Salter, M., Longmuir, A., Benson, M., & Adachi, C. (2020). Transformation or evolution?: Education 4.0, teaching and learning in the digital age. *Higher Education Pedagogies*, *5*(1), 223–246. https://doi.org/10.1080/23752696.2020.1816847

Cabrita, M. D. R., Safari, H., & Muñoz Dueñas, M. del P. (2020). Preparing for Education 4.0: Skills Facing Economic, Social and Environmental Challenge. *International Journal of Innovation, Management and Technology*, *11*(1), 33–37. https://doi.org/10.18178/ijimt.2020.11.1.872

Celik, I. (2023). Towards Intelligent-TPACK: An empirical study on teachers' professional knowledge to ethically integrate artificial intelligence (AI)-based tools into education. *Computers in Human Behavior*, *138*, 107468. https://doi.org/10.1016/j.chb.2022.107468

Cesareni, D., Martini, F., & Mancini, I. (2011). Building a community among teachers, researchers and university students. A blended approach to training. *International Journal of Computer-Supported Collaborative Learning*, *6*(4), 625–646. https://doi.org/10.1007/s11412-011-9126-8

Coles, A., & Brown, L. (2001). NEEDING TO USE ALGEBRA. *Research in Mathematics Education*, *3*(1), 23–36. https://doi.org/10.1080/14794800008520082

Da Costa, E. V. (2019). A Formação no Seminário do Programa de Português para Estrangeiros da Universidade Federal do Rio Grande do Sul: Uma modalidade híbrida de aprendizagem do professor-autor. *Calidoscópio*, *17*(1), 78–96. https://doi.org/10.4013/cld.2019.171.05

De Carvalho-Filho, M. A., Tio, R. A., & Steinert, Y. (2020). Twelve tips for implementing a community of practice for faculty development. *Medical Teacher*, *42*(2), 143–149. https://doi.org/10.1080/0142159X.2018.1552782

de Souza, A. S. C., & Debs, L. (2024). Concepts, innovative technologies, learning approaches and trend topics in education 4.0: A scoping literature review. *Social Sciences & Humanities Open*, *9*, 100902. https://doi.org/10.1016/j.ssaho.2024.100902

Defise, R. (2013). Supporting the implementation of curriculum reform through learning communities and communities of practice. *PROSPECTS*, *43*(4), 473–479. https://doi.org/10.1007/s11125-013-9286-6

Duryan, M. (2023). Reflective practices and learning in construction organisations via professional communities of practice. In *Construction Project Organising* (pp. 149–164). Wiley Blackwell; Scopus.

Falkner, K., & Larsson, J. D. (2020). Professional formation of Swedish special education teachers in the tension between formal education at university and informal learning in practice. *Nordic Journal of Studies in Educational Policy*, *6*(1), 79–87. https://doi.org/10.1080/20020317.2020.1736870

Fraser, W. J. (2018). Filling gaps and expanding spaces – voices of student teachers on their developing teacher identity. *South African Journal of Education*, *38*(2), 1–11. https://doi.org/10.15700/saje.v38n2a1551

García-Monge, A., González-Calvo, G., & Bores-García, D. (2019). 'I like the idea but…': The gap in participation in a virtual community of practice for analysing physical education. *Open Learning: The Journal of Open, Distance and e-Learning*, *34*(3), 257–272. https://doi.org/10.1080/02680513.2018.1505486

Godinho Soares, R., Pugliero Coelho, C., Carrazoni Lopes Viçosa, C. S., Ribeiro Mucharreira, P., Vilanova Ilha, P., & Ruppenthal, R. (2023). Professional Profile and Needs of Basic

Education Teachers: Envisioning Nurturing Communities of Practice. *Acta Scientiae*, *25*(5), 59–85. Scopus. https://doi.org/10.17648/acta.scientiae.7459

González Alfaya, M. E., Olivares García, M. Á., & Mérida Serrano, R. (2017). Collaborative action research between schools, a continuing professional development centre for teachers and the university: A case study in Spain. *Educational Action Research*, *25*(5), 770–789. https://doi.org/10.1080/09650792.2016.1233125

González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of Education 4.0 in 21st Century Skills Frameworks: Systematic Review. *Sustainability*, *14*(3), 1493. https://doi.org/10.3390/su14031493

Gorozidis, G. S., Tzioumakis, Y. S., Krommidas, C., & Papaioannou, A. G. (2020). Facebook group PETCoN (Physical Education Teacher Collaborative Network). An innovative approach to PE teacher in-service training: A self-determination theory perspective. *Teaching and Teacher Education*, *96*, 103184. https://doi.org/10.1016/j.tate.2020.103184

Haas, A., Abonneau, D., Borzillo, S., & Guillaume, L.-P. (2021). Afraid of engagement? Towards an understanding of engagement in virtual communities of practice. *Knowledge Management Research and Practice*, *19*(2), 169–180. Scopus. https://doi.org/10.1080/14778238.2020.1745704

Hussin, A. A. (2018). Education 4.0 Made Simple: Ideas For Teaching. *International Journal of Education and Literacy Studies*, *6*(3), 92. https://doi.org/10.7575/aiac.ijels.v.6n.3p.92

Indrajit, R. E., Wibawa, B., & Suparman, A. (2021). University 4.0 in developing countries: A case of indonesia. *International Journal of Sociotechnology and Knowledge Development*, *13*(3), 33–59. Scopus. https://doi.org/10.4018/IJSKD.2021070103

Kgosi, M., Makgato, M., & Skosana, N. (2023). Teachers' Views on the Application of Educational Technologies in the Classroom: A Case of Selected Tshwane West Secondary Schools in Gauteng. *Journal of Curriculum Studies Research, 5(*2), 151-166. https://doi.org/10.46303/jcsr.2023.23

Koatz, D., Torres-Castaño, A., Salrach-Arnau, C., Perestelo-Pérez, L., Ramos-García, V., González-González, A. I., Pacheco-Huergo, V., Toledo-Chávarri, A., González-Pacheco, H., & Orrego, C. (2024). Exploring value creation in a virtual community of practice: A framework analysis for knowledge and skills development among primary care professionals. *BMC Medical Education*, *24*(1), 1–13. Scopus. https://doi.org/10.1186/s12909-024-05061-6

Kosztyán, Z. T., Csizmadia, T., & Katona, A. I. (2021). SIMILAR – Systematic iterative multilayer literature review method. *Journal of Informetrics*, *15*(1), 101111. https://doi.org/10.1016/j.joi.2020.101111

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation* (1st ed.). Cambridge University Press. https://doi.org/10.1017/CBO9780511815355

Lee, D., Jung, J., Shin, S., Otternbreit-Leftwich, A., & Glazewski, K. (2020). A Sociological View on Designing a Sustainable Online Community for K–12 Teachers: A Systematic Review. *Sustainability*, *12*(22), 9742. https://doi.org/10.3390/su12229742

Lekhu, M. (2023). Pre-Service Science Teachers' Preparedness for Classroom Teaching: Exploring Aspects of Self-Efficacy and Pedagogical Content Knowledge for Sustainable Learning Environments. *Journal of Curriculum Studies Research, 5*(1), 113-129. https://doi.org/10.46303/jcsr.2023.9

Li, Z., Wang, C., & Bonk, C. J. (2025). Generative AI for Teachers' Self-Directed Professional Development: A Mixed-Methods Study. *TechTrends*, 1–16. https://doi.org/10.1007/s11528-025-01123-8

López, M. A., Vila-Villasante, E., & Quintero, N. (2023). Scaling up the training of teachers through digitalization: The case of the aeioTU network. *Frontiers in Education*, *8*, 1–7. Scopus. https://doi.org/10.3389/feduc.2023.1165610

Lubinga, S., Maramura, T., & Masiya, T. (2023). The Fourth Industrial Revolution Adoption: Challenges in South African Higher Education Institutions. *Journal of Culture and Values in Education, 6*(2), 1-17. https://doi.org/10.46303/jcve.2023.5

Mahlo, L., Waghid, Z., & Chigona, A. (2024). Hybrid Communities of Practice Towards Developing Educators' Tpack: Implications for Teacher Education. *South African Journal of Higher Education*, *38*(5), 103–122. https://doi.org/10.20853/38-5-6416

Mashiane-Nkabinde, B., Nkambule, B., & Ngubane, S. (2023). Foundation Phase Educators' Views on the Management of Professional Development in Historically Disadvantaged Schools. *Research in Educational Policy and Management, 5*(2), 289-311. https://doi.org/10.46303/repam.2023.32

Mlangeni, N., & Seyama-Mokhaneli, S. (2024). Challenges in Equipping Learners for the Fourth Industrial Revolution: School Leaders' and Teachers' Powerlessness. *Research in Social Sciences and Technology, 9*(2), 176-195. https://doi.org/10.46303/ressat.2024.31

Mariyono, D., & Nur Alif Hd, A. (2025). AI's role in transforming learning environments: A review of collaborative approaches and innovations. *Quality Education for All*, *2*(1), 265–288. https://doi.org/10.1108/QEA-08-2024-0071

Masood, A., Zakaria, N., & Kamarudin, M. A. I. (2024). Empowering E-Learning Excellence: Unveiling the Influence of Outcome Expectation, Learning Motivation, and Self-Efficacy in the Industrial Era 4.0. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, *42*(1), 254–264. https://doi.org/10.37934/araset.42.1.254264

Mercieca, B. M., & McDonald, J. (2021). *Sustaining Communities of Practice with Early Career Teachers: Supporting Early Career Teachers in Australian and International Primary and Secondary Schools, and Educational Social Learning Spaces*. Springer Singapore. https://doi.org/10.1007/978-981-33-6354-0

Merino, C., Pacheco, G., Arenas-Martija, A., Becerra, R., & Solís-Pinilla, J. (2025). Continuing professional development in teachers: Insights for designing a formative trajectory in scientific education. *Frontiers in Education*, *10*, 1537502. https://doi.org/10.3389/feduc.2025.1537502

Milara, I. S., Pitkänen, K., Laru, J., Iwata, M., Orduña, M. C., & Riekki, J. (2020). STEAM in Oulu: Scaffolding the development of a Community of Practice for local educators around STEAM and digital fabrication. *International Journal of Child-Computer Interaction*, *26*, 1–14. https://doi.org/10.1016/j.ijcci.2020.100197

Murtagh, L., & Rushton, E. A. C. (2023). The role of teacher educator virtual communities of practice (VCoPs) in mobilising policy engagement: A case study of the initial teacher training market review from England. *Asia-Pacific Journal of Teacher Education*, *51*(5), 480–498. Scopus. https://doi.org/10.1080/1359866X.2023.2191306

Nguyen, H. T. T., Duong, N. T., & Dang, T. T. P. (2024). A Comprehensive Analysis of Teacher Professional Learning Communities: A Scopus Based Review (2019–2024). *International Journal of Learning, Teaching and Educational Research*, *23*(8), 158–179. https://doi.org/10.26803/ijlter.23.8.9

Nhlumayo, B. (2024). Developing Teachers through School-Based Leadership: A Case Study of One Rural Primary School in South Africa. *Journal of Culture and Values in Education, 7*(2), 173-187. https://doi.org/10.46303/jcve.2024.18

Nielsen, L. M., Reitan, J. B., & Hassel, R. M. (2023). Nettverk for formgiving, kunst og håndverk i universitets- og høgskolesektoren (KHUH): 10 år med praksisfellesskap i utvikling. *FormAkademisk*, *16*(2). https://doi.org/10.7577/formakademisk.4966

Noble, K. (2021). 'Getting Hands On with Other Creative Minds': Establishing a Community of Practice around Primary Art and Design at the Art Museum. *International Journal of Art & Design Education*, *40*(3), 615–629. https://doi.org/10.1111/jade.12371

Okoli, C. (2015). A Guide to Conducting a Standalone Systematic Literature Review. *Communications of the Association for Information Systems*, *37*, 879–910. https://doi.org/10.17705/1CAIS.03743

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, n71. https://doi.org/10.1136/bmj.n71

Patton, K., & Parker, M. (2017). Teacher education communities of practice: More than a culture of collaboration. *Teaching and Teacher Education*, *67*, 351–360. https://doi.org/10.1016/j.tate.2017.06.013

Perumal, J. C. (2013). Pedagogy of refuge: Education in a time of dispossession. *Race Ethnicity and Education*, *16*(5), 673–695. https://doi.org/10.1080/13613324.2013.792797

Petersen, N., & Henning, E. (2018). Service learning and the practice of social justice and care. *Journal of Human Behavior in the Social Environment*, *28*(4), 436–448. https://doi.org/10.1080/10911359.2017.1418697

Sahn, S. F., & Riesen, K. (2024). Building a community of practice for instruction librarians: Programmatic elements and strategies for implementation. *Journal of Academic Librarianship*, *50*(5), 1–7. Scopus. https://doi.org/10.1016/j.acalib.2024.102928

Salmon, G. (2019). May the fourth be with you: Creating education 4.0. *Journal of Learning for Development*, *6*(2), 95–115.

Salo, P., Francisco, S., & Olin Almqvist, A. (2024). Understanding professional learning in and for practice. *Professional Development in Education*, *50*(3), 444–459. https://doi.org/10.1080/19415257.2024.2311108

Stevenson, B. (2015). Third spaces and video-stimulated recall: An exploration of teachers' cultural role in an Indigenous education context. *Educational Action Research*, *23*(2), 290–305. https://doi.org/10.1080/09650792.2014.990986

Summers, D., & Turner, R. (2011). Outside the green box: Embedding education for sustainable development through cooperative inquiry. *Educational Action Research*, *19*(4), 453–468. https://doi.org/10.1080/09650792.2011.625682

Tarman, B. (2016). Innovation and Education. *Research in Social Sciences and Technology*, *1*(1), 77–97. https://doi.org/10.46303/ressat.01.01.4

Tiwari, R. G., Misra, A., Kukreja, V., Jain, A. K., & Ujjwal, N. (2022). *Education 4.0: Classification of Student Adaptability Level in E-Education*. 1–6. Scopus. https://doi.org/10.1109/ICRITO56286.2022.9964851

Truscott, D., & Barker, K. S. (2020). Developing Teacher Identities as In Situ Teacher Educators through Communities of Practice. *The New Educator*, *16*(4), 333–351. https://doi.org/10.1080/1547688X.2020.1779890

Tyrer, C. (2019). Beyond social chit chat? Analysing the social practice of a mobile messaging service on a higher education teacher development course. *International Journal of Educational Technology in Higher Education*, *16*(1), 13. https://doi.org/10.1186/s41239-019-0143-4

Vargas, E.G., Chiappe, A. & Durand, J. (2024). Reshaping education in the era of artificial intelligence: insights from Situated Learning related literature. *Journal of Social Studies Education Research, 15(*2), 1-28. https://jsser.org/index.php/jsser/article/view/5428/665

Vičič Krabonja, M., Kustec, S., Skrbinjek, V., Aberšek, B., & Flogie, A. (2024). Innovative Professional Learning Communities and Sustainable Education Practices through Digital Transformation. *Sustainability*, *16*(14), 6250. https://doi.org/10.3390/su16146250

Wang, X., Niu, J., Fang, B., Han, G., & He, J. (2025). Empowering teachers' professional development with LLMs: An empirical study of developing teachers' competency for instructional design in blended learning. *Teaching and Teacher Education*, *165*, 105091. https://doi.org/10.1016/j.tate.2025.105091

Wenger, E. (2010). Communities of practice and social learning systems: The career of a concept. In *Social learning systems and communities of practice* (pp. 179–198). Springer. http://link.springer.com/chapter/10.1007/978-1-84996-133-2_11

Yandell, J., & Turvey, A. (2007). Standards or communities of practice? Competing models of workplace learning and development. *British Educational Research Journal*, *33*(4), 533–550. https://doi.org/10.1080/01411920701434052