

Review Article

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Exploration of Emerging Trends in PCK for Natural Sciences: Innovation and Continuous Improvement in Teacher Education

Karen Patricia Agudelo Arteaga , Samuel González-Arizmendi

Abstract

Background/purpose. This study aims to analyze emerging trends in Pedagogical Content Knowledge (PCK) for natural sciences over the last 17 years. The research identifies key thematic areas and examines their contribution to teacher training and pedagogical innovation through the suvidagogical model.

Materials/methods. A systematic review was conducted using the Interpretive Documentary Analysis (IDA) method, guided by PRISMA. Ten primary publications from 2007 to 2024 were selected through rigorous inclusion criteria based on Boolean search strategies.

Results. The analysis revealed four dominant themes: (1) teaching and learning processes, (2) teacher training and professional development (TPD), (3) didactic methodologies and strategies (DMS), and (4) contextual applications (CA). These contribute to the design and implementation of the suvidagogical pedagogy model.

Conclusion. Findings support the construction of a critically engaged pedagogical framework that recognizes the vital and reflective role of the teacher, fostering inclusive and context-sensitive educational practices.

1. Introduction

"Pedagogical Content Knowledge" (PCK) is a fundamental concept in education, introduced by Lee Shulman in 1986. Shulman developed this term to describe a particular type of knowledge that teachers possess, going beyond the mere mastery of disciplinary content and separate pedagogical knowledge. According to Shulman, PCK represents a unique understanding of how subject matter can be organized and presented in ways that are accessible and comprehensible to students. This conceptualization emerged in response to the need to recognize and value the specialized knowledge that teachers use to transform content into forms that facilitate learning.

However, despite its theoretical robustness, the evolving educational demands and sociocultural realities of science education require a renewed and contextually sensitive understanding of PCK.

PCK has been widely discussed and expanded in the decades following its introduction. In 1996, Jiménez introduced the term in Spain, adapting it conceptually and translating it as 'Didactic Content Knowledge' (DCK). This adaptation was not merely a translation but also an enrichment of the concept, incorporating new dimensions into the theoretical framework proposed by Shulman. In the Spanish context, DCK emphasizes the integration of content knowledge with specific didactic strategies, enabling teachers to tailor their instruction to the specific features of the educational environment and their students' characteristics.

The concept also expanded into Latin America, where Mora and Parga (2008) adopted the term DCK, recognizing its value for interpreting Teachers' Professional Knowledge (TPK). In their interpretation, DCK is presented as a complex network of knowledge and beliefs that teachers must integrate to teach effectively. This network includes not only content and pedagogical knowledge but also disciplinary, metadisciplinary, psychopedagogical, and contextual knowledge. Integrating these elements allows teachers to develop teaching strategies adapted to both contextual and individual needs of each educational situation.

The development of PCK has been the subject of numerous studies that have contributed to a deeper understanding of its nature and practical applications. Research by Van Driel, Verloop, and De Vos (1998) and Abell (2007) has explored how PCK manifests in the teaching of natural sciences, emphasizing its role in transforming disciplinary content into teachable and learnable knowledge for students. This transformation process is crucial for making academic content accessible and meaningful, thus highlighting PCK as an essential and integrative component of teacher professional knowledge.

In the academic literature, PCK has been characterized as a practical and professionalized form of knowledge built from the interaction of various knowledge types and the personal and professional traits of the teacher. Valbuena (2007) argues that PCK is a dynamic construct that adapts to contextual needs and specific demands of the educational setting. Additionally, researchers such as Grossman (1990), Carlsen (1999), Gess-Newsome (1999), and Magnusson et al. (1999) agree that PCK is a key domain that defines the teacher's professional identity and directly impacts classroom effectiveness.

PCK has also been analyzed in terms of its relationship to contextual knowledge, acknowledging that educational practice is influenced by factors such as culture, society, family, and school. According to Marcelo (1999), for PCK to be effective, it is essential that teachers understand the socioeconomic and cultural characteristics of their environment, as well as the expectations and needs of their students. This contextual understanding allows teachers to adapt their strategies to address the specific realities of their students, enriching the educational process and making it more relevant and effective.

However, despite its wide acceptance and development, concerns remain about the training of future teachers concerning PCK. Reyes and Martínez (2013) warn that many teacher training programs place little emphasis on reflecting on the didactic content that teachers in training must teach. This limited approach could affect their ability to develop strong and effective PCK, ultimately impacting teaching quality.

In conclusion, Pedagogical Content Knowledge (PCK) has evolved significantly since Shulman introduced it in 1986. Its development has been driven by extensive research that has broadened its scope and adapted it to diverse educational contexts, underlining its importance as an essential component of teacher knowledge. PCK not only integrates content and pedagogy but also includes a deep understanding of the context and the individual needs of students, making it a cornerstone for effective teaching and learning in the classroom.

2. Literature Review

Numerous studies have expanded and contextualized PCK in diverse educational settings. For instance, Van Driel et al. (1998) and Abell (2007) explored how PCK emerges in science education as a transformative tool that bridges theory and practice. Valbuena (2007) emphasized the dynamic and context-sensitive nature of PCK in Latin America, while Grossman (1990) and Gess-Newsome (1999) provided foundational models for understanding how teachers integrate subject knowledge with pedagogical reasoning.

In Spanish-speaking contexts, Jiménez (1996) and Marcelo (1993) helped reinterpret PCK as "Didactic Content Knowledge" (DCK), incorporating socio-cultural dimensions. González and Rossi (2015) and Mora and Parga (2008) enriched the conceptualization of PCK by emphasizing subjectivity, context, and didactic integration. These contributions highlight the importance of critical reflection, adaptation, and contextual understanding in shaping effective teacher knowledge.

3. Methodology

This research employed the interpretive documentary analysis methodology (IDA), using a variety of national and international sources to identify emerging trends in Pedagogical Content Knowledge (PCK) and its impact on the continuous improvement of science teaching. According to Corona (2018), documentary analysis involves reviewing bibliographic material related to the study's subject, allowing for a detailed examination of the selected content. Therefore, it was essential to carry out a careful interpretation, which involved selecting scientific articles indexed in various electronic repositories, postgraduate theses, and institutional documents to offer a comprehensive view of the investigated topic. The 2007–2024 timeframe was deliberately selected to capture the evolution of PCK scholarship following the regional expansion of critical pedagogical frameworks in Latin America and the influence of contemporary epistemological trends in teacher education.

Documentary research is defined as a process that aims to acquire new knowledge through the retrieval, analysis, and interpretation of secondary data. This data is obtained and published by other researchers or scientific institutions in various documentary sources (Arias & Odón, 2016). Additionally, the relevance of documentary research is highlighted as a valuable tool for collecting key information on the study topic. This approach includes the analysis and interpretation of written, electronic, or other documentary sources that provide useful data for research, emphasizing its flexibility and rigor, which make it applicable across various fields of study.

In this regard, based on a prior bibliometric analysis of scientific publications exploring emerging trends in Pedagogical Content Knowledge (PCK), the ways in which this knowledge contributes to improving teaching practice and strengthening both disciplinary and pedagogical-didactic learning of students can be identified. Consequently, a classification was developed that corresponds to the

requirements and contributions relevant to the objectivity of the research, which is evidenced at the following link: <https://lc.cx/dQaAx3>.

Likewise, a path of processes and sub-processes was used to carry out the interpretative documentary analysis (IDA), which is presented in Figure 1. This scheme includes the following steps: (i) Systematic review strategy: here the objective or research question was defined, together with the strategy for searching and identifying relevant publications; (ii) Conducting the search: in this phase, non-relevant publications were systematically filtered, using inclusion and exclusion criteria, and relevant (RP) or analytical publications were selected; (iii) Results and discussions: this section established the criteria for analysis, developed a characterisation scheme and analysed the results; (iv) Findings and conclusions: here contributions and gaps in the research were identified. This research reviewed scientific literature from the last 17 years (2007-2024), using search strategies that included Boolean operators and specific identification criteria. Therefore, it is necessary to present a clear methodological route for the development of this research (see Figure 1).

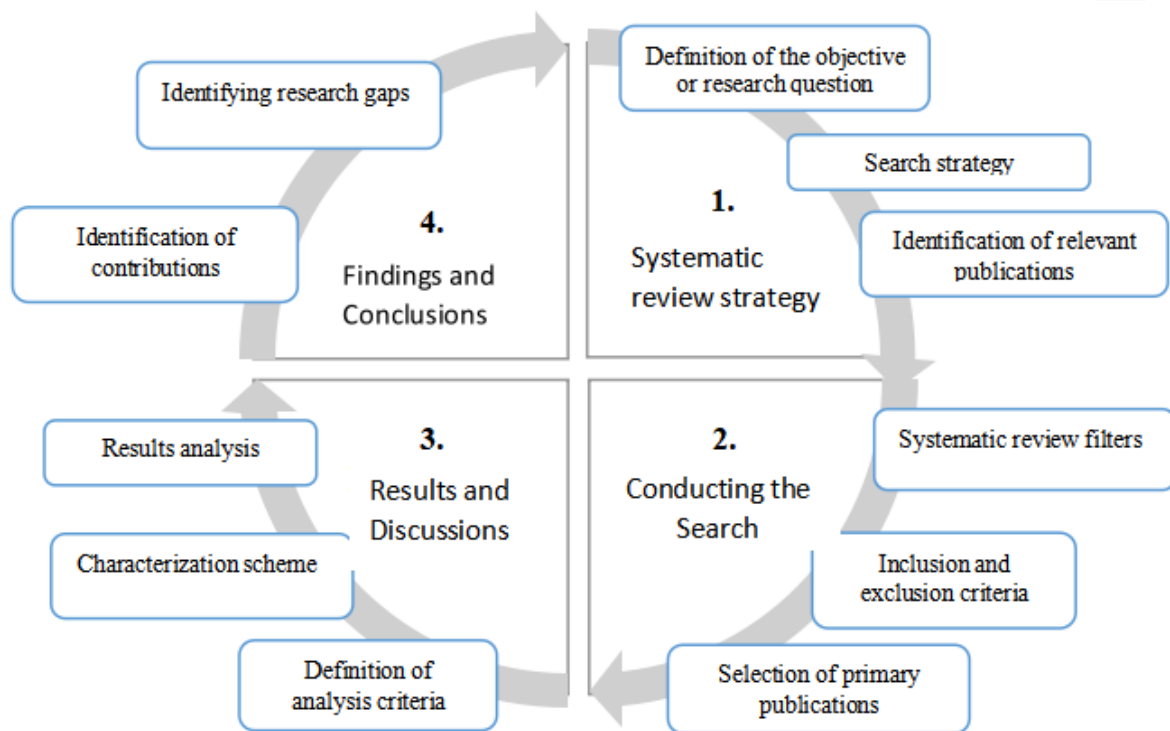


Figure 1. Route of ADI Processes and Sub-Processes (Source: Own Creation)

3.1. Search Strategy

The search for information was carried out using English and Spanish terms, using Boolean operators AND or AND/WITH to include and connect all the specified terms. OR was also used to broaden the search, obtaining information on one or both of the specified terms, separating two of the three terms by various possible combinations. Specific search criteria were established, limiting the results to titles, abstracts, conference manuscripts, book chapters, articles published in scientific journals, papers, and theses, located in databases and Google Scholar, using search strings (see Table 1). The study had a non-experimental design and a simple descriptive cross-sectional level. The search was narrowed down, excluding patents and third-party citations.

3.2. Identification of Relevant Publications

Identification of relevant publications for this study was done using search strings in databases and Google Scholar to reduce bias during the review (Table 1).

Table 1. Relevant Publications Sites

Databases and Google Scholar	Search strings	No. of research found
Elibro	<i>"Teacher training" AND "Professional development"; "Pedagogical knowledge of content" OR 'Didactic knowledge of content'"</i>	1
scielo	<i>"Teacher training" AND "Professional development"; "Pedagogical knowledge of content" OR 'Didactic knowledge of content'"</i>	2
Dialnet	<i>"Methodologies" AND "Teaching strategies"; "Pedagogical knowledge of the content" OR "Didactic knowledge of the content"</i>	14
Academic Google	<i>"Pedagogical knowledge of content" OR 'Didactic knowledge of content'; Continuous improvement OR professional development 'Science education' OR natural science teaching.</i>	33

Keywords related to the object of study of this research were used. This is why Villegas (2003) considers that the Boolean search allows the incorporation of corrections and synonyms learned in successive searches; a specialist would avoid such incorporation and then the Boolean search would speed up finding writings on subjects of interest to him/her. Given this, an adjustment to the formats of the selected databases, repositories and search strings was achieved.

3.3. Systematic Review Filters

During the selection phase of the primary publications, rigorous review filters were implemented that included: (i) a preliminary assessment of the titles and abstracts of the published research, and (ii) an exhaustive review of the full text of those publications that passed the first filter. Garcia (2022) argues that the systematic review is based on the elaboration of a summary and a detailed analysis of the evidence relevant to a specific question, carried out in a structured, explicit and systematic manner. It is imperative to detail the method used to locate, select, analyse and synthesise primary sources, as this approach ensures an accurate and reliable synthesis of the existing literature. Accordingly, strict inclusion and exclusion criteria were applied to all final research, with the aim of selecting only those that would be subject to detailed analysis.

3.4. Inclusion and Exclusion Criteria

It is pertinent to consider that the inclusion criteria took into account those works, journals and articles that were close to the categories of analysis, understanding that, if they were related to the subject matter, they would make a significant and vital contribution to the teacher. Consequently, publications without a defined methodology or paradigmatic dimensions within their discursive analysis were excluded, and research other than education in natural or social sciences were not taken into account, as well as publications that did not contain a relationship with the search strings and studies in which the participant population was not defined.

3.5. Results and Discussion

Approximately one thousand six hundred and eighteen records were obtained from the different bibliographic sources shown in Figure 2, of which 200 were taken after eliminating duplicates and removing those that were not related to the object of study.

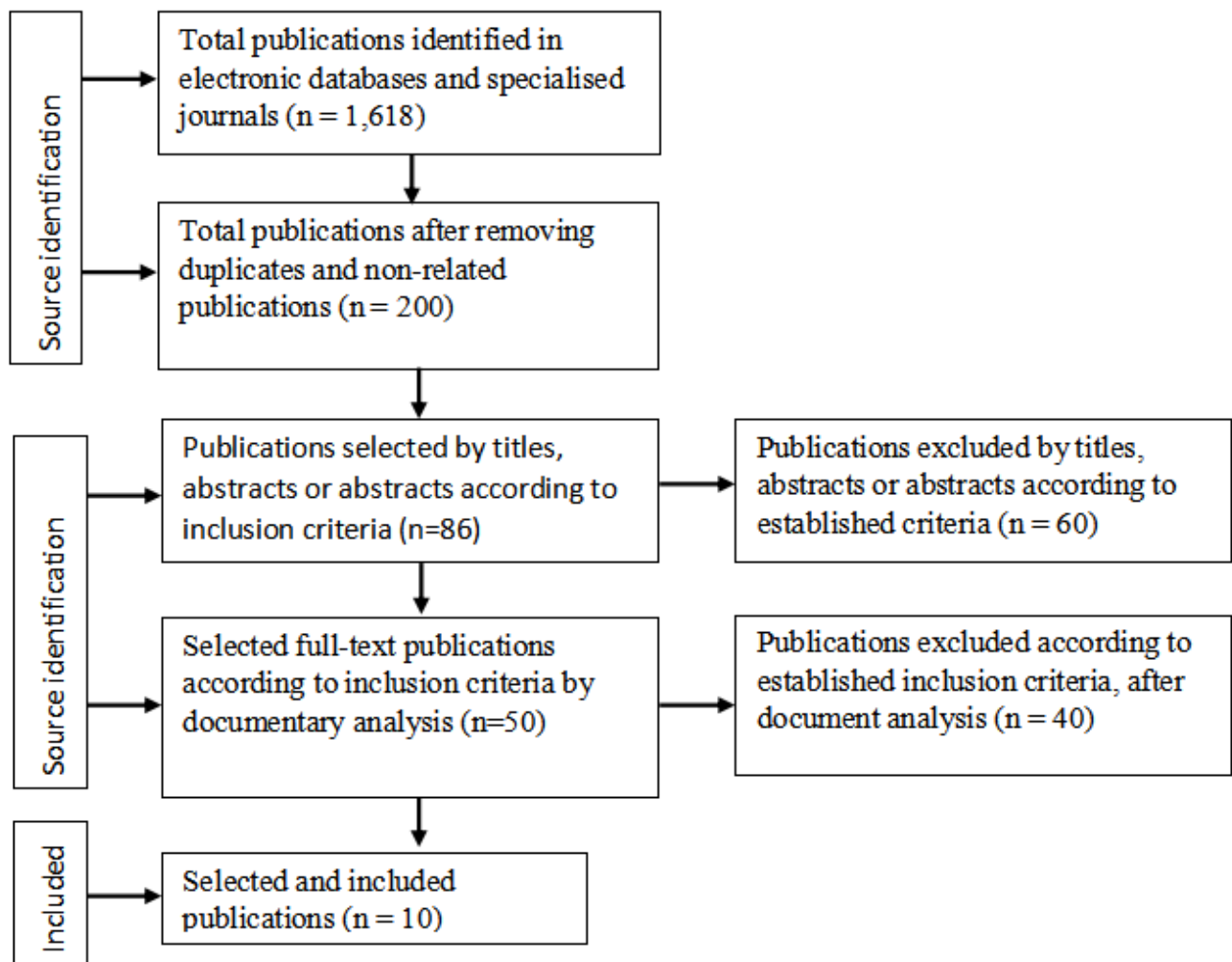


Figure 2. ADI Search Strategy Flowchart (Source: Own Creation)

Once the titles and abstracts were examined, 60 research studies that did not correspond to the initial criteria for inclusion in the ADI were excluded, leaving 50 publications, of which 40 were not taken into account because they did not meet any of the inclusion criteria established when reviewed in their total content.

3.6. Selection of the Primary Publications

The selection of the primary publications took place after applying the first and second filters, resulting in ten (10) relevant research studies. The flow chart in Figure 3 shows the search strategy implemented and the results of the ADI at each stage and filter.

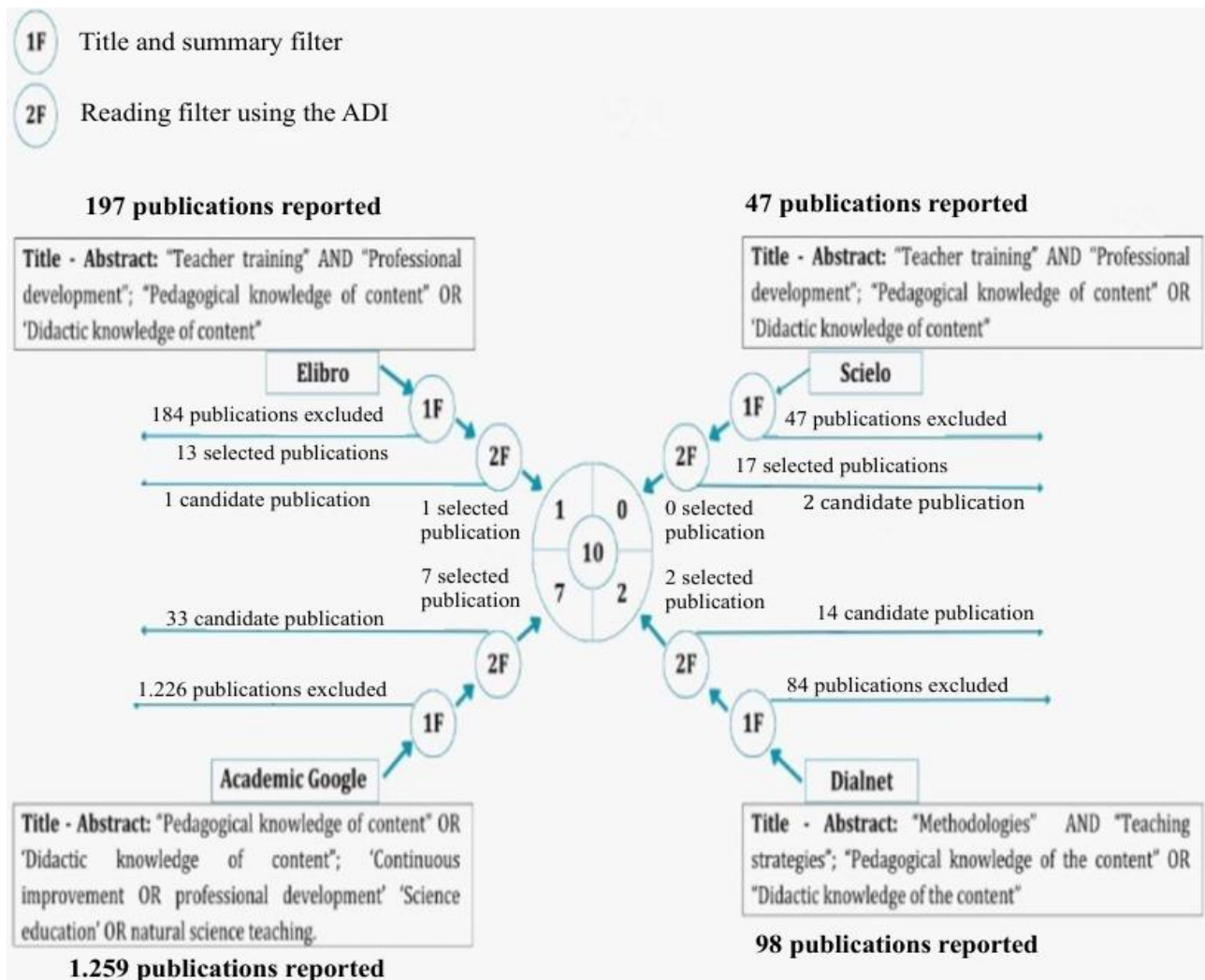


Figure 3. Search Route for Primary Publications (Source: Own Creation)

It should be added that, both in the preliminary search and in the selected databases, no unavailable publications were recorded as they could all be obtained directly.

4. Results and Discussion of the Systematic Review

This summary shows the search strategy implemented and the results of the ADI in each phase and filter comprising the selection of the four subcategories (Table 2).

Table 2. Synthesis of Selected Primary Publications.

PP	Authors	Year	Publication's Source – Country	Classification Areas
PP1	Edgar Orlay Valbuena Ussa	2007.	Google Academic-Spain	TPD
PP2	Diana Lineth Parga Lozano and William Manuel Mora Penagos	2016.	Google Academic - Colombia	DMS
PP3	Diana Lineth Parga Lozano and William Manuel Mora Penagos	2008.	Google Academic - Colombia	CA
PP4	Jairo Andrés Velásquez Sarria, Gloria Marcela Flórez Espinosa and Óscar Eugenio Tamayo Alzate	2015.	Elibro - Colombia	TPD

PP	Authors	Year	Publication's Source – Country	Classification Areas
PP5	Carla Hernández Silva, Damián Ruz López and Silvia Tecpan Flores	2017.	Dialet – Spain	DMS
PP6	Ali José Carrillo Paz and Hau Fung Moy Kwan	2009.	Dialet – Venezuela	DMS
PP7	Norma González and Alejandra Rossi	2015.	Dialet - Argentina	PCK
PP8	Cejas León, Roberto Navío Gámez, Antonio Barroso Osuna, Julio Manuel	2016.	Google Academic - Spain	TPD
PP9	José Carlos Libâneo	2014.	Google Academic - Colombia	TPD
PP10	Norma Viviana González	2017.	Google Academic - Argentina	CA

Note: PP: Primary Publications

Based on this classification, the interpretative documentary analysis was carried out. The following table presents the information:

Table 3. Relationship and Classification of the Study Areas (PCK, TPD, DMS, CA)

Title	Authors – Year – Location	Keywords	Classification	Contribution
The didactic knowledge of the content Biological: study of the conceptions, Disciplinary and didactic of future Teachers of the pedagogical university National (COLOMBIA)	Edgar Orlay Valbuena Ussa (2007, Madrid)	Didactic Content Knowledge (DCK), Teacher Training, Disciplinary Conceptions, Biology	TPD	This study develops the DCKB model, providing a framework for transforming disciplinary content into teachable knowledge. It emphasizes the importance of integrating students' preconceptions and balancing academic and practical knowledge, enhancing continuous professional development in science teaching.
Environmental didactics and didactic content knowledge in chemistry	Diana Lineth Parga Lozano and William Mora Penagos (2016, Colombia)	Environmental didactics, didactic content knowledge, environmental education, chemistry teacher training	DMS	The article proposes a didactic model for environmental education that integrates the STS approach with DCK. It emphasizes contextualizing chemistry content through active student participation and real-world problems.

Title	Authors – Year – Location	Keywords	Classification	Contribution
Didactic content knowledge in chemistry: integration of the historical-epistemological content frameworks with the context-learning frameworks	Diana Lineth Parga Lozano and William Mora Penagos (2008, Colombia)	Didactic content knowledge, professional development, didactic integration, and didactic plots	CA	The study integrates historical and epistemological perspectives into chemistry education through DCK, using tools such as CoRe and Redp. This enhances relevance and applicability in various teaching contexts.
Knowledge needed for teaching: a key category in teacher education	Jairo Andrés Velásquez Sarria, Gloria Marcela Flórez Espinosa and Óscar Eugenio Tamayo Alzate (2015, Colombia)	Pedagogical Content Knowledge (PCK), Science Didactics, Research Methodology, Teacher Education	TPD	This work proposes a framework that integrates disciplinary knowledge and PCK with curriculum awareness and student understanding. It incorporates the Erte trend to promote critical reflection and contextualized teacher training.
Future physics teachers' views on lesson planning as a tool for using pedagogical content knowledge	Carla Hernández Silva, Damián Ruz López and Silvia Tecpan Flores (2017, Spain)	Teacher training, Educational planning, Physics education	DMS	The study stresses the importance of lesson planning in developing PCK through active learning strategies. It encourages reflective practice and adaptation to students' difficulties to enhance conceptual understanding.
Didactic model for meaningful learning in automatic control systems	Ali José Carrillo Paz and Hau Fung Moy Kwan (2009, Venezuela)	Meaningful learning, automatic control systems, and didactic model	DMS	Presents a didactic model for linking theory with real-life applications in engineering education. Highlights the need for teacher training in innovative and technological methodologies.
Pedagogical content knowledge for teaching the topic of mitosis	Norma González and Alejandra Rossi (2015, Argentina)	Didactic content knowledge (DCK), mitosis, content representation, formative assessment	PCK	The research emphasizes integrating curricular knowledge and student understanding to enhance science learning. It promotes formative assessment and adaptation to student diversity through reflective teaching.

Title	Authors – Year – Location	Keywords	Classification	Contribution
The competences of university teaching staff from the TPACK model	Cejas León, Roberto; Navío Gámez, Antonio; Barroso Osuna, Julio Manuel (2016, Spain)	TPACK, Competences, ICT Training, Higher Education	TPD	This article explores the TPACK model in higher education, advocating for the integration of technological, pedagogical, and content knowledge. It supports ICT-based instructional design and competency development in university teaching.
The integration between disciplinary knowledge and pedagogical knowledge in teacher training	José Carlos Libâneo (2014, Colombia)	Teacher training, pedagogical and disciplinary knowledge, developmental teaching theory	TPD	Libâneo proposes a training model based on Davydov's developmental teaching, emphasizing the unity between epistemology and didactics. This approach addresses gaps between theory and practice in teacher education.
Influence of context on the development of a university teacher's technological pedagogical content knowledge (TPACK)	Norma Viviana González (2017, Argentina)	TPACK, context, technology, teacher training	CA	The study highlights how contextual levels shape TPACK development in higher education. It calls for situated professional development aligned with evolving educational technologies and socio-pedagogical demands.

These publications are focused on the theoretical field of Pedagogical Content Knowledge (PCK). Although they will not focus on specific categories, a classification was made in order to organise and understand the areas of focus of this research. The classification is structured into four main aspects: training and professional development (TPD), methodologies and teaching strategies (DMS), contexts and applications (CA), and teaching and learning processes (PCK) (Figure 4). This organisation enables the identification of emerging trends within the CPC and how they contribute to the development of the supra-pedagogical pedagogy model.

Figure 4 illustrates the number of publications corresponding to each classification area, highlighting the concentration of research in the different thematic areas related to Pedagogical Content Knowledge (PCK). It can be seen that most of the relevant publications are in the area of teaching and learning processes (PCK), closely followed by the area of training and professional development (TPD), with only a difference of two publications between them. The area of teaching methodologies and strategies (DMS) has 10 publications, while the area of contexts and applications (CA) has the lowest number of publications, with only 4 records. This structure not only allows a clearer and more detailed analysis of each relevant aspect in the field of education, but also facilitates the integration of different perspectives and approaches that enrich pedagogical knowledge.

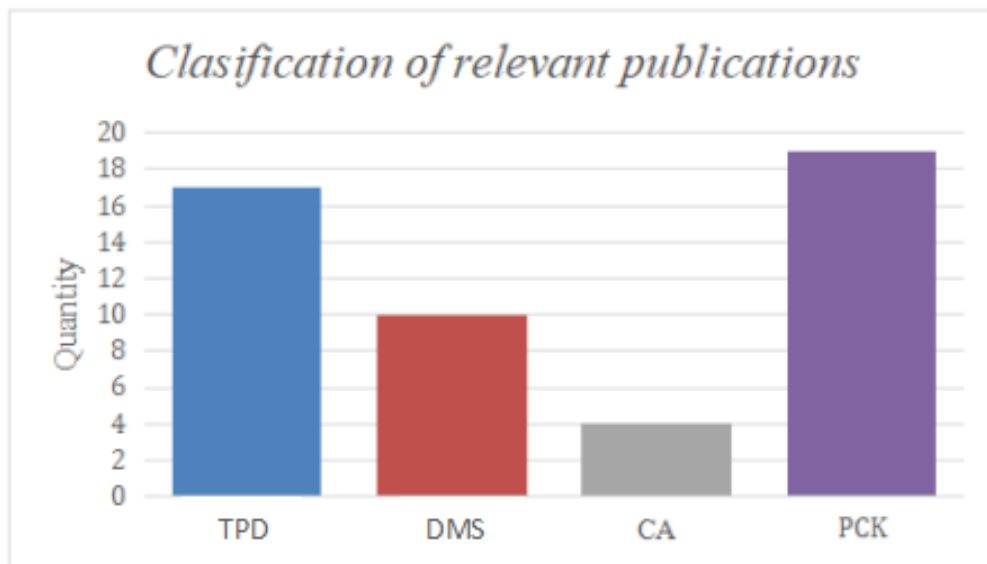


Figure 4. Relationship and Classification of Relevant Publications (Source: Own Creation)

4.1. Distribution of Research by Country

Figure 5 shows the distribution of primary publications by country, highlighting the intensity of research activity in each country. Colombia is positioned as the leader with twenty research studies, which reflects a notable commitment in the field of CPC. It is followed by Spain with twelve studies, Argentina with five, Chile with four, and Mexico with two studies. Other countries report only one research study, indicating a moderate level of activity. This pattern of distribution highlights Colombia as the most active in research, followed by a group of countries and regions with a more moderate research focus. This analysis is crucial to understanding how research effort is distributed in the international context based on the data collected and analyzed.

NUMBER OF RESEARCHES

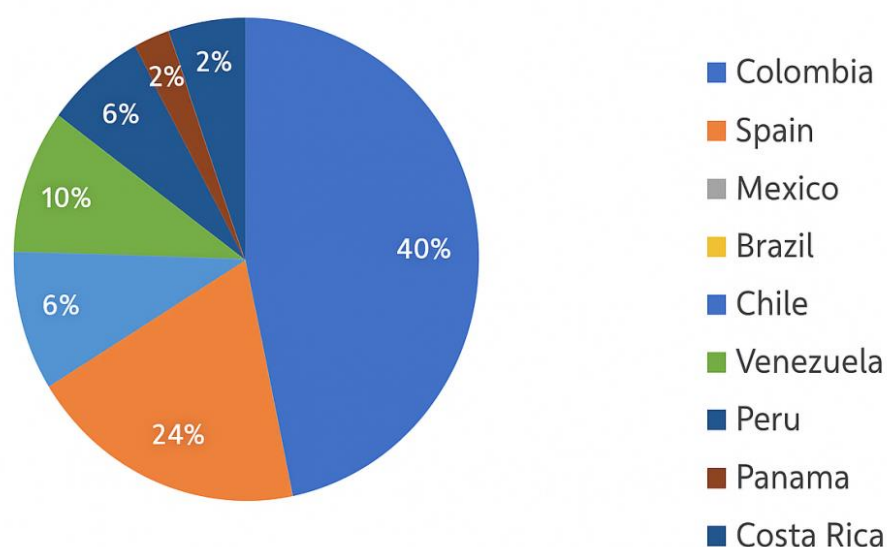


Figure 5. Type of Contribution of Primary Publications by Country. (Source: Own Creation)

5. Discussion

Pedagogical Content Knowledge (PCK) is a crucial concept in education, as it encompasses how teachers transform their content knowledge into effective teaching. One of the main significant trends for CPC was introduced by Lee Shulman in 1986, who stressed that teachers must not only master the content they teach, but also know how to teach it in a way that is understandable to students. He further emphasised that CPC includes a deep understanding of how students think and learn, which allows teachers to anticipate difficulties and approach concepts from multiple perspectives.

Based on this approach, it is possible to identify significant emerging trends in the field of CPC, classified into four key areas: teaching and learning processes (TLP), training and professional development (TDP), methodologies and teaching strategies (DMS), and contexts and applications (CA).

5.1. Teaching and Learning Processes (TLP)

Teaching and learning processes (TLP) is one of the key areas in the development of Pedagogical Content Knowledge (PCK). This area focuses on how teachers plan, implement and evaluate the educational process, and how students acquire and process knowledge. In the context of CPC, PEAs are involved in in-depth reflection on the methodologies, strategies, and approaches used to facilitate learning, as well as the teacher's ability to adapt their teaching to the specific needs of students.

In this context, González and Rossi (2015) provide an enriching vision through the trend of Didactic Content Knowledge (DCK), highlighting several key aspects. First, they propose that DCK should be subject- and context-specific, requiring teachers to adopt a flexible and adaptable approach to the changing needs of students. This idea of adapting and contextualising learning is fundamental to facilitating more meaningful teaching, in which students can connect what they learn to their own experiences and to the real world.

Furthermore, they emphasise continuous reflection on the part of teachers, who must constantly evaluate and adjust their pedagogical practices. This critical reflection is essential for improving both teaching and learning, as it allows difficulties that may arise during the educational process to be identified and overcome. Through formative assessment, teachers can obtain real-time feedback on students' progress and adjust their methods to improve results.

Finally, this trend promotes student-centred teaching, recognising diversity in levels of understanding and adapting methodologies to cater for these differences. This approach translates into greater effectiveness in ASP, contributing to science teaching that is dynamic, inclusive and oriented towards the continuous improvement of the educational process.

5.2. Training and Professional Development (TDP)

This area encompasses the processes and strategies aimed at the continuous improvement of teachers' competencies and skills throughout their careers. It focuses on providing educators with the tools necessary to stay current in their disciplines, adapt to new methodologies and pedagogical approaches, and develop critical skills to meet educational challenges. Initial training and continuing professional development are essential to ensure that teachers can deliver high-quality education and respond effectively to the changing needs of students.

Valbuena (2007), in his Didactic Biological Content Knowledge (DCKB) approach, emphasises how biology teachers transform and organise content knowledge to adapt it to the needs of the classroom. DCKB is conceived as the core around which other components of Professional Teaching Knowledge are processed, integrated and complexified. This enables teachers not only to master

biological content, but also to transform it into knowledge that can be understood and used effectively in the classroom. In addition, DCKB is composed of several interrelated elements, which enable teachers to make key decisions about what content to teach, how to teach it and how to integrate students' preconceptions.

This trend also highlights how teachers can overcome difficulties in the teaching-learning process by anticipating the challenges students face when learning biology. By focusing on the transformation of knowledge in pedagogical practice, the DCK provides teachers with tools to respond to the challenges of teaching biology. This ensures that biological knowledge is not transmitted in isolation, but is adapted to the contextual needs of students, thus facilitating more meaningful and effective learning.

For their part, Velasquez, Florez, and Tamayo (2015) highlight in their approach the integration of various types of knowledge for effective science teaching. This trend combines subject knowledge with pedagogy, enabling teachers to organise and present content in a way that is understandable to students. In addition, it stresses the importance of knowing the curriculum and understanding students' ideas and mental models in order to overcome barriers to learning. This approach also promotes the integration of knowledge of the curriculum, the learner and the context in order to provide more contextualised and effective teaching.

This approach, in turn, proposes the Educational Reconstruction of Teacher Education (Erte) trend, initially developed by Van Dijk and Kattmann in 2007. This trend focuses on designing learning environments based on a critical analysis of the subject matter and an empirical study of students' pre-scientific conceptions. Its aim is to 'reconstruct' the educational practice of teachers, promoting a deep reflection on teacher training processes in order to optimise teaching strategies and more effectively address students' learning difficulties.

Similarly, Libâneo (2014) emphasises the importance of integrating pedagogical knowledge and disciplinary knowledge in teacher training, addressing the gap that exists between these two areas. He proposes overcoming the separation between didactics, epistemology of disciplines and teaching methodologies, advocating a more coherent integration between training in specific content and pedagogical training. It emphasises that this integration is essential for a more critical and humane education. This approach stresses the need to connect pedagogical theory with socio-cultural and institutional practices, based on Vasili Davydov's theory of developmental teaching. This proposal seeks to rethink and redesign teacher training to make it more effective and contextualised, orienting the planning and conduct of the teaching-learning process towards more integrated and relevant training.

On the other hand, Cejas, Navío & Barroso (2016) emphasise the TPACK (Technological Pedagogical Content Knowledge) trend, which seeks to effectively integrate technological, pedagogical and content knowledge in teaching practice. This trend was initially developed by Mishra and Koehler (2006) and is based on the concept of pedagogical content knowledge (PCK) proposed by Schulman (1986). It emphasises that teachers must possess not only deep subject knowledge (CK), but also pedagogical skills and technological competencies that intertwine to facilitate meaningful learning in the classroom.

This holistic approach seeks to ensure that teachers not only have a deep mastery of the subject matter they teach, but are also competent in appropriate pedagogical strategies and in the use of information and communication technologies (ICT). The intersection of these three types of knowledge enables educators to create relevant and meaningful learning experiences, adapting to the needs of their students and the current educational context. Furthermore, it emphasises the importance of researching and analysing good practices in the use of ICT in order to improve the quality of teaching and learning in higher education, thus responding to the demands of the 21st-century knowledge society.

5.3. Didactic Methodologies and Strategies (DMS)

Focuses on the pedagogical methods and approaches used to facilitate effective learning. This area includes the development and implementation of strategies that enable teachers to transmit knowledge efficiently and adapt to the needs and contexts of learners. Teaching methodologies encompass a variety of approaches, from traditional techniques to innovations based on new technologies and emerging educational theories. The aim is to optimise the teaching and learning process, ensuring that students can acquire and apply knowledge in a meaningful and contextualised way.

In this context, Carrillo and Moy (2009) emphasise a didactic trend that facilitates meaningful learning in automatic control systems and is based on the idea that students should relate theoretical concepts to practical, everyday situations. This is aligned with the Curriculum by Competences approach, which seeks to develop skills and competences in students so that they can apply their knowledge in real contexts.

This trend underscores the critical importance of continuous teacher training in innovative methodologies and educational technologies. It also encourages the diversification of instructional strategies to address the limitations of traditional theoretical models. By connecting learning with practical and real-life contexts, this approach enhances students' comprehension and motivation, fostering more meaningful and relevant educational experiences.

In a similar vein, the integration of content and pedagogy is exemplified by the emergence of Environmental Didactics. Parga and Mora (2016) emphasize that this trend, which centers on embedding environmental content within educational frameworks, aims to merge the didactic understanding of environmental topics with pedagogical strategies suitable for effective instruction in secondary education. Rather than adhering to a reductionist perspective, Environmental Didactics promotes a holistic approach that embraces constructivism, interdisciplinarity, and complexity. It highlights the necessity of aligning content knowledge with context-appropriate teaching strategies to foster meaningful and situated learning on environmental issues.

This pedagogical shift presents a significant challenge for educators, as it calls for the deep integration of environmental knowledge into subject-specific teaching, such as chemistry. It advocates for a reconfiguration of traditional didactic models—often criticized for their dogmatic and positivist assumptions—toward a more constructivist and critical paradigm. The trend urges educators to move beyond intuitive or habitual practices, instead embracing teaching approaches grounded in constructivist and complexity-based principles.

In contrast, Hernández, Ruz and Tecpan (2017) stress the importance of integrating Pedagogical Content Knowledge (PCK) into lesson planning through active learning strategies. This approach goes beyond the simple transmission of knowledge, suggesting that teachers design lessons that not only focus on the transmission of knowledge, but also consider students' possible learning difficulties and use didactic strategies that facilitate the reorganisation of students' knowledge schema.

The use of tools such as lesson planning is essential for prospective teachers to reflect deeply on key aspects of teaching, such as what to teach, how to teach it, and for what. This continuous reflection contributes directly to the development of CPC, as it enables teachers to effectively integrate disciplinary and pedagogical knowledge. Through this process, teachers can adapt their teaching strategies to meet the specific needs of their students, optimising their understanding of the content and ensuring that learning is not only accessible but also relevant and contextualised for each student.

5.4. Contexts and Applications (CA)

The area of Contexts and Applications (CA) focuses on how pedagogical and disciplinary knowledge is adapted and applied in diverse educational settings. This includes consideration of contextual factors that affect teaching and learning, such as student characteristics, the school environment, available resources and the demands of the educational context. Furthermore, it encompasses the practical application of educational theories and methods in real situations, ensuring that the content taught is relevant and useful to students in their specific contexts.

Mora and Parga propose a Didactic Content Knowledge (DCK) trend focused on chemistry teaching, which emphasises the professionalisation of curriculum design and the integration of historical-epistemological frameworks. This trend aims for teachers not only to design effective curricula, but also to adapt the historical and epistemological knowledge of chemistry to the different educational levels. With this approach, a deeper and more contextualised understanding of the subject is fostered, ensuring that students can relate the content to real-life situations.

In addition, the trend underlines the importance of continuous teacher training, promoting ongoing updates of their knowledge and methods. To optimise teaching, the authors introduce tools such as Representations of Content (ReCo) and Repertoires of Didactic Professional Experience (ReEpd), which allow teachers to reflect on their practice and adjust their pedagogical strategies. These tools hTLP to improve the quality of chemistry teaching and foster greater innovation in the classroom.

Along the same lines, the trend that integrates TPACK and context proposed by González (2017) is called 'Technological Pedagogical Content Knowledge (TPACK) in Context'. This trend considers the influence of different levels of context (microcontext, mesocontext and macrocontext) on teachers' TPACK development, emphasising the importance of understanding how these contextual factors influence teachers' ability to effectively integrate technology into their educational practice. This trend is based on the premise that pedagogical content knowledge (CPC) cannot be considered in isolation, but must be contextualised within the realities in which teachers operate (González, 2017).

González (2017) posits that in order for educators to cultivate a robust and contextually responsive Technological Pedagogical Content Knowledge (TPACK), it becomes essential for them to not only recognize but also deeply engage with the multifaceted environments in which they operate. This epistemological positioning transcends a mere acquisition of technical or pedagogical tools; rather, it demands a dynamic interweaving of these domains within specific educational landscapes. The process of constructing TPACK, therefore, cannot be dissociated from the social, cultural, and institutional frameworks that shape teaching practices.

Moreover, González underscores—although perhaps indirectly—the indispensability of continuous, situated professional development, one that evolves in tandem with the shifting configurations of educational technology and the ever-transforming sociopedagogical demands. Static or decontextualized training, no matter how comprehensive, falls short of addressing the nuanced intricacies that define actual classroom experiences.

These epistemic shifts have, in recent years, exerted a substantive influence on the reconfiguration of Pedagogical Content Knowledge (PCK), or what some traditions refer to as CPC in Spanish-speaking contexts. Our understanding of effective teaching has not merely been expanded but problematized. Innovative didactic strategies, when mapped onto diverse educational realities, reveal a multiplicity of paths for enhancing teacher agency and instructional impact.

It is within this intellectual terrain that the theoretical-critical model of suvidagogía arises—not merely as another framework, but as a deeply philosophical orientation. As González-Arizmendi (2021) systematizes, suvidagogía emerges from a biographical and epistemic commitment to reposition the teacher as a *docente vital*, intertwining subjectivity, affectivity, and critical pedagogy. This model, further expanded by Agudelo Arteaga and González-Arizmendi (2023), articulates a robust link between PCK, problem-based learning, and vital subjectivity as core to pedagogical transformation. Their work offers both the theoretical matrix and empirical reflections necessary to consolidate suvidagogía as a legitimate and context-sensitive pedagogical paradigm in teacher education. Suvidagogía articulates an inclusive, reflective, and critically engaged pedagogy. It valorizes the lived subjectivity of both teachers and learners, proposing a model of education that is affective, contextual, and intrinsically transformative. This paradigm does not merely integrate recent advancements in PCK; it resemanticizes them, infusing pedagogical praxis with existential relevance and cultural specificity.

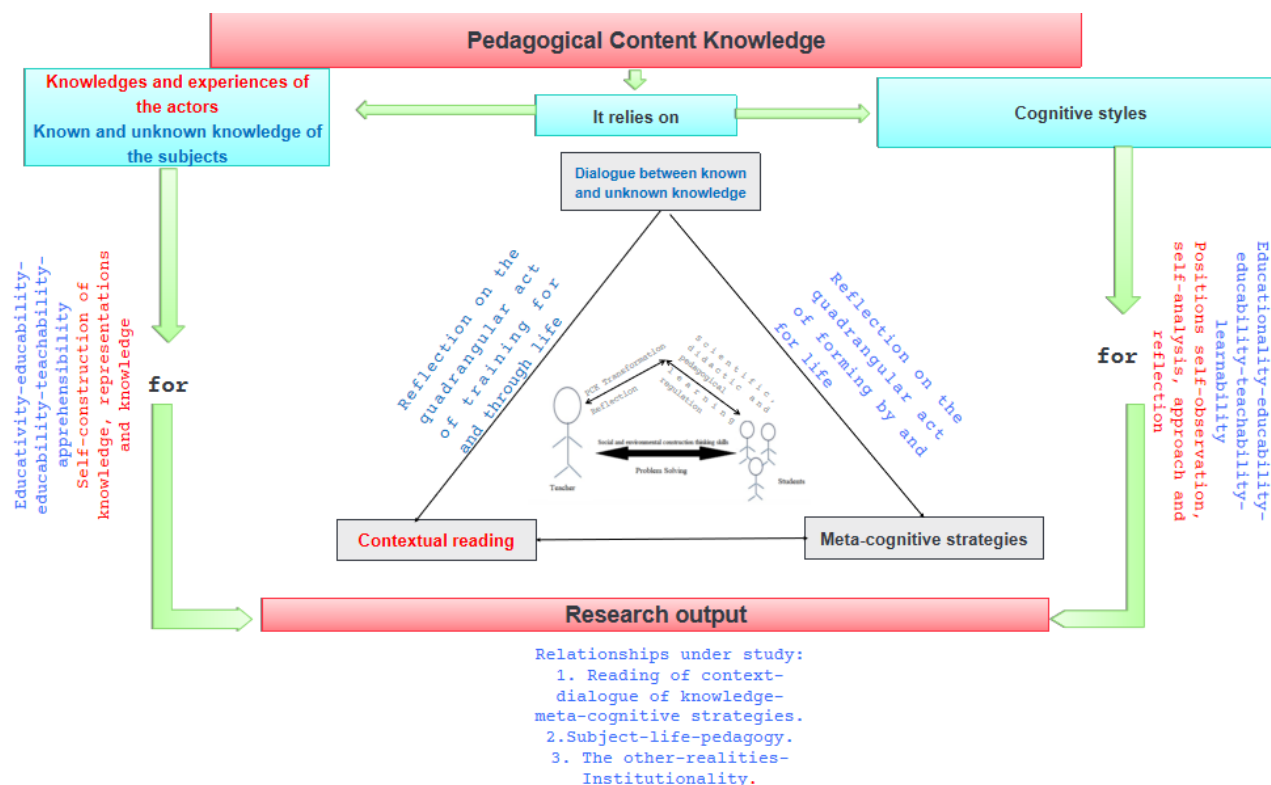


Figure 6. Theoretical Thesis of the Suvidagogic Pedagogy (Source: Author's Own Creation)

Suvidagogía, articulated through a theoretical-critical lens, unfolds a dense constellation of conceptual possibilities that serve as the foundational grammar of a substantive pedagogical theory. This framework posits the teacher not merely as a technical operative, but rather as a *docente vital*—a subject enmeshed in life itself. Pedagogical practice, under this logic, is interpreted not as a technique but as an existential relation, and praxis becomes a reflective-intentional movement rooted in the subjective comprehension of the suvidagogo.

Emerging from this conceptual lattice is a vibrant epistemic terrain that seeks to reposition the teacher and the learner in relational symmetry. In doing so, suvidagogía proposes a radical ethic of

intersubjective reciprocity: the subjectivity of each is constituted through the mutual interweaving of the other's experience. A classroom, in this light, ceases to be a transmission site and becomes a living archive of affections, perceptions, and symbolic exchanges.

This pedagogical orientation crystallizes over a biographical arc of more than two decades, during which the author systematically explored the psychopedagogical dimensions of his own existence. The triangular relation between subject, life, and pedagogy—previously diffuse—gains theoretical texture through successive phases of identification, inscription, semantic refraction, and situated enactment. From this hermeneutic sedimentation, the coordinates of what the author terms an “emergent suvidagogic source” begin to surface.

The teacher as a vital subject, encircled by the tensions of institutional inertia and socio-affective multiplicities, is thus reconceptualized through a prism of phenomenological inquiry and cultural-political critique. This subject engages not only with a discipline or a learner, but with entire topographies of meaning. Everyday pedagogical acts—often trivialized—are now reclaimed as events saturated with ontological and epistemic significance.

From this standpoint, the suvidagogic posture engenders a pedagogical becoming—what might be termed a form of radical re-humanization. Through critical-reflective processes, rooted in both institutional dynamics and individual praxis, the subject mobilizes concepts not merely for comprehension but for emancipation. This confers upon teaching a hermeneutic-discursive weight and a phenomenological-political telos that transcends the boundaries of formal schooling.

The methodological procedures underpinning suvidagogía are not linear. They entail recursive cycles of identification, inscription, semantic remodeling, interpretive synthesis, and situational performance. These movements allow the teacher to perceive the educational encounter as a field of subjectivation rather than a mere didactic obligation. Thus, pedagogical routines are reimagined as ontological laboratories in which the subject navigates between what-is and what-could-be.

Importantly, suvidagogía breaks from the deterministic logic of technocratic education. It refuses to reduce learning to quantifiable outputs. Instead, it cultivates the poetic and the personal: biographies, essays, poems, and fragmented narratives populate its discursive space. Through these textualities, the suvidagogo does not transmit doctrine, but invites the learner to co-compose meaning, echoing Freirean dialogical traditions yet carving its own semantic paths.

The psychic and socio-educational transformation facilitated by this model is neither predictable nor sequential. It unfolds through what the author calls suvidagogic behavioral stages—perception, acceptance, appropriation, and enactment—each signifying deeper strata of internalization. These stages are not pedagogical steps but existential moments that recalibrate the subject's relation to knowledge, to others, and to self.

Besides, suvidagogía asserts the primacy of the vital condition—not merely biological vitality, but the philosophical posture of serving life and society. To be vital is to recognize the interdependence of all cognitive and emotional engagements. This recognition demands that the subject transcend professional narcissism and embrace an anthropo-educational mode of being: one that situates teaching within an ethic of social reciprocity and political care.

This, perhaps, is where suvidagogía most radically distinguishes itself: in its demand that the teacher engage not only in cognitive reflection but in biographical interrogation. It is not enough to teach; one must narrate, revise, and, at times, dismantle the very grounds upon which one teaches. Such a disposition renders the classroom a space of epistemic insurgency—a place where knowledge is neither consumed nor delivered, but constructed through lived contradiction.

Suvidagogía, in this sense, becomes less a method and more a lifeworld—an existential position from which to inhabit the pedagogical vocation. It does not merely advocate for inclusion or context-sensitivity; it enacts these through the ontological politicization of teaching itself. In this way, the model offers a counter-narrative to normative educational practices, functioning as both a critique and a speculative project.

Within this framework, theory becomes suspended—no longer a prescriptive structure, but an emergent discourse shaped by the social co-construction of meaning. The suvidagogic teacher does not transmit truths; they accompany others in the co-fabrication of understanding, grounded in the epistemological instability of lived experience.

There are, of course, inconsistencies and paradoxes within the model—intentional or otherwise. For instance, the notion that “the subjectivity of one is the accumulation of many others” may conflict with certain post-structuralist views of fragmented selfhood. Yet these tensions are not flaws but constitutive features of suvidagogía’s philosophical complexity.

Finally, in alignment with the Texto Abierto Conceptual (TAC or Open Conceptual Text), suvidagogía embraces a fluid, non-prescriptive understanding of knowledge. Knowledge is not a repository but a field of contestation, renegotiated constantly through culture, memory, and social location. The goal is not mastery, but re-signification; not reproduction, but transformation.

6. Conclusion

This study highlights the importance of Pedagogical Content Knowledge (PCK) as a dynamic and context-sensitive framework that underpins effective science teaching. Through the interpretive documentary analysis of primary publications from 2007 to 2024, four emerging thematic areas were identified: teaching and learning processes (TLP), teacher training and professional development (TPD), didactic methodologies and strategies (DMS), and contextual applications (CA). These areas reflect the evolving demands of teacher education and the need to integrate disciplinary expertise, pedagogical innovation, and contextual awareness. The findings support the development of the suvidagogical pedagogy model, which conceptualizes teaching as a reflective, existential, and affective practice rooted in social and cultural realities. By repositioning the teacher as a vital and situated subject, suvidagogía offers a transformative perspective on teacher education that redefines knowledge construction as a shared, lived, and humanizing process (González, 2017).

These results reaffirm the relevance of PCK as a foundational element in educational innovation. By mapping emerging pedagogical trends and their contextual applications, the study provides a roadmap for designing more adaptive and inclusive training strategies. Moreover, the suvidagogical model enriches the theoretical debate on teacher subjectivity and affectivity, contributing to a rehumanization of educational practice. Its theoretical foundations, as developed by González-Arizmendi (2021), and its recent applications to models of pedagogical content knowledge (Agudelo Arteaga & González-Arizmendi, 2023), provide a fertile ground for rethinking teacher formation from an existential, reflective, and problematizing lens.

The integration of these findings can inform curriculum reform and inspire educational policies that align pedagogical content knowledge with the realities and challenges of diverse school settings. This comprehensive framework can also serve as a reference for future empirical studies assessing teacher development and student outcomes. As teacher education programs evolve, incorporating flexible, critical, and contextual models like suvidagogía may foster more meaningful and socially responsive teaching across disciplines.

7. Limitations and Challenges of the Research

Despite the valuable insights generated by this study, several limitations must be acknowledged. First, the number of primary publications selected for in-depth analysis was limited to ten, which may constrain the generalizability of the findings. Second, the research was predominantly focused on the Latin American and Spanish contexts, with a strong concentration of studies from Colombia, Spain, and Argentina, potentially introducing geographical bias in the interpretation of trends. Furthermore, the interpretive documentary analysis (IDA) approach, while rich in depth, is inherently subjective and reliant on the researcher's interpretive lens, which may influence the analysis and synthesis of the data (Corona, 2018). Additionally, the research excluded studies that did not explicitly align with the predefined search strings or that lacked methodological rigor, which may have led to the omission of relevant contributions. Additionally, the temporal range (2007–2024) was defined by the authors to focus on recent theoretical developments; however, this may limit the inclusion of earlier foundational literature.

8. Suggestions

In light of the findings, several recommendations emerge. First, it is essential to strengthen initial and ongoing teacher training programs through the incorporation of pedagogical models such as *suvidagogía*, which emphasize critical reflection, contextual sensitivity, and affective engagement. These models can bridge the gap between theoretical knowledge and real-world teaching practices, particularly in natural science education. Second, future research should expand the scope of analysis to include diverse cultural and disciplinary contexts, allowing for a more comprehensive understanding of the evolution of PCK. Third, further empirical studies are needed to examine the practical implementation of the *suvidagogical* model in classroom settings, assessing its impact on student learning and teacher development. Finally, policymakers and educational institutions are encouraged to design flexible training strategies that integrate ethical, technological, and inclusive dimensions of teaching, fostering a more responsive and human-centered education system (Libâneo, 2014; Cejas León et al., 2016).

Declarations

Author Contributions. K.P.A.A.: conceptualization, literature review, methodology design, manuscript writing. S.G.A. and T.A.P.C.: support in data analysis, review and editing. All authors have read and approved the final version of the article.

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