Discourses, Epistemologies, and Approaches in Technology Education: A Qualitative Documentary Analysis of Colombian Teacher Training

- Discursos, epistemologias e abordagens na educação tecnológica: uma análise documental qualitativa da formação de professores na Colômbia
- Discursos, epistemologías y enfoques en la educación tecnológica: un análisis documental cualitativo de la formación docente en Colombia

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Abstract

This article presents a qualitative study that analyzes the conceptualizations, discourses, and pedagogical orientations that have shaped Technology Education within teacher training programs in Colombia over the past decade. Grounded in critical pedagogy and curriculum theory, and employing document analysis and coding with Atlas.ti, the study pursues three objectives: to examine the discourses structuring technology education, to identify the epistemological perspectives embedded in national and international normative frameworks, and to characterize the prevailing pedagogical approaches. The findings—organized around the epistemological dislocation of the field, its marginalization within curricular policy, and the emergence of a formative paradigm centered on critical and creative thinking—reveal significant tensions between educational policies and pedagogical practices, underscoring the urgent need to reconceptualize this field as a key space for the formation of sociotechnical citizenship. Although

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the corpus is limited to official sources, excluding the voice of teaching practice, the study contributes to the ongoing debate on educational policy by proposing an inclusive and context-sensitive curricular framework aligned with critical and transformative pedagogical approaches aimed at strengthening technology teaching in Colombia.

Keywords

technology education; teacher training; documentary research; literature reviews; STEM

Resumo

Este artigo apresenta uma pesquisa qualitativa que analisa as conceptualizações, os discursos e as orientações pedagógicas que têm configurado a Educação em Tecnologia nos programas de formação docente na Colômbia durante a última década. Fundamentado na pedagogia crítica e na teoria do currículo, e utilizando análise documental e codificação com o software Atlas.ti, o estudo aborda três objetivos: examinar os discursos que estruturam a educação tecnológica, identificar as perspectivas epistemológicas presentes nos marcos normativos nacionais e internacionais, e caracterizar as abordagens pedagógicas predominantes. Os achados — organizados em torno da deslocação epistemológica do campo, da sua marginalização nas políticas curriculares e da emergência de um paradigma formativo centrado no pensamento crítico e criativo — revelam tensões entre as diretrizes da política educacional e as práticas pedagógicas efetivas, evidenciando a urgência de ressignificar este campo como um espaço central para a formação da cidadania sociotécnica. Embora o corpus analisado se restrinja a fontes oficiais, excluindo a prática docente, o estudo contribui para o debate sobre política educacional ao propor um marco curricular inclusivo e contextualizado, alinhado a abordagens críticas e transformadoras que fortaleçam o ensino de tecnologia na Colômbia.

Palavras-chave

educação tecnológica; formação de professores; pesquisa documental; revisão da literatura; STEM

Resumen

Este artículo presenta una investigación cualitativa que analiza las conceptualizaciones, discursos y orientaciones pedagógicas que han configurado la Educación en Tecnología en los programas de formación docente en Colombia durante la última década. Basado en la pedagogía crítica y la teoría del currículo, y utilizando análisis documental y codificación con ATLAS.TI, el estudio aborda tres objetivos: examinar los discursos que estructuran la educación tecnológica, identificar las perspectivas epistemológicas en marcos normativos nacionales e internacionales, y caracterizar los enfoques pedagógicos predominantes. Los hallazgos, organizados en torno a la dislocación epistemológica del campo, su marginación curricular y la emergencia de un paradigma formativo centrado en el pensamiento crítico y creativo, revelan tensiones entre las políticas educativas y las prácticas pedagógicas, subrayando la urgencia de resignificar este campo como espacio para la formación de ciudadanía sociotécnica. Si bien el corpus se limita a fuentes oficiales, excluyendo la práctica docente, el estudio contribuye al debate sobre política educativa al proponer un marco curricular inclusivo y contextualizado, alineado con enfoques críticos y transformadores para fortalecer la enseñanza de la tecnología en Colombia.

Palabras clave

educación en tecnología; formación docente; investigación documental; revisión de la literatura; STEM

Introduction

Technology Education (EduTech) plays a crucial role in preparing citizens to critically navigate a digitally mediated and globalized society. In the Colombian context, this field—recognized nationally as Technology and Informatics (AT&I)—was formally integrated into the educational system with the enactment of Law 115 in 1994. Since then, various curricular guidelines have been developed, the most recent of which appeared in 2022. These policy documents stress the importance of training professionals capable of addressing technological and social disparities in a dynamic, knowledge-driven world. Within this framework, it becomes imperative to critically examine the discourses, epistemological perspectives, and pedagogical approaches that shape teacher education in EduTech, given that teachers are key agents in fostering technological competencies among future generations. Nonetheless, the foundational principles guiding this training—be they epistemological, pedagogical, or normative—remain fragmented and insufficiently analyzed, as highlighted by Ramírez (2020) and Ramírez and Mora (2019).

Responding to this gap, the present study seeks to explore how various discourses, epistemologies, and pedagogical models configure EduTech within Colombian teacher education programs, especially as reflected in national and international policy frameworks. The central research question guiding this inquiry is: How do discourses, epistemological perspectives, and pedagogical approaches shape the configuration of EduTech in Colombian teacher training programs? To address this, the study pursues three specific objectives: (a) to examine the dominant discourses in teacher education regarding EduTech; (b) to identify the epistemological foundations underpinning national and global education policies; and (c) to characterize the pedagogical strategies currently developed in Colombian teacher training. These focal points were selected not only because of their current relevance in shaping educational practices, but also because they reflect recent transformations in how EduTech is perceived both nationally and internationally.

Methodologically, the research is grounded in a qualitative paradigm, adopting a hermeneutic-philosophical approach aligned with critical pedagogy and curriculum theory. A comprehensive content analysis was performed using Atlas.ti, focusing on curricular documents, public policies, and related texts produced between 2012 and 2022. This theoretical lens is informed by perspectives on technology (Carvajal, 2021), the Colombian legal and curricular framework (Ramírez, 2016), epistemological discourses (Martínez & Suárez, 2008), and pedagogical models specific to teacher education (Ramírez, 2020). The analysis revealed a lack of cohesion among these sources, manifesting in fragmented theoretical foundations, ambiguous goals, and inconsistent curricular implementations in teacher training programs.

By approaching EduTech from an interdisciplinary standpoint, the study underscores its complexity beyond the mere use of tools. It situates EduTech at the confluence of epistemological, historical, and normative processes, illustrating how public policies, theoretical frameworks, and pedagogical practices have evolved. This evolution reflects an increasingly critical understanding of technology—not just as a technical artifact, but as a social, cognitive, and cultural construct that plays a fundamental role in shaping contemporary societies.

Within this broader framework, teacher training in technology requires a critical examination of the discourses and epistemological foundations that underpin its teachability,

particularly in response to the educational challenges of the 21st century. Revisiting diverse knowledge systems is essential to fully apprehend the pedagogical potential of technology for addressing real-world problems, meeting community needs, and advancing sustainable development (Lind *et al.*, 2020). This study seeks to provide analytical tools for researchers, teacher educators, and policymakers by reconceptualizing EduTech as a catalyst for socio-technical citizenship and inclusive curriculum design. By illuminating the intersections among policy, pedagogy, and epistemology in shaping technology teacher education, it aims to inform educational policies that are not only context-sensitive and sustainable, but also critically engaged.

Background

García (2013) reflects on the importance of building a technological culture in teacher training, conceptualized as a framework that encompasses not only technical knowledge and practices but also symbolic systems, contextual norms, and the ethical, legal, and social implications of technology. This vision emphasizes the need for educators to engage critically with the technological environments in which they operate, and to integrate these dimensions into curriculum design.

Alonso (2014) underscores the value of the Science, Technology, and Society (STS) approach in cultivating critical and reflective thinking among future teachers, emphasizing pedagogical strategies that enable them to interrogate, evaluate, and respond to scientific and technological issues. While García addresses the broader cultural integration of technology, Alonso focuses more narrowly on teacher competencies. Building upon these contributions, Palacios et al. (2022) advance the discussion by examining the incorporation of emerging technologies—such as Artificial Intelligence and Augmented Reality—within STEM-oriented frameworks, highlighting their practical role in promoting inclusive learning environments and expanding access to complex scientific experiences through virtual laboratories.

Taken together, these contributions reveal complementary but distinct dimensions of teacher training in EduTech. García provides a cultural-epistemological foundation, Alonso introduces a reflective-pedagogical lens, and Palacios points toward innovation and inclusion through technological mediation. These perspectives converge in underscoring the need for a critical, interdisciplinary, and future-oriented approach to EduTech. They also justify the present research's aim to explore how discourses, epistemological perspectives, and pedagogical models shape teacher training programs, especially in light of ongoing digital transformations and the need for inclusive, context-sensitive educational policies. These conceptual underpinnings serve as the theoretical lens through which the present study examines the configuration of EduTech in teacher training programs in Colombia (Ministerio de Educación Nacional, 1996; 2008; 2022)

Conceptual Framework

This framework is developed from two perspectives: the disciplinary perspective, which emphasizes epistemological approaches and the characterization of knowledge components relevant to societal needs; and the historical perspective, which reflects on the sociopolitical contexts that enabled civic oversight of technological advancement, especially during the post-war period, emphasizing responsibility toward life and future generations globally.

Disciplinary Perspective:

Carl Mitcham (1994), in *Thinking Through Technology*, outlines four central epistemological approaches to technology: manufacturing, mechanistic engineering, humanistic, and Science, Technology, and Society (STS). These are complemented by the cognitive model proposed by Herbert Simon and the design-centered approach articulated by Norman (1988, 2005).

- The manufacturing approach centers on production and efficiency, often sidelining the social implications of technology (Bönsiepe, 1996).
- The mechanistic approach focuses on scientific application for productivity and environmental control (Gasset, 1982; Feenberg, 2002).
- The humanistic approach positions technology as a cultural force, requiring ethical and social scrutiny (Mitcham, 1994; Ellul, 2021).
- The cognitive model (Simon, 1996) sees technology as a problem-solving process grounded in strategic thinking.
- The design-centered view emphasizes creativity and aesthetic innovation in technological artifact creation (Norman, 1988, 2005; Dessauer, 1927).

Historical Perspective

From a historical perspective, the value that governments worldwide have placed on the study of science and technology is particularly evident in the post-war period (1945 onward). Science and technology are seen not only as drivers of reconstruction and development but also as essential tools for fostering citizenship and managing technoscientific advancements to safeguard human life and address the risks these developments pose for future generations.

The report Science, the Endless Frontier by Vannevar Bush (1945), alongside the Einstein-Russell Manifesto (1955) and the Pugwash Conference Declaration (1957), underscores the significance that governments and academics attribute to technological learning and development. This value is considered even more consequential than that of the Industrial Revolution due to both the immense opportunities technology offers and the existential risks it can generate. Consequently, integrating technology into education from early stages became a priority to equip citizens with the ability to question, monitor, and manage technology, fostering equity and sustainability.

The World Declaration on Education for All (UNESCO, 2008) reaffirmed the importance of promoting a scientific and technological culture to address the complexities of the contemporary world. This approach was further reinforced by subsequent declarations, such as the Education 2030: Framework for Action (2015), in which UNESCO emphasized that science and technology play a crucial role in generating innovative solutions that promote sustainable and equitable progress while transforming educational processes.

In Colombia, educational policy has integrated these approaches since 1946, consolidating them in the General Education Law of 1994, which established the "Technology and Informatics Area" as a mandatory subject for primary and secondary education (Law No. 115, Articles 23 and 31, 1994). Additionally, initiatives such as EduTech for the 21st Century (Ministerio de Educación Nacional, 1996) and General Guidelines for Technology Education: Being Competent in Technology (Ministerio de Educación Nacional, 2008; 2022) have been implemented, providing guidelines for addressing this area within educational institutions.

Integrative Reflection

Disciplinary and historical perspectives jointly position EduTech as a multidimensional field, where epistemological models—ranging from mechanistic to humanistic and cognitive—illuminate how societies conceptualize and interact with technology. When situated within broader historical and policy shifts, these models highlight the need for a critical, participatory, and ethically anchored approach to technology education. This is especially pertinent in Colombia, where global discourses have influenced national education policies since the mid-20th century, culminating in the institutionalization of the AT&I.

Recent Latin American scholarship (Duque-Escobar *et al.*, 2015; Avello Martínez & Duart 2016; Lozano & Bolivar, 2021) reinforces the relevance of contextualizing epistemological models within regional realities, highlighting the challenges and advances in implementing EduTech policies that are inclusive and socially responsive.

Methodology

This research adopts a qualitative approach aimed at understanding and interpreting the discourses and perspectives associated with EduTech within the context of teacher training in Colombia. Emphasizing subjective and intersubjective realities as fields of knowledge, the study is framed within a hermeneutic philosophical perspective that recognizes the multidimensional and dynamic nature of educational and social phenomena.

To meet the research objectives, a document review was conducted as the primary method for theoretical data collection and analysis, following an interpretative, inductive approach. This entailed a critical bibliographic review of relevant literature from the past decade, sourced from databases such as Web of Science, Scopus, Google Scholar, and EBSCO. A total of 172 documents were examined—including peer-reviewed articles, doctoral and master's theses, official curricula, and policy papers—distributed as follows: 46 for the first objective, 69 for the second, and 57 for the third. Inclusion criteria prioritized materials directly addressing teacher training in EduTech, demonstrating methodological rigor and relevance to the study's theoretical framework, while documents lacking academic validity or unrelated to the study's core focus were excluded.

The research process was structured in several stages: searching and compiling relevant documents, developing specialized analytical summaries (RAE), constructing analysis matrices, and coding the data using Atlas.ti software. The use of this software facilitated the organization, systematization, and analysis of data, enabling the identification of general, axial, and core categories. These categories were subsequently correlated to generate a robust theoretical construction that supports the study's conclusions. Figure 1 outlines the process.

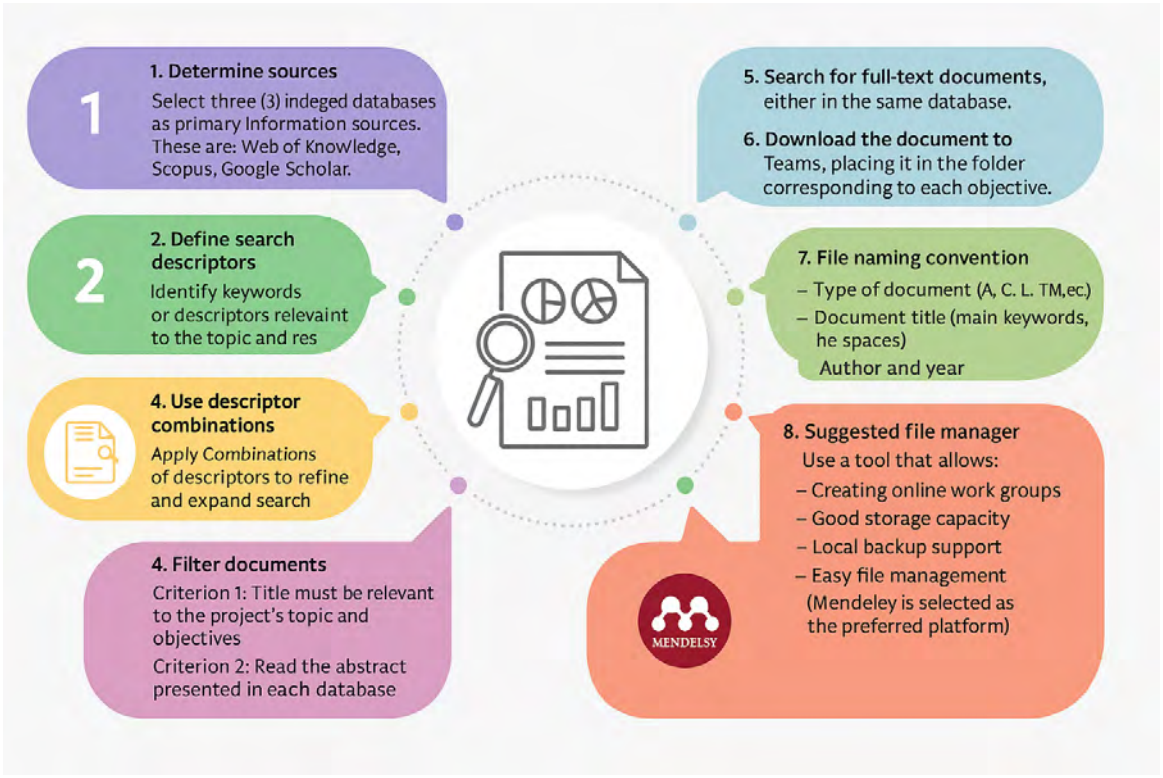

Figure 1.
Methodological pathway for document search.

Source: *Own elaboration.*

In addition to the document review, seven teacher training programs in EduTech from national universities were examined, as classified by the National Higher Education Information System (SNIES). The selection of these programs was based on criteria ensuring institutional diversity, including representation from both public and private institutions, various geographic regions, and different modalities (in-person and virtual). This analysis aimed to identify underlying discourses, epistemological perspectives, and pedagogical approaches within these programs.

The critical analysis was conducted from an interdisciplinary perspective that integrates epistemological, historical, and legal dimensions, essential for understanding EduTech in the country. Finally, the research team discussed and refined the findings, using the generated categories to strengthen the theoretical framework and address the proposed objectives. This methodological process allowed for the

establishment of an updated and critical state of the art regarding teacher training in technology in Colombia, providing a solid foundation for future research and the design of educational policies in this field.

Results and Analysis

In the development of this article, and consideration of the proposed methodology, the knowledge production results are addressed according to each objective.

1. First Objective: Discourses Guiding EduTech in Teacher Training Programs in Colombia

The inquiry into the discourses shaping EduTech in Colombian teacher training was conducted through two main avenues: a review of specific training programs and a bibliographic analysis of academic databases. The first involved examining active AT&I programs listed in SNIES, filtered by year and status. Invitations requesting relevant information were sent to selected institutions, supported by official letters from the Department of Technology at Universidad Pedagógica Nacional. The analysis centered on three programs with longstanding contributions to technological education: the Bachelor's in Technological Design, the Bachelor's in Electronics, and the Master's in Information Technologies Applied to Education. Additionally, an undergraduate research project from the Bachelor's in Electronics program, approved under Act No. 24 of 2022, enriched the study.

The second avenue included a qualitative review of academic literature on EduTech from major databases. Using coding and categorization, axial categories such as "Competencies," "Technology Education – Technology," "Problem-Projects Solving – PBL – Teamwork," "Curriculum – Integration," and "STEM" were identified and organized into nodal categories. Figure 2 illustrates the network for 'Curriculum Design' and its links to other categories like Competencies and Curriculum, with each nodal category accompanied by a corresponding network diagram. The figure presents a dense structure that highlights the multiple interconnections among the identified categories, reflecting the complexity of the discursive relationships in technology education.

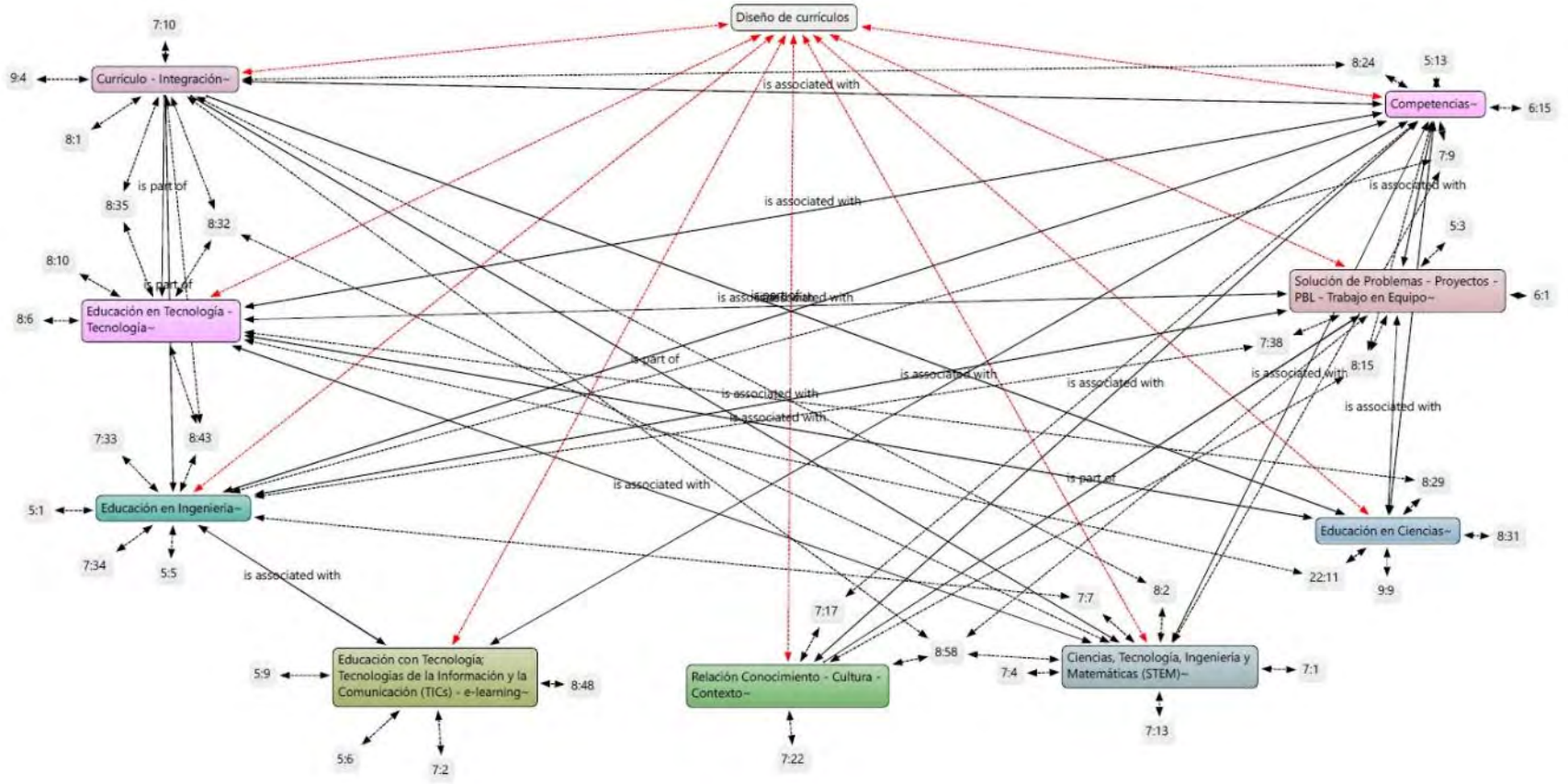

Figure 2.
Network View. Nodal Category of Curriculum Design and Its Relationships with Axial Categories.

Source: *Own elaboration.*

The analysis revealed that technology, philosophically, is seen not only as artifact creation (Carvajal, 2021) but as knowledge tied to know-how, distinct from scientific knowledge (Jones *et al.*, 2013; Williams, 2013). EduTech thus calls for a pedagogy centered on solving problems through the interaction of theory, practice, and reasoning (Ramírez, 2020).

Curricular models from the U.S., U.K., Canada, and Australia show the impact of STEM and VET initiatives on educational design (Ritz & Fan, 2015). These approaches, including Project-Based Learning (PBL) and Design and Technology (D&T), are echoed in Colombian programs like the Bachelor's in Electronics and Technological Design.

In Colombia, EduTech is anchored in legal mandates such as Decrees 1419 (1978), 1002 (1984), and Law 115 (1994), supplemented by updated competency standards and curricular guidelines (Ramírez, 2016). Epistemologically, programs are shifting toward sociocultural models, combining STEM and PBL strategies to develop applied technological competencies (Martínez & Suárez, 2008; Ramírez & Mora, 2019). Yet, tensions remain regarding the conceptual boundaries between technology, science, and engineering (Petrina, 2008; Stokes, 2010; Sjøberg, 2002).

EduTech promotes contextual, hands-on learning, aligning theory with practice (Jones *et al.*, 2013). Curriculum should tackle how technology works, innovates, and affects individuals and the environment (Williams *et al.*, 2000). Teacher candidates must learn to integrate science and mathematics with technology, assess engineering solutions, and foster self-directed learning (Ramírez, 2020).

The discourses underscore EduTech's role in aligning technology with human, environmental, and cultural needs, while bridging global and local educational goals. Practical, contextualized learning remains central, expanding learning opportunities and equipping students to tackle real-world challenges interdisciplinarily (Jones *et al.*, 2013).

Despite progress, challenges persist: blurred lines between EduTech and science education, limited resources, and insufficient teacher training hinder the field's consolidation.

2. Second Objective: Epistemological Perspectives in EduTech from National and International Policy

This objective was addressed using the described methodology. The bibliographic analysis matrix was reduced to 30 key documents, which comprised the most relevant sources for this review. Through an exhaustive analysis, 29 initial codes were identified and subsequently consolidated into 20 axial categories through a process of densification and fusion, resulting in three nodal categories: Learning, EduTech, and Epistemology.

The nodal category "Learning" demonstrated a strong connection with Problem Solving, Epistemology, Technology, and Knowledge, reflecting the centrality of these concepts in technological education practices. Meanwhile, the nodal category "EduTech" revealed significant relationships with Curriculum Development, Design, and Teamwork, highlighting the importance of these components for integrating technology into educational processes. Finally, the nodal category "Epistemology" showed key interrelations with Knowledge and Problem Solving, emphasizing the need for a solid epistemological foundation in technological education. Figure 3 illustrates the network view of the Epistemology nodal category and its relationship with other axial categories such as Teamwork and Science. Each nodal category in the study includes an associated graphical network representation. This figure presents a high-density network that visually encapsulates the intricate and multifaceted interrelations among epistemological, methodological, and pedagogical dimensions in technology education.

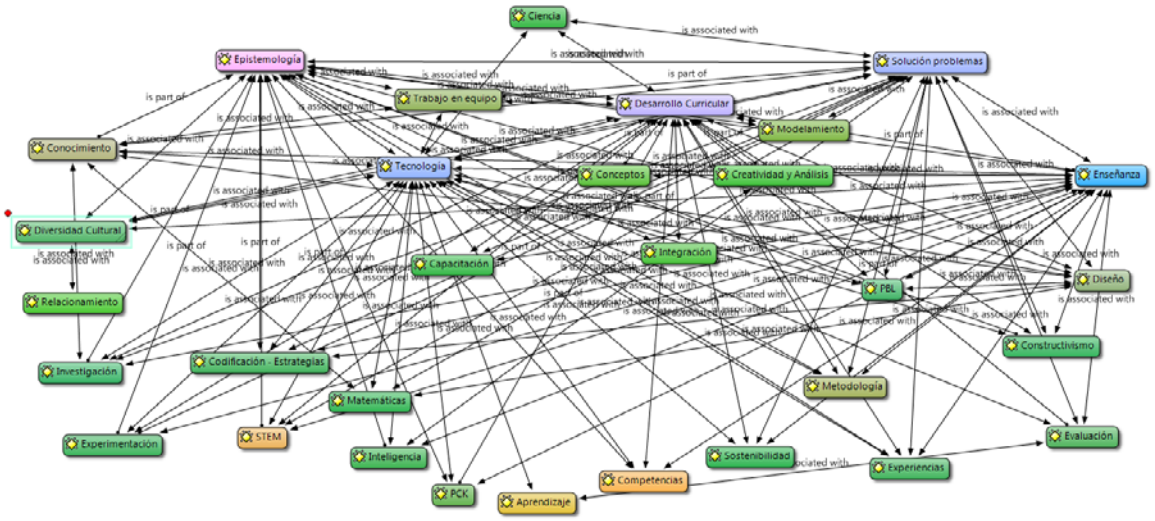

Figure 3.
Network View: Epistemology Nodal Category and Its Relationship with Axial Categories.

Source: *Own elaboration.*

From the document analysis, on the international front, Liao *et al.* (2017) and Grubbs *et al.* (2018) identified global trends where EduTech is influenced by globalization and intercultural processes, highlighting the role of design in cognition. These processes facilitate cross-context comparison and contribute to curriculum design. Similarly, McLain (2021) proposed three fundamental dimensions in professional preparation: thinking, performing, and acting with integrity. These dimensions, combined with Pedagogical Content Knowledge (PCK), reflect the necessity for a more articulated EduTech that integrates both theoretical and practical knowledge (Reiner & Gilbert, 2000).

Regarding technological conceptualization, Mitcham (1994) and DiGironimo (2011, cited in Wu and Ding, 2020) described technology as a set of dimensions encompassing artifacts, activities, knowledge, and human attributes. These dimensions provide a comprehensive framework to understand the role of technology in education. Jablansky (2019)

suggested that the STEM approach benefits EduTech as it emphasizes relational reasoning and the integration of disciplines as a foundation for technological learning. However, the study also identified discrepancies between educational policy and pedagogical practice, particularly in integrating research and design activities within STEM education (Vossen *et al.*, 2020). In this regard, the Consensus Model for PCK (Gess-Newsome, 2015, cited in Vossen *et al.*, 2020) offers a useful theoretical foundation for addressing these gaps by integrating general and specific knowledge into curricula.

From an epistemological perspective, Martínez and Suarez (2008) identified five key epistemological currents applicable to EduTech:

1. Technological Instrumentalism: Views technology as a neutral tool devoid of inherent values.
2. Technological Determinism: Examines technology's role in driving social change.
3. Social Construction of Technology (SCOT): Emphasizes that technologies are socially constructed and stabilized within specific contexts.
4. Technological Systems (Hughes): Argues that technological development integrates social and cultural elements rather than adhering to a rigid order.
5. Technological Path Dependency: Highlights how economic and contextual factors influence technological trajectories, such as the persistence of the QWERTY keyboard despite its historical origin.

On the other hand, Echeverría (2003) proposed technoscience as an emerging epistemological current combining science and technology in applied research contexts, emphasizing interdisciplinary collaboration in complex projects, such as the Manhattan Project. These epistemological currents offer frameworks to understand the interplay between science, technology, and society.

In analyzing design and modeling as educational strategies, Davies and Gilbert (2010) underscored the importance of mental and material modeling for fostering creativity and solving technological problems. These processes, involving visual and material representations, are essential for developing technological competencies and everyday creativity. Similarly, Lind (2020) and Middleton (2005, cited in Lind, 2020) proposed integrated methodologies to address technological problems through iterative design processes, emphasizing technological literacy as a blend of practical skills and communication capabilities (Davies & Gilbert, 2003).

According to Morrinson-Love (2022), problem-solving is a central theme. This process involves a transformative epistemology in which students develop their ideas from initial concepts to tangible solutions. This transformation nurtures practical and conceptual skills essential for technological education. Morrinson-Love classified technological knowledge into three types: procedural, conceptual, and tacit. These interact within educational processes, enabling students to build practical and reflective competencies. As McCormick (1997, cited in

Morrinson-Love, 2022) indicated, this comprehensive approach facilitates the real-world application of technological principles.

Furthermore, technological literacy emerges as a key tool for developing capabilities such as problem-solving, idea communication, prototype design, and solution evaluation (Indeed Editorial Team, 2023). In the context of educational policies, initiatives promoting technology integration into school curricula were identified. However, persistent challenges include resource deficiencies, inadequate teacher training, and a lack of a coherent philosophy of technology (Citrohn *et al.*, 2023; Jablansky *et al.*, 2020). Internationally, integrated STEM curricula have proven effective in connecting science and engineering with practical applications. Froyd and Ohland (2005) emphasized that these approaches improve student retention and foster a deeper understanding of scientific and technological principles.

Finally, Citrohn and Svensson (2020) argued that teaching technology should incorporate iconic, indexical, and symbolic models to facilitate the comprehension of complex technological concepts. These models, combined with organizational and economic strategies, provide a robust framework for EduTech.

3. Third Objective: Approaches to the Development of EduTech in Teacher Training Programs in Colombia

The literature analysis identified seven predominant approaches. These approaches are associated with didactic strategies aimed at enriching EduTech by integrating it with diverse knowledge areas, particularly in the context of digital transformation following the Covid-19 pandemic. However, attention was primarily focused on Science, Technology, Society, and Environment (STS-E), STEM initiatives, and the integration of ICTs. These trends were analyzed in detail due to their relevance and the relationships identified in the reviewed documents. Figure 4 shows the network view of the nodal category "Technology Education Approaches" and its relationships with axial categories such as STEAM and STS. The figure highlights a dense and interconnected structure that illustrates the convergence of pedagogical models, technological integration, and interdisciplinary requirements in the evolving landscape of technology education.

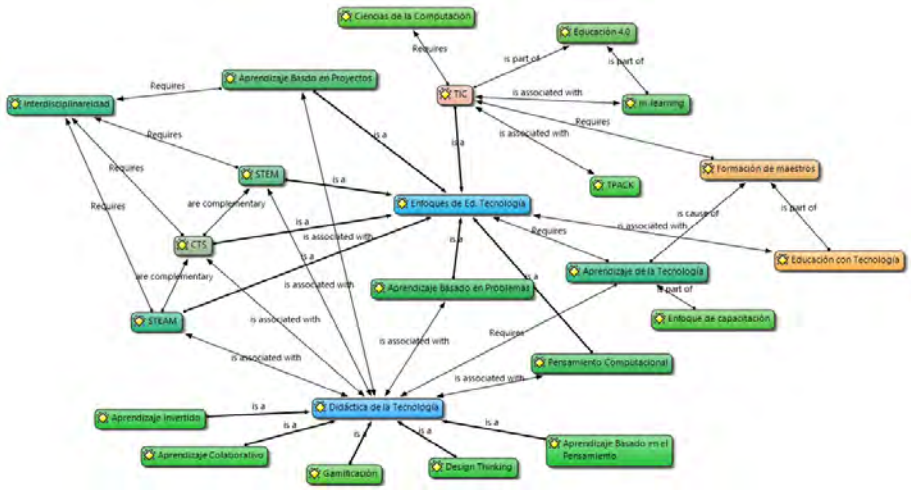

Figure 4.
Network View: EduTech Approaches Nodal Category and Its Relationship with Axial Categories.

Source: *Own elaboration.*

a. STS-E Approach: Science, Technology, Society, and Environment

The STS-E approach proposes a comprehensive understanding of technology within its social, historical, and cultural contexts. Gordillo and Galbarte (2002) emphasize that this perspective transcends linear and utilitarian visions of technology, fostering innovation and critical analysis. This approach highlights the interdependence between technology, science, and social phenomena, as Bybee (2010) suggests. It further stresses the need to incorporate social responsibility into school curricula, considering human, cultural, and environmental impacts (Romero Jeldres, 2009).

Osorio (2002) argues that applying the STS approach in developing countries should address its potential to reduce inequalities and improve quality of life. He also introduces the concept of technoscience as an element that influences the social and cultural fabric, broadening technological literacy possibilities in secondary education. This approach aims to equip students with critical skills to engage in debates about the use of emerging technologies.

Furthermore, the STS approach focuses on preparing students for a knowledge-based society, where the value lies in knowledge itself rather than material resources (Bell, 1976; Castells, 1999). Rozo *et al.* (2012) emphasize the need to update curricula to include technological competencies across all areas, promoting knowledge transversality in teacher training.

In Colombia, Vélez de la Calle *et al.* (2014) identified STS-E research trends, particularly in teaching-learning processes and ICT use, while pointing out the lack of a consolidated theoretical-pedagogical framework. According to these authors, the approach has significant potential to raise awareness among students about social, environmental, and cultural problems and generate technological applications that benefit their communities.

The findings suggest that integrating STS-E and STEM approaches within Colombian teacher training programs enhances the development of critical thinking and problem-solving skills among pre-service teachers. This integration challenges traditional pedagogical models and underscores the need for curricula that are responsive to technological advancements and socio-environmental considerations.

b. STEM-STEAM Initiatives: Science, Technology, Engineering, Arts, and Mathematics

STEM-STEAM initiatives aim to foster essential skills for the modern world, promoting interdisciplinary approaches and problem-solving through creative strategies (Chen *et al.*, 2021). These initiatives integrate disciplines and encourage scientific and technological vocations (Fuentes-Hurtado & González-Martínez, 2017). The success of STEM-STEAM depends on teachers possessing extensive knowledge of their discipline, technological proficiency, and innovative teaching methodologies.

A notable initiative within STEM-STEAM education involves the use of gamification and educational "Escape Rooms" to integrate content from Science, Technology, Engineering, Arts, and Mathematics into collaborative learning scenarios, significantly enhancing motivation and active participation, as evidenced in master's programs in Barcelona (Lopez Secanell & Ortega Torres, 2020). In this context, the "Arts" component extends beyond artistic disciplines to encompass the liberal arts, including the social sciences. In Latin America, however, the implementation of these interdisciplinary models has been uneven. Duque-Escobar *et al.* (2015) highlights promising, albeit limited, experiences such as the Greta Center in the Dominican Republic and the STEM program at Universidad de los Andes in Colombia. These cases underscore the critical role of collaboration among academia, governmental bodies, and international organizations in advancing STEM education throughout the region.

c. ICT: Information and Communication Technologies

The integration of ICT in education has transformed teaching-learning processes, facilitating access to information, self-directed learning, and pedagogical innovation (Avello Martínez *et al.*, 2016; Castelss, 1999). Lozano García and Bolívar García (2021) emphasize that ICTs are not merely teaching tools but also a means to develop digital competencies in teachers, aligning with recommendations from organizations such as UNESCO (2008).

Teacher training in ICT must move beyond instrumental use to foster classroom innovation (Rozo & Prada, 2012). This requires not only adequate technological resources but also time to explore, create, and discuss pedagogical strategies. Avello Martínez *et al.* (2016) stress the importance of integrating ICT transversally into initial teacher training programs to ensure effective use across all knowledge areas.

Innovative initiatives, such as m-learning (mobile learning), which uses mobile devices for interactive activities like solving puzzles via QR codes, demonstrated high satisfaction levels among students and teachers, showcasing ICT's potential for meaningful learning (Madrid *et al.*, 2013; Traxler, 2005). Meanwhile, Pinto-Santos and García (2022) argue for a holistic development of teachers' digital competencies, incorporating them into initial training programs and adapting them to specific socio-economic contexts.

Pantoja and Huertas (2010) propose that EduTech incorporating ICT should train critical citizens capable of engaging with contemporary dynamics and using these tools to improve their communities. While existing literature extensively covers STEM, STS-E, and ICT approaches, there is a paucity of research examining the integration of these frameworks within the specific socio-cultural context of Colombian teacher training programs. This study addresses this gap by providing an in-depth analysis of how these approaches are contextualized and implemented in Colombia, offering insights that can inform localized curriculum development and policy-making.

Future research on Technology Education in Colombia must evaluate the long-term effects of integrated EduTech models on teacher performance and student outcomes, while conducting comparative analyses between urban and rural institutions to illuminate context-specific challenges. Such inquiry must address entrenched regional, ethnic, gender, and socioeconomic disparities that shape both access to and appropriation of technology—particularly in marginalized territories where infrastructure is fragile and training policies often replicate standardized, context-insensiti-

ve models. A critical reading of the national context must expose these systemic inequities and elevate the alternative technological practices and epistemologies rooted in Indigenous and Afro-descendant communities. Furthermore, the prevailing narrative of technological innovation—frequently portrayed as inherently positive—requires scrutiny regarding its intended beneficiaries, ideological underpinnings, and consequences. This discourse often conceals power asymmetries, sustains exclusions, and casts educators and students as passive recipients of externally imposed frameworks. Reclaiming a political vision of technology grounded in local knowledge and collective struggle is essential for fostering emancipatory and contextually relevant practices.

Conclusions

This study reaffirms the urgency of transforming Technology Education (EduTech) through a comprehensive approach that integrates epistemological, curricular, and practical dimensions in teacher training. By exploring epistemological perspectives, the research reveals the complex and interconnected nature of EduTech, advocating for a tighter alignment between theoretical foundations and pedagogical practice. This connection promotes the development of curricula that are not only contextualized but also inclusive and critically oriented. Furthermore, the findings reinforce and extend the theoretical framework, emphasizing the significant influence of sociocultural epistemologies in shaping technological education. The analysis of curricular discourses, particularly in Objective 1, exposed persistent theoretical fragmentation—echoing the concerns of Martínez & Suárez (2008)—and underscored the pressing need for conceptual coherence.

Current models of Technology Education in Colombia—shaped by international frameworks and global innovation agendas—often reproduce a technocratic and reductively instrumental conception of knowledge, one that marginalizes local epistemologies and constrains critical thought. Rooted in the flawed assumption of technological neutrality, these approaches disregard the socio-political conditions of learners and the contextual ramifications of technological practices. In response, we advocate for a situated critical model grounded in decolonial perspectives and the principle of technological justice—one that values ancestral and community-based knowledge systems, reframes technology as a vehicle for ethical, context-sensitive transformation, and promotes not only technical competencies but also politically engaged reflection on the sociocultural and environmental dimensions of education.

In the landscape of teacher education, discourses on technology are predominantly shaped by models such as STEM-STEAM, Project-Based Learning (PBL), and ICT integration. However, these frameworks often coexist with a disconnect between theory and practice, compounded by unclear or overlapping definitions of key terms like "digital literacy" and "technological competencies." Such ambiguities hinder consistent implementation, reinforcing the need for a unified and

clear conceptual structure to support effective pedagogical strategies.

The research situates EduTech within a broader movement toward interdisciplinary and critical pedagogy. These emerging approaches support technological literacy and aim to cultivate essential skills—creativity, critical thinking, and problem-solving—in future educators. What distinguishes this study is its contribution to the state of the art: it not only maps global pedagogical models but also contextualizes them within the Colombian teacher education system. Through the integration of empirical data from curricular analyses and policy documents, the research offers a nuanced understanding of the epistemological tensions and curricular gaps often overlooked in Latin American contexts.

Despite these insights, significant challenges remain. Gaps in teacher preparation, insufficient resources, and limited interdisciplinary integration persist. Yet, notable programs such as Siemens Stiftung's "Experimento" in Medellín and Colombia's Escuela Nueva model illustrate how context-sensitive and student-centered methodologies can enhance technological literacy, especially in underserved areas. These cases offer valuable pathways to bridge existing divides.

Approaches like STS-E and STEM-STEAM signal EduTech's potential to transcend instrumental purposes and contribute to broader social transformation. These paradigms foster digital literacy and empower learners to engage critically with the social, ethical, and cultural implications of technology. Achieving this vision, however, depends on systematic institutional support and coherent curricular development.

ICTs, central to educational innovation, offer the capacity to revolutionize pedagogy. However, to avoid superficial or instrumentalist applications, teacher education must emphasize comprehensive digital training and resource accessibility. National programs promoting digital skills—such as those initiated by Colombia's Ministry of Education—represent promising steps, albeit ones that must still contend with practical implementation barriers.

By combining theoretical rigor with empirical evidence, this study provides a strong foundation for designing teacher training programs and influencing educational policy. Its conclusions advocate for critical, interdisciplinary, and context-aware strategies that respond effectively to the demands of 21st-century education.

More than ever, EduTech transformation requires a systemic perspective—one that includes both pre-service and in-service teacher education. This entails the thoughtful integration of varied pedagogical models to build an education system that is innovative, inclusive, and adaptive to both local and global challenges. Central to this transformation is the persistent need to bridge the theory-practice divide through curricula that link content with practical applications, enabling teachers to operate effectively in complex real-world settings.

In the Colombian context, it becomes especially critical to develop curricular strategies attuned to community needs. Although STEM, STS-E, and ICT models dominate existing debates, their limited adaptability to the Colombian socio-pedagogical landscape is apparent. The study thus proposes a locally grounded EduTech framework rooted in social justice, environmental ethics, and indigenous knowledge—an area still underrepresented in current academic discourse.

The analysis also reaffirms the interdisciplinary nature of EduTech. Fusing fields such as science, mathematics, engineering, arts, and technology enables educators to approach problems holistically, enriching learning

processes across disciplines. Ensuring technological literacy requires inclusive curricula that foster reflective and critical engagement with digital tools.

EduTech's continued relevance will depend on curricular innovation. Dynamic and participatory methods are essential to foster meaningful learning. Empowering teachers as leaders in this transformation must remain a central goal of training initiatives.

Ultimately, true educational transformation demands constant evaluation. Creating participatory mechanisms to assess the implementation and effectiveness of EduTech strategies will allow for continuous refinement. Future research should investigate the long-term effects of locally adapted EduTech frameworks on both teaching practice and student achievement. Comparative studies between urban and rural settings can illuminate structural inequities and guide differentiated policy interventions. Through its integrative and forward-looking perspective, this study outlines a roadmap for building educational systems that are inclusive, innovative, and resilient enough to address the pressing challenges of our time.

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