



Learning Ecologies in University Teacher Training: an Analytical Model for Professional Development in Digital Contexts

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Abstract

Despite growing recognition of the role of digital technologies in teacher professional development, the learning ecologies of university teacher in Colombia higher education remain insufficiently examined, particularly amid persistent ICT integration gaps and weak institutional policies. This study analyzed the elements configuring the learning ecologies of university teachers in faculties of education in the Colombian Caribbean, through a mixed methods sequential exploratory design. An initial qualitative phase comprised a multiple case study with 15 purposively selected teachers, using semi-structured interviews, documentary review, and Atlas.ti-supported analysis. A subsequent quantitative phase administered a validated 40-item questionnaire to 382 teachers across 15 institutions; a Principal Component Analysis accounted for 68.5% of the variance across thirteen components ($KMO = 0.831$; $\alpha = 0.922$). Findings show that teachers' learning ecologies function as dynamic, personalized systems shaped by contextual factors, formal and informal learning processes, digital resources, and digital competencies, with informal learning through social networks and open platforms proving particularly significant for professional development. Results point to the need for institutional policies recognizing diverse learning trajectories and fostering collaborative learning communities in digitally mediated settings.

Keywords

Learning Environments; Faculty Development; Higher Education; Digital Literacy; Digital Literacy.

Registration

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Ecologías de aprendizaje en la formación de docentes universitarios: un modelo analítico para el desarrollo profesional en contextos digitales

Resumen

A pesar del creciente reconocimiento de las tecnologías digitales en el desarrollo profesional docente, las ecologías de aprendizaje de docentes universitarios en la educación superior colombiana siguen; Alfabetización digital poco estudiadas, ante brechas persistentes en la integración de las TIC y la ausencia de políticas institucionales sostenidas. El estudio analizó los elementos que configuran las ecologías de aprendizaje de docentes universitarios adscritos a facultades de educación del Caribe colombiano, mediante un diseño exploratorio secuencial de métodos mixtos. La fase cualitativa comprendió un estudio de casos múltiples con 15 docentes, mediante entrevistas semiestructuradas, revisión documental y análisis apoyado en Atlas.ti. La fase cuantitativa administró un cuestionario validado de 40 ítems a 382 docentes de 15 instituciones; un Análisis de Componentes Principales explicó el 68,5% de la varianza en trece componentes ($KMO=0,831$; $\alpha=0,922$). Los hallazgos muestran que las ecologías de aprendizaje docentes funcionan como sistemas dinámicos y personalizados, moldeados por factores contextuales, procesos formales e informales, y recursos y competencias digitales. Los resultados evidencian la necesidad de políticas que reconozcan las trayectorias de aprendizaje y fomenten comunidades de práctica colaborativas en entornos digitalmente mediados

Palabras clave

Entornos de aprendizaje; Formación de docentes; Educación superior; Tecnología educativa.

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1. Introduction

Learning ecologies constitute a key conceptual framework for understanding how individuals in general, and teachers in particular, configure learning settings where formal, informal, and non-formal modalities intersect, mediated by digital technologies that enhance lifelong learning and pedagogical innovation ([González-Sanmamed, Muñoz-Carril and Santos-Caamaño, 2019](#); [Sangrà, Estévez, Iglesias and Souto-Seijo, 2019](#); [González-Sanmamed, Estévez, Souto-Seijo and Muñoz-Carril, 2020](#)). These learning ecologies bring together diverse resources, social interactions, contextual conditions, and digital technologies, creating opportunities for personalized, collaborative, and ubiquitous learning across higher education and other educational contexts ([Babak, 2023](#); [Peters and Romero, 2019](#)).

In Latin America, and particularly in Colombia, efforts to integrate digital technologies into teacher education have been uneven and frequently limited to formal and institutional spaces. This represents a significant challenge for faculties of education, which bear responsibility not only for training future teachers but also for modelling innovative and continuous learning practices among their own teaching staff.

Traditional approaches to professional development - centered primarily on structured workshops or compulsory training modules - are found to be insufficient to address the complex, dynamic, and often informal ways in which university teachers learn ([Smith and Wyness, 2024](#)). Such practices frequently emerge from self-directed activities, peer collaboration, participation in online communities, and the use of diverse digital resources ([Krug and Arntzen, 2010](#)).

This article presents the findings of doctoral research in the learning ecologies of university teachers ([Baloco, 2023](#)), examining the elements that constitute these ecologies and analyzing their contribution to the ongoing professional development of faculty members in faculties of education in the Colombian Caribbean.

2. Literature Review

The notion of learning ecologies has acquired considerable relevance in the field of higher education, particularly in contexts where digital transformation and the need for lifelong learning have intensified ([Sangrà et al., 2019](#)). This conceptual framework may facilitate the analysis of how individuals articulate diverse contexts, resources, and experiences in order to construct personalized, autonomous, and situated learning trajectories across the lifespan ([Barron, 2006](#); [Jackson, 2013](#); [Sangrà et al., 2019](#)). In this connection, [Jackson \(2013\)](#) understands “professional learning trajectories” as vital learning journeys that unfold within changing learning ecologies, comprising contexts, resources, actions, and relationships that are linked over time and support both formative and professional development.

What follows is a theoretical overview underpinning the present study, highlighting contributions from the literature and their implications for teacher professional development mediated by information and communication technologies (ICT).

The metaphor of “learning ecology” was initially proposed by [Barron \(2006\)](#), building on Bronfenbrenner’s (1979) account of human development ecologies in order to understand learning as a distributed, dynamic, and contextualized phenomenon. According to [Jackson \(2013\)](#), learning ecologies are self-constructed systems built by individuals that integrate environments, experiences, resources, and relationships, thereby configuring opportunities for meaningful and transferable learning. This approach emphasizes the hybrid character of learning, integrating formal, non-formal, and informal dimensions ([Sangrà and Wheeler, 2013](#); [Cobo and Moravec, 2011](#); [Williams, Karousou, Mackness, 2011](#)).

Along these lines, connectivism theory ([Downes, 2008](#); [Siemens, 2005](#)) complements the ecological approach by proposing a network-based epistemology that responds to information overload and

technological evolution, positioning ICT as key mediators of learning beyond institutional boundaries ([Sangrà and Wheeler, 2013](#); [Cabrera Lanzo, Maina, Sangrà, 2021](#)). Within this framework, digital technologies - such as platforms, social networks, open resources, and collaborative tools - are seen to favour more flexible and personalized learning trajectories ([Coll, 2013](#); [Burbules, 2014](#); [González-Sanmamed, Sangrà, Souto-Seijo and Estévez, 2018](#); [Sangrà et al., 2019](#)), although the challenge is not limited to access but extends to evidencing learning that is transferable to professional practice ([Sangrà and Wheeler, 2013](#)). The literature on teacher professional development recognizes learning ecologies as a pertinent framework for understanding how educators update and transform their practices through the strategic use of technologies and participation in communities of practice, thereby strengthening their social capital and transversal competencies ([Van den Beemt and Diepstraten, 2016](#); [Cabrera Lanzo et al., 2021](#); [Twining, Raffaghelli, Albion and Knezek, 2013](#); [Prenger, Poortman and Handelzalts, 2017](#); [Adam, Bakar, Fakhreldin and Majid, 2018](#)). According, lifelong learning articulates both formal and informal knowledge through self-directed and sustained practices ([Barnett, 2011](#); [Macià and García, 2016](#)), integrating personal pedagogies and mobile technologies that expand learning opportunities and promote teacher empowerment ([Maina and García, 2016](#); [Tabuenca, Ternier and Specht, 2015](#); [Frawley and Dyson, 2014](#)).

The systematic analysis of university teachers' learning ecologies remains incipient, both across Latin America generally and in Colombia particularly. International research indicates insufficient attention to training needs in blended or virtual modalities ([Nick et al., 2012](#); [Law et al., 2014](#)), while in Colombia persistent gaps in the critical integration of ICT are evidenced associated with institutional conditions, territorial inequalities, and the absence of sustained digital training policies ([Cardona and Ángel, 2023](#); [García-Pinilla, Rodríguez-Jiménez, Olarte-Dussan, 2023](#); [Ministerio de Educación Nacional \[MEN, 2013](#); [Barragán, Giraldo and Amador Báquiro, 2020](#); [Mesa Rave and Hoechsmann, 2023](#)). These limitations point to the need to examine actual learning practice and their articulation with institutional frameworks. A relevant contribution is the meta- analysis by [Baloco and Ricardo \(2021\)](#), who, drawing on 25 studies, defined five analytical categories for a corpus oriented toward technology-mediated continuing professional development, identifying patterns in teaching roles and in the configuration of learning ecologies; these categories constitute the foundation of the present study, which is the result of doctoral dissertation research at Universidad del Norte ([Baloco, 2023](#)).

At the institutional level, technological integration has been driven by policies such as the National Ten-Year Education Plan 2016-2026 ([Ministerio de Educación Nacional \[MEN\], 2017](#)) and the National Policy for Digital Transformation ([Departamento Nacional de Planeación \[DNP\], 2019](#)), although their implementation faces challenges in terms of both training and sustainability ([Ministerio de Educación Nacional \[MEN, 2013](#); [Radinger, Echazarra, Guerrero and Valenzuela, 2018](#)).

From a complementary theoretical perspective, Bronfenbrenner's ecological framework (1979) remains central to understanding the interaction among different level of the environment micro, meso, exo, and macro - and their bearing on educational processes. This approach has been taken up by studies analyzing the impact de ICT on learning system ([Fisher, Denning, Higgins and Loveless, 2012](#); [Krug and Arntzen, 2010](#)), as well as by authors who underscore the dissolution of boundaries between formal and informal learning in digital contexts ([Redecker, 2017](#); [Cobo and Moravec, 2011](#)). Various studies have explored how teaches design their own learning ecologies, institutional, and technological context, as well as the ongoing negotiation between professional expectations and environmental demands ([Barnett, 2011](#); [González-Sanmamed et al., 2018](#)).

Furthermore, it has been indicated that the development of digital competencies constitutes an essential component of teachers' learning ecologies (Ferrari, 2014; [Ministerio de Educación y Formación Profesional and Administraciones Educativas de las Comunidades Autónomas \[MRCDD\], 2022](#)). The effective integration of these competencies requires not only technological literacy but also pedagogical, collaborative, and reflective skills

In this direction, recent research underscores the importance of understanding learning ecologies as open dynamic systems, capable of adapting to technological and social change ([Sangrà et al., 2019](#); [González-Sanmamed et al., 2018](#)). This approach is particularly pertinent in the context of Latin American higher education, where processes of digital transformation and the need for a more flexible and inclusive education point to new challenges and opportunities for teacher professional development.

This landscape has been further destabilized, since 2022, by the rapid diffusion of generative artificial intelligence tools among teachers and students, a development that had not yet consolidated when earlier accounts of learning ecologies were formulated. [Cope, Kalantzis and Sears \(2020\)](#) argue that AI-enabled environments alter not only how knowledge is accessed but how it is produced and assessed, positioning generative AI as an active mediator, rather than a peripheral resource, within teachers' learning ecologies. Building on research on learning ecologies developed since 2009, their work suggests that the boundaries between formal, non-formal, and informal learning identified by [Barron \(2006\)](#) and [Jackson \(2013\)](#) are being further reconfigured by AI-mediated practices in writing, feedback, and content production, which points to the need to examine this emerging dimension alongside the more established contextual and technological factors addressed in this review.

3. Method

The present study developed under a mixed methods approach, specifically through a sequential exploratory design of descriptive and correlational scope, in alignment with the guidelines proposed by [Creswell and Plano Clark \(2011\)](#). This design was structured in two complementary phases: an initial qualitative phase, oriented toward the in-depth exploration of the phenomenon, and a subsequent quantitative phase, directed at the validation and generalization of findings. The central purpose was to analyze the elements that configure the learning ecologies of university teachers affiliated with faculties of education in the Colombian Caribbean.

In the qualitative phase, a multiple case study design was adopted in order to achieve a situated understanding of the practices, perceptions, and conditions that configure teachers' learning processes. Purposive sampling was employed, based on criteria of institutional diversity and professional trajectory, resulting in the selection of 15 university teachers. Data collection was carried out through semi-structured interviews and documentary review, and the analysis yielded a conceptual and empirical foundation that guided the design of the quantitative instrument.

Subsequently, in the quantitative phase, a structured questionnaire was administered to an expanded sample of teachers, with the objective of characterizing and contrasting the learning ecologies identified in the preceding phase. The study was conducted across 15 higher education institutions in the Colombian Caribbean. In the phase, 382 teachers participated, of whom following the data cleaning process, 328 valid responses were obtained. The instrument was administered online through the QuestionPro platform, with the logistical support of Ascofade (Colombian Association of Faculties of Education) and Universidad del Norte.

The questionnaire was designed on the basis of the qualitative findings and comprised 40 items distributed across four analytical dimensions: context, learning, resources and activities, and digital competencies. A five-point Likert scale was employed. The instrument was subjected to content validation through expert judgement and to a pilot test that allowed for adjustments to its structure and clarity.

Quantitative data analysis was carried out using SPSS software (version 21.0). In a first stage, preliminary analyses were conducted in order to verify the consistency of the database and to control for potential errors. Descriptive analyses were then developed, including frequencies, means, and standard deviations, in order to characterize responses according to the dimensions of the instrument. Along these lines, inferential analyses were performed in order to identify statistically significant relationships among variables, primarily through correlation tests.

In a complementary direction, a Principal Component Analysis (PCA) was conducted with the purpose of identifying the underlying factorial structure of the learning ecologies. This analysis accounted for 68.5% of the total variance on the basis of the first thirteen components. Sampling adequacy was confirmed through the Kaiser-Mayer-Olkin index ($KMO = 0.831$) and Bartlett's test of sphericity ($\chi^2 = 7892.241$; $p < .001$), which together indicate the pertinence of the factorial analysis.

Finally, the internal reliability of the instrument was assessed through Cronbach's alpha coefficient, yielding a value of 0.922, which suggests a high level of internal consistency among items and supports the reliability of the measurements obtained.

4. Results

The results are presented by phases in accordance with the sequential exploratory design of the research, beginning with the qualitative phase, followed by the quantitative phase, and concluding with a contrast between the two approaches.

The qualitative phase was developed through a multiple case study involving 15 teachers from universities with faculties of education in the Colombian Caribbean. This stage sought to identify the elements that configure their learning ecologies from an interpretive perspective. Through semi-structured interviews and documentary review, the following categories were analyzed: context, learning processes, resources and activities, and digital competencies. A mixed coding approach was employed with the support of Atlas.ti software. Open coding made it possible to identify emerging subcategories, such as the influence of family, the role of learning communities, teacher autonomy, and the critical integration of ICT.

Among the principal findings, the following were evidenced: informal learning through social networks and collaborative experiences carries significant weight in teachers' continuing professional development; personal motivations, prior experiences, and institutional conditions influence the integration of digital resources; learning ecologies are dynamic, contextually situated, and mediated by unique professional development trajectories; and the COVID-19 pandemic marked a turning point in the ways in which teachers interact with technology and reconceptualize their teaching and learning processes.

The quantitative phase consisted of the administration of a questionnaire to 382 teachers from faculties of education. The instrument underwent expert validation and consisted of items organized into four dimensions: context, learning processes, resources and activates, and digital competencies. Data were analyzed through both descriptive and inferential statistics, and a Principal Component Analysis (PCA) was conducted in order to explore underlying structures.

The Principal Component Analysis (PCA) was carried out in order to explore the underlying structure of the variables associated with university teachers' learning ecologies. Sampling adequacy for the factorial analysis was confirmed through the Kaiser-Meyer-Olkin test ($KMO = 0.831$), indicating a meritorious level of adequacy, while Bartlett's test of sphericity was statistically significant ($\chi^2 = 7892.241$; $p < .001$), supporting the suitability of the data for analysis. On the basis of the retention criterion of components with eigenvalues greater than 1, thirteen principal components were extracted, which together account for 68.5% of the total variance in the dataset. These components represent latent patterns that structure teachers' learning ecologies, integrating dimensions linked to both institutional and personal context, professional learning processes, the use of digital resources and activities, and the development of digital competencies. The factorial solution obtained provides a robust representation of the complexity of the phenomenon under study and constitutes a fundamental input for the analytical model proposed in the research.

Along these lines, additional findings from the quantitative phase indicate a preferences for in-person and blended training modalities, although moderate use of digital resources such as MOOC platforms (Coursera, MiriadaX) was also identified; a high perceived level of both family and institutional support for continuing professional development was reported; and overall instrument reliability was high ($\omega = 0.923$), with equally

consistent subdimensions across context ($\omega = 0.704$), learning processes ($\omega = 0.886$), resources ($\omega = 0.935$), and digital competencies ($\omega = 0.917$).

The contrast between qualitative and quantitative findings made it possible to construct a more holistic understanding of teachers' learning ecologies. In the context dimension, findings ranged from the macro level - encompassing globalization and educational policies - to the micro level - including family and workplace realities - all of which are seen to influence both access to and the type of professional formation received. With regard to learning processes, a combination of formal, non-formal, and informal learning was evidenced; teachers indicate recognition of the usefulness of digital tools for information retrieval, lesson planning, and peer collaboration. In the digital competencies dimension, a high valuation of the pedagogical use of ICT was identified, particularly in didactic strategies such as problem-based learning, project-based learning, and the flipped classroom.

The integrated analysis reveals that teachers' learning ecologies function as open, complex, and personalized systems, configured through the dynamic interplay of individual interests, professional learning needs, available opportunities, and contextual constraints. The findings are seen to correspond with the analytical model proposed in this research (see [Figure 1](#)), which offers o frameworks for mapping and analyzing professional learning trajectories in environments mediated by digital technologies.

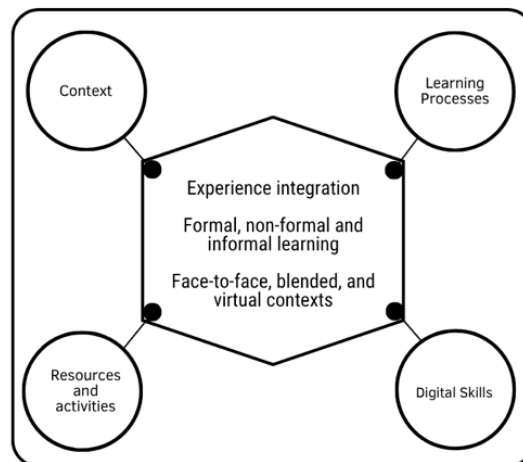


Figure 1. Analytical Model of Teachers' Learning Ecologies

Note. Original work

5. Discussion

The findings of this research have made it possible to broaden the understanding of university teachers' learning ecologies, highlighting the richness, diversity, and complexity of the environments in which these professionals configure their development. The empirical evidence is seen to support the pertinence of the ecological framework for the analysis of teacher education processes, moving beyond the limitations of linear and normative models centered on formal institutional formation ([Sangrà, Guitert-Catasús and Behar, 2023](#); [Smith and Wyness, 2024](#)).

One of the most significant contributions of the study is the finding that teachers do not learn exclusively in institutionally planned settings, but rather construct highly personalized learning trajectories that combine formal, non-formal, and informal strategies. These findings are consistent with the perspectives of [Jackson \(2013\)](#) and [Barron \(2006\)](#), who describe learning as distributed across multiple environments and shaped

by individual interests, available opportunities, and contextual conditions; a similar view is presented by [Babak \(2023\)](#). Accordingly, professional learning is conceived as a self-regulated and situated process in which the teacher functions as an active agent of their own formation.

The strong presence of informal learning in the practices of the participating teachers (particularly through the use of social networks, open platforms, and digital communities) resonates with prior research ([Castañeda and Adell, 2013](#); [González-Sanmamed et al., 2018](#)) that recognizes the formative value of these spaces. Recent studies indicate that ICT-mediated informal learning constitutes a key component in teacher professional development, in that it facilitates continuous updating and the construction of knowledge networks ([Trust and Whalen, 2020](#); [Rapanta, Botturi, Goodyear, Guàrdia and Koole, 2021](#); [König, Jäger-Biela and Glutsch, 2022](#); [Blanco-Hernandez, Arias-Pertu, Franco-Fajardo and Miranda-Pájaro, 2024](#)). In this direction, the integration of resources such as YouTube, Coursera, WhatsApp, and educational blogs is not merely instrumental, but rather represents a legitimate form of knowledge acquisition, circulation and co-construction ([Panigrahi, Srivastava and Sharma, 2018](#); [Hew, Bai, Dawson and Lo, 2021](#)).

Furthermore, it has been evidenced that these spaces contribute to the strengthening of teachers' digital competencies, particularly in areas such as information management, digital communication, content creation, and participation in virtual learning communities ([Redecker, 2017](#); [Ferrari, 2014](#); [Cabero-Almenara, Romero-Tena, Barroso-Osuna and Palacios-Rodríguez, 2020](#)). However, recent research points to the fact that informal learning and autonomously developed digital competencies continue to receive scarce recognition in institutional professional development policies ([Bond, Zawacki-Richter and Nichols, 2018](#); [Trust and Whalen, 2020](#); [Peters and Romero, 2019](#)). This gap between actual teaching practice and the institutional approach limits the potential of learning ecologies to promote more comprehensive and personalized professional development. Overcoming this disconnect requires rethinking teacher education frameworks and generating policies that both value and accredit informal learning trajectories

From the contextual dimension, the findings of the study reaffirm that factors such as workload institutional policies, access to technological infrastructure, and family dynamics exert a significant influence on the ways in which teachers configure their learning ecologies. Analyzed in alignment with Bronfenbrenner's ecological framework (1979), this dimension suggests that learning opportunities are neither neutral nor equitable, but rather profoundly conditioned by structural factors. Along these lines, [Musikavanhu and Scheepers \(2024\)](#) highlight how contextual and systemic constraints in higher education affect teachers' professional learning trajectories, particularly in digitally mediated settings.

With regard to the learning processes identified, a growing tendency is observed toward the use of ICT-mediated active methodologies, such as the flipped classroom, project-based learning, and collaborative learning. These methodologies promote active student engagement and favour more flexible and personalized learning settings ([Trust and Whalen, 2020](#); [Hew et al., 2021](#)). Additionally, recent research indicates that the integration of technologies within these methodologies enhances deep learning and the development of digital competencies in both students and teachers ([Bond et al., 2018](#); [Rapanta et al., 2021](#)). It has likewise been documented that approaches such as the flipped classroom and project-based learning are seen to facilitate collaboration, critical thinking, and the transfer of knowledge to real professional contexts ([Baig and Yadegaridehkordi, 2023](#)), consolidating their adoption in higher education settings. This may be seen to reflect a more critical and creative didactic integration of technologies, which contrasts with traditional approaches centered on the mere transmission of content, a methodological transition also reported by [Sangrà et al. \(2019\)](#), which reaffirms the importance of reconceptualizing teacher education models in order to make them more flexible and personalized.

The statistical analysis conducted in the quantitative phase made it possible to identify principal components that structure teachers' learning ecologies. This statistical representation reinforces the understanding that such ecologies do not constitute a homogeneous structure, but rather emerge from the dynamic interaction of multiple interdependent factors, including institutional context, personal trajectories [Jackson, \(2011\)](#), learning experiences, and technological mediation ([Bond et al., 2018](#); [Rapanta et al., 2021](#); [König et al.,](#)

2022). The findings support the perspective that learning ecologies are open and adaptive systems, highly sensitive to changes in both the digital and pedagogical environment ([Baig and Yadegaridehkordi, 2023](#)). These results are in alignment with recent research underscoring the need to employ integrated analytical models in order to characterize learning ecologies in educational context ([Nistor and Hernández-García, 2018](#); [Viberg, Hatakka, Bälter and Mavroudi, 2018](#)), and are accordingly consistent with the emerging tendency toward the use of robust quantitative approaches for mapping the hidden dimensions of teacher learning experience in hybrid and digital settings ([Bond et al., 2018](#); Barbour and Hodges, 2024). Taken together, these findings provide a valuable basis for advancing the comparative analysis of learning ecologies and for informing the design of more contextualized and effective interventions in teacher professional development.

The present study is in alignment with the positions advanced by [Barbour and Hodges \(2024\)](#), who indicate that teacher preparation remains a critical and underattended dimension in initial teacher education, particularly in light of the challenges evidenced during the COVID-19 pandemic. Consistent with this, [Van den Beemt and Diepstraten \(2016\)](#) argue that teachers configure their own learning ecologies through dynamic interactions with digital tools, communities of practice, and institutional conditions, which reinforces the utility of the ecological framework for understanding professional development. In this direction, the integration of both qualitative and quantitative findings in the present study made it possible to construct an explanatory model encompassing both observable practice and the subjective, contextual, and cultural dimensions that mediate teacher learning processes. This methodological triangulation is in alignment with the position advanced by [Creswell and Plano Clark \(2011\)](#), who highlight the value of the mixed methods approach for addressing complex educational phenomena. On the basis of these findings, the study offers elements for analyzing learning trajectories configured across diverse contexts, in which the pertinence of flexible institutional policies, access to open technologies, and the articulation of collaborative networks is recognized. Specifically, [Konstantinidou and Scherer \(2021\)](#) highlight that both teacher characteristics and the institutional environment are associated with the sustained pedagogical integration of ICT, and that both continuing professional development and organizational support are relevant components in this process.

6. Conclusion

The present research made it possible to characterize the learning ecologies of university teachers from faculties of education in the Colombian Caribbean, evidencing that their professional learning trajectories are constructed through the dynamic articulation of contexts, resources, learning processes, and digital competencies. Far from being limited to formal institutional spaces, teachers are seen to configure diverse, flexible, and situated personal learning environments in which individual agency, the creative use of technologies, and contextual conditions play a determining role.

One of the principal contributions of the study resides in the model proposed for the analysis of learning ecologies, empirically validated through a mixed methods approach. This model may be employed both in future research and in institutional processes of diagnosis and in the design of professional formation strategies more closely aligned with the realities of teaching practice. Accordingly, the analytical model resulting from this research conceptualizes university teachers' learning ecologies as dynamic structures comprising four interrelated components: context, learning processes, resources and activities, and digital competencies. These components emerge from the integration of formal, non-formal, and informal experiences, which teachers articulate flexibly across in-person, blended, and virtual contexts. The model makes it possible to visualize how contextual factors (institutional, familial, and sociocultural) together with personal trajectories and professional agency, configure differentiated patterns in learning ecologies. It likewise incorporates the role of ICT, including emerging AI-mediated tools, as key mediators in the construction of personalized learning environments. Through this approach, the model provides both a theoretical and operational framework for the analysis of teacher professional development practices, facilitating both the characterization of the elements that comprise learning ecologies and the identification of opportunities and barriers in their consolidation.

However, the study also points to significant tensions between institutional discourses on teacher education and the actual practices developed by teachers, given that structural barriers persist (including work overload, the low valuation of informal learning, and the limited flexibility of professional formation programs) that hinder the full development of sustainable and meaningful learning ecologies..

In practical terms, it is recommended that higher education institutions strengthen the conditions for autonomous and situated learning, generating policies that recognize the diversity of professional learning trajectories, promote access to open technologies, and foster interdisciplinary and collaborative learning communities. Along these lines, it is considered necessary to advance in the critical development of digital competencies, not only from an instrumental perspective, but from an ethical, pedagogical, and transformative one. This is particularly urgent as generative artificial intelligence is already reconfiguring learning ecologies in higher education, demanding critical stances toward algorithmic bias, platform dependency, and inequalities of access ([Cope, Kalantzis and Sears Smith, 2020](#)).

From a research standpoint, the study opens new possibilities for the investigation of learning ecologies among other university actors, such as students and administrative staff, as well as across different educational modalities, particularly in virtual and hybrid contexts. It is further suggested that quantitative analyses be deepened through more advanced multivariate statistical models, and that inter-institutional alliances be promoted in order to broaden the sample and enable comparisons across regional and national realities.

In sum, the study reaffirms that reconceptualizing teacher professional development within the framework of learning ecologies makes it possible to move toward a more inclusive, pertinent, and adaptive higher education, capable of responding to the challenges of the contemporary world without losing sight of the singularity of each individual human learning trajectory.

Future Work

The present research opens new lines of inquiry into learning ecologies in higher education. Recent work by Cope, Kalantzis and Sears Smith (2020) shows that generative artificial intelligence is already reconfiguring learning ecologies as an active pedagogical mediation, particularly in writing, assessment, multimodal production, and feedback processes. In light of this emerging landscape, the following lines of inquiry are proposed.

A first direction consists of conducting comparative studies across institutions from different regions and international contexts, in order to identify patterns, convergences, and divergences in professional learning trajectories. Along these lines, it is considered pertinent to extend the analysis to other university actors, such as students and administrative staff, particularly in hybrid and virtual settings, where informal learning and the critical integration of ICT acquire specific configurations.

A further line of work is oriented toward the design and validation of diagnostic instruments that integrate structural, cultural, and organizational dimensions in the analysis of learning ecologies. The incorporation of multivariate statistical models (such as cluster analysis or structural equation modelling) would make it possible to deepen the understanding of the patterns that configure them.

Finally, it is proposed that progress be made in the design of pedagogical interventions grounded in the ecological framework, and that their impact on teacher professional development be evaluated. The integration of artificial intelligence and learning analytics, in dialogue with the work of [Cope, Kalantzis and Sears Smith \(2020\)](#) on AI-enabled learning ecologies, offers opportunities to develop diagnostic and support systems capable of mapping professional learning trajectories and identifying specific needs, thereby favoring more contextualized processes in higher education.

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Data Availability

The article provides the relevant data sources and links.

Disclosure statement

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Disclaimer

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Co-authorship

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Carmen Ricardo-Barreto: Conceptualization; Methodology; Supervision; Writing – Review & Editing.

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