Educational Technology Course Design in Pre-Service Teachers Education: A Bibliometric Review of the Research Landscape

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ABSTRACT

The integration of Educational Technology (EdTech) courses within pre-service teacher education programs is crucial for equipping future educators with the competencies to leverage technology in their teaching practices effectively. This study employs a bibliometric analysis to map the research landscape of EdTech course design for pre-service teachers. From Scopus database covering the period from 2020 to 2025, a total of 920 relevant publications were identified and analysed by using tools such as biblioMagika® and VOSviewer. The findings reveal a significant increase in research output in this field, and Germany, Spain, Turkey, the United States, and Australia have been the leading contributors. Three dominant thematic clusters emerged from the co-occurrence analysis, teacher education core, technology integration in learning environments, and institutional contexts and design frameworks. Based on 110 analysed publications, these clusters reflect the field's shift from technical skill training to holistic pedagogical reasoning. The study also identifies challenges, including the theory-practice gap, equity and access issues, and the rapid evolution of technologies such as AI and immersive platforms. It calls for a balanced approach to EdTech course design, which prioritises pedagogical adaptability, addresses equity gaps, and embeds ethical frameworks for emerging technologies. Findings advocate for educational technology courses with strong teaching adaptability and a focus on fairness to enhance the capabilities of future educators.

Keywords: Educational Technology; Pre-service Teachers; Course Design; Bibliometrics

INTRODUCTION

The integration of technology into the 21st-century classroom requires educators to go beyond their basic digital literacy, develop professional knowledge in teaching, and use these technologies to enhance students' learning outcomes (Howard et al., 2021; UNESCO, 2023). Teacher education programs bear significant responsibility for cultivating pre-service teachers (PSTs) to have the competencies of integrating technology in their future practice effectively. EdTech courses stand as the foundation of this preparation within pre-service curricula (Tondeur et al., 2012). Despite this necessity, the design of these courses remains a complex challenge, such as the content must be updated with technological development, pedagogical approaches must bridge theory and practice, theoretical foundations (e.g., TPACK) need to be adjusted to adapt to the changes of educational environment, and assessment strategies need to reflect the real classroom demands. All these dimensions impact the technological and pedagogical readiness of PSTs (Mishra & Koehler, 2006; Kopcha et al., 2020).

Although it is widely acknowledged that integrating EdTech into teaching is important (ISTE, 2017), studies have repeatedly shown that there are still ongoing gaps between what technology can achieve in classrooms and how it is being used effectively in real K-12 teaching situations (Ertmer & Ottenbreit-Leftwich, 2010). Usually, these gaps can be traced back to the insufficient preparation of PST, where EdTech courses may have difficulty of bridging theoretical knowledge with real classroom application, to adapt to the rapid changing of technological landscapes, or sufficiently develop key literacy like digital citizenship and critical evaluation tools (Tondeur et

al., 2018; Polly et al., 2010). The design of these courses has become more complex due to different environmental factors, including institutional resources, faculty expertise, program structures, and different conceptions that constitutes basic technological knowledge and skills (Kimmons et al., 2020).

The academic circles have made great efforts in understanding and enhancing the integration of educational technology in teacher education. Some significant frameworks, such as Technological Pedagogical Content Knowledge (TPACK), provide important theoretical perspectives for conceptualizing the knowledge that teachers need (Mishra & Koehler, 2006). Many empirical studies have explored specific interventions, pedagogical models (e.g., design thinking, project-based learning), or the impact of particular technologies in EdTech courses (e.g., Tondeur et al., 2012; Mouza et al., 2014). Literature reviews and meta-analyses have synthesised findings on effective strategies, barriers, and facilitators (e.g., Tondeur et al., 2012; Sailer et al., 2021; Scherer et al., 2021). These contributions are invaluable, yet they often focus on specific aspects (e.g., effectiveness of a particular pedagogy) or aggregate findings qualitatively.

What remains less explored is a comprehensive, quantitative mapping of the entire research landscape dedicated explicitly to the design of EdTech courses for PSTs. How has this specific field evolved over time? What are the predominant research themes, and how have they shifted? Which authors, institutions, and journals are driving the conversation? Where are the geographic concentrations and collaborations? What foundational theories underpin this research? Crucially, where are the knowledge gaps and emerging frontiers? A systematic understanding of the field's intellectual structure, evolution, and current foci is essential for guiding future research, informing program development, and identifying under-explored areas critical for preparing PSTs in a digital age.

Bibliometric analysis offers a robust methodological approach to address this need. By applying quantitative and computational techniques to scholarly publications, bibliometrics allows researchers to map the structure, dynamics, and relationships within a specific research domain (Zupic & Čater, 2015; Donthu et al., 2021). It can identify core publications, track the evolution of research topics, visualise collaborative networks, and reveal the intellectual foundations of a field through citation patterns. This analysis breaks through the limitations of traditional narrative reviews and offers a data-driven, macroscopic view of academic dialogue.

To address this gap, this study employed a comprehensive bibliometric analysis and systematically mapped out the research landscape of EdTech course design for PSTs. This bibliometric analysis aims to provide researchers, teacher educators, program managers, and policymakers with a clear, evidence-based overview of the current state of research on EdTech course design for PSTs. By clarifying the knowledge structure, key participants, thematic concentrations, and potential gaps, this analysis aims to inform more strategic and impactful future research agendas, contribute to the design of EdTech course, and truly empower the next generation with digital education capabilities.

LITERATURE REVIEW

In the 21st century, the necessity of effectively integrating technology into K-12 Education is undeniable, which has brought tremendous pressure to teacher education programs to equip PSTs with the necessary competencies (Howard et al., 2021; UNESCO, 2023). Educational Technology (EdTech) courses serve as the cornerstone of this preparation within pre-service curricula, tasked with developing not only technical skills but, more crucially, the pedagogical knowledge to leverage technology meaningfully for enhancing student learning (Tondeur et al., 2012). However, persistent gaps exist between the potential of educational technologies and their actualised, effective use in classrooms, often traced back to inadequacies in PST preparation (Ertmer & Ottenbreit-Leftwich, 2010).

Seminal frameworks, notably TPACK model (Mishra & Koehler, 2006), have fundamentally shaped our understanding of the complex and comprehensive knowledge base which is necessary for teachers to effectively integrate technology. TPACK emphasizes the complex interaction among content knowledge, pedagogical knowledge, and technological knowledge, and stresses that effective technology integration requires an understanding of how technology changes teaching and learning specific content. This framework led the research and discussion around PST technological preparation, serving as a lens for evaluating course design

and outcomes (Voogt et al., 2013; Scherer et al., 2021). Consequently, a great deal of academic efforts has been dedicated to exploring the development of TPACK in EdTech courses, examining interventions, and pedagogical models (e.g., design thinking, project-based learning), as well as the impact of specific technologies (e.g., Mouza et al., 2014; Tondeur et al., 2012). Recent bibliometric analyses have confirmed the central position of TPACK in research on PST technology preparation. Su (2023), has specifically studied on TPACK development of PSTs, highlighting its lasting advantages as a research theme. Wu et al. (2024) further verified its general influence through a comparative bibliometric analysis across major databases.

Although the TPACK framework has been adopted widely, it is not the only model relevant to understanding technology integration. This field is increasingly influenced by other conceptual frameworks, which offer different but complementary perspectives. For instance, The SAMR model (Substitution, Augmentation, Modification, Redefinition) provides a ladder-like structure for conceptualizing how technology can transform learning activities, moving from simple enhancement to significant redesign (Puentedura, 2006). On the other hand, the European Digital Competence Framework for Educators (DigCompEdu) describes a comprehensive set of digital competencies specific to educators, providing a detailed and behavior-oriented framework for the development of these competencies (Redecker, 2017). While TPACK effectively conceptualizes the knowledge types teachers need, SAMR and DigCompEdu contribute valuable guidance on the levels of integration and the specific competencies required, respectively. Therefore, in the course design research, over-reliance on TPACK might lead to the neglect of the practical and ability-based insights provided by these emerging models. The cross-framework integration can offer a more dynamic and operational conceptual framework for designing educational technology courses.

Besides the research on TPACK, many empirical investigations and literature reviews have synthesised findings on effective EdTech integration strategies, barriers, and promoting factors in teacher education (Tondeur et al., 2012; Sailer et al., 2021; Scherer et al., 2021). These contributions are invaluable, providing multi-faceted insights into specific pedagogies, contextual challenges, and changes in teachers' adoption of technology (Ertmer & Ottenbreit-Leftwich, 2010). However, as Kopcha et al. (2020) argue, the field is evolving beyond a focus solely on the product (e.g., specific tools, discrete skills) towards understanding the process of technology integration, emphasising pedagogical reasoning and adaptability. This shift necessitates examining how course design fosters these deeper competencies. the COVID-19 pandemic has thrust teachers' digital competencies into the spotlight, revealing both strengths and critical gaps in preparedness, as evidenced by bibliometric analyses of digital competency research (Gökdaş et al., 2024).

Despite this rich body of scholarship, critical limitations persist. Much of the existing research tends to focus on specific aspects of EdTech course design or PST preparation – such as the effectiveness of a particular pedagogical approach, the impact of a single tool, or the measurement of TPACK components (Kopcha et al., 2020). While qualitative syntheses provide depth (e.g., Tondeur et al., 2012), and some domain-specific bibliometric reviews exist (e.g., Boateng et al., 2024 on EdTech in Elementary Education; Mariappan et al., 2024 on technology in art education), there is a conspicuous lack of a comprehensive, quantitative mapping dedicated explicitly to the overall research landscape concerning the design of EdTech courses specifically for PSTs. Broader reviews, such as those by Boateng et al. (2024), offer valuable insights into EdTech trends but do not focus on the unique context and design challenges of pre-service teacher preparation. Similarly, Mariappan et al. (2024), while demonstrating the utility of bibliometric mapping in educational technology sub-fields, focus on art education, rather than PST EdTech course design.

This gap presents several unanswered questions crucial for advancing the field systematically:

Limited understanding of **temporal evolution** in research volume, thematic focus, and impact of major events (e.g., COVID-19, policy shifts) on EdTech course design.

Unclear identification of **seminal influences**: foundational works (beyond TPACK), high-impact authors/journals/institutions, and landmark publications shaping theory/practice.

Insufficient synthesis of **dominant and emergent themes** (e.g., AI, gamification, equity) and their conceptual interrelationships.

Incomplete analysis of **geographical leadership** (countries/institutions) and **global collaboration patterns** in EdTech course design research.

Underexplored **knowledge gaps** in current research (e.g., assessment methods, instructor training, contextual adaptability) despite understanding the field's state.

Bibliometric analysis provides a comprehensive methodological approach to address these questions (Zupic & Čater, 2015; Donthu et al., 2021). By applying quantitative and computational techniques to scholarly publications, bibliometrics enables the mapping of a field's intellectual structure, dynamics, and relationships. It can identify core publications and authors, visualise collaborative networks, track the evolution of research topics through keyword analysis and citation patterns, and reveal the underlying intellectual foundations. This data-driven, macroscopic view surpasses the limitations of traditional narrative reviews by offering an objective and systematic overview of the entire scholarly conversation (Donthu et al., 2021).

As shown in Table 1, bibliometric analysis has been widely applied to investigate research trends and patterns in teacher education and digital competency development, particularly among PSTs. Wu Huihui et al. (2024), Jiahong Su (2023), Ibrahim Gökdaş et al. (2024), Punithavili Mariappan et al. (2024), and Sheena Lovia Boateng et al. (2024) has demonstrated this approach in their research, examining aspects such as author collaboration, institutional involvement, keyword trends, citation networks, publication trends, and thematic clusters within their specific EdTech domains and timeframes.

Therefore, this study conducts a comprehensive bibliometric analysis of the current research landscape of EdTech course design for PSTs to address the identified gaps. Based on foundational frameworks, such as TPACK (Mishra & Koehler, 2006), and using the rigorous methods of bibliometrics (Zupic & Čater, 2015; Donthu et al., 2021), this analysis aims to systematically map the trends, key contributors, thematic clusters, and potential gaps in this field. By providing this evidence-based overview, the study seeks to inform more strategic and impactful future research agendas, guide teacher educators and program developers, and ultimately contribute to designing EdTech courses that effectively empower the next generation of educators in an increasingly digital world.

Table 1. Previous articles on EdTech Course Design for PSTs related studies and bibliometric analysis.

Author	Objective	Data Source & Years Covered	TDE	Bibliometric Attributes Examined
Wu Huihui et al. (2024)	Analyse research status, hotspots, and trends of pre-service teachers' TPACK; compare differences between WOS and CNKI databases.	WOS Core Collection & CNKI 2010–2022	875	•Top contributors (authors/institutes) • Most-cited studies • Co-country/institution networks • Keyword cluster mapping • Time-zone evolution trends • Annual publication distribution
Jiahong Su (2023)	Map global trends in pre-service teachers' TPACK development; identify productive sources/authors and potential research gaps.	Scopus 2007–2022	112	• Annual publication trends •Journal/country/institution productivity • Funding agencies • Author collaboration patterns

				•Keyword co-occurrence/clustering • Research area distribution
Ibrahim Gökdaş et al. (2024)	Identify trends and principal themes in teachers' digital competencies; explore COVID-19 impact using bibliometrics and topic modelling.	WOS Core Collection & Scopus 1994–2024	3352	• Publication/citation trends • Journal impact (h-index/g-index) • Most-cited documents/authors • Funding agencies • LDA topic modelling (10 themes) • Temporal topic evolution
Punithavili Mariappan et al. (2024)	To explore emerging trends in technology and art education using bibliometric mapping analysis	Scopus 2019-2023	29	•Annual publication trends (TP, NCP, TC, C/P, C/CP, h-index, g-index) •Top contributing countries •Top keywords (e.g., Educational Computing, E-learning, Virtual Reality) •Research gaps (access, pedagogy, technical issues, assessment) •Keyword visualisation (VOSviewer)
Sheena Lovia Boateng et al. (2024)	To analyse the trajectory of educational technology in primary/elementary Education via bibliometric review	Scopus 1986–2023	293	• Annual growth trajectory • Most impactful journals (h-index, citations) • Most impactful authors (h-index, citations) • Country/institutional contributions • Most cited articles • Keyword analysis (frequency, co-occurrence, thematic evolution) • Gender/disability focus • Collaboration networks

*TDE: Total Documents Examined

Research Questions

This study conducts a bibliometric mapping of scholarly work on EdTech course design in pre-service teacher education, guided by the following six research questions:

RQ 1: What is the current status of research regarding the design of EdTech courses for PSTs?

RQ 2: What new or developing patterns are apparent in published works concerning the design of EdTech courses for PSTs?

RQ 3: Which academic journals and publications are primary sources for foundational research on the design of EdTech courses for PSTs?

RQ 4: Who are the leading contributors including - authors, institutions, and countries – in the research and development of EdTech course design for PSTs?

RQ 5: Which highly influential papers have significantly shaped the theory, practice, and discourse around EdTech course design for PSTs?

RQ 6: What are the central research themes and knowledge areas that form the scholarly foundation of EdTech course design for PSTs?

This study employs bibliometric and network analysis to map the scholarly landscape of educational technology course design for pre-service teachers (PSTs), directly addressing the six research questions posed. By examining longitudinal publication trends (RQ1), identifying key publication venues (RQ2), recognising seminal works and influential authors (RQ3), determining prolific countries/institutions (RQ4), analysing keyword clusters and thematic foci (RQ5), and identifying significant research gaps (RQ6), it provides a structured understanding of the domain's evolution, current state, and future directions. The insights gained are crucial for informing the development of more effective educational technology courses for PSTs, ensuring they align with evolving technological and pedagogical standards. Ultimately, this analysis aims to delineate the complex realm of PST-focused educational technology course design, setting a foundation for future innovation and enhanced effectiveness in preparing teachers through technology integration.

METHODS

This study utilised Scopus database (data accessed 10 July 2025) to conduct a bibliometric analysis of the literature on EdTech course design for PSTs. The selection of Scopus was a well-considered methodological decision based on its reputation as one of the most extensive and detailed abstract and citation databases in peer-reviewed research. The broad scope of Scopus covers a wide range of disciplines, social, scientific, medical, and technical science, which is essential for this research of EdTech course design for PSTs. The dataset of Scopus is broad and precise due to its comprehensive scope of computer science, social sciences, engineering, as well as arts and humanities. Scopus's stringent quality controls and wide geographical coverage has made it be an appropriate tool for thorough bibliometric analysis. It can provide a diverse range of metadata, including citation information and authors' affiliations, which further reinforced its position as the primary source for this research (Aghaei Chadegani et al., 2013). The collected data included document type, source type, languages, subject fields, publication trends, the average number of authors per document, the publishing contributions of institutions, the distribution of publications by country, and dominant keywords.

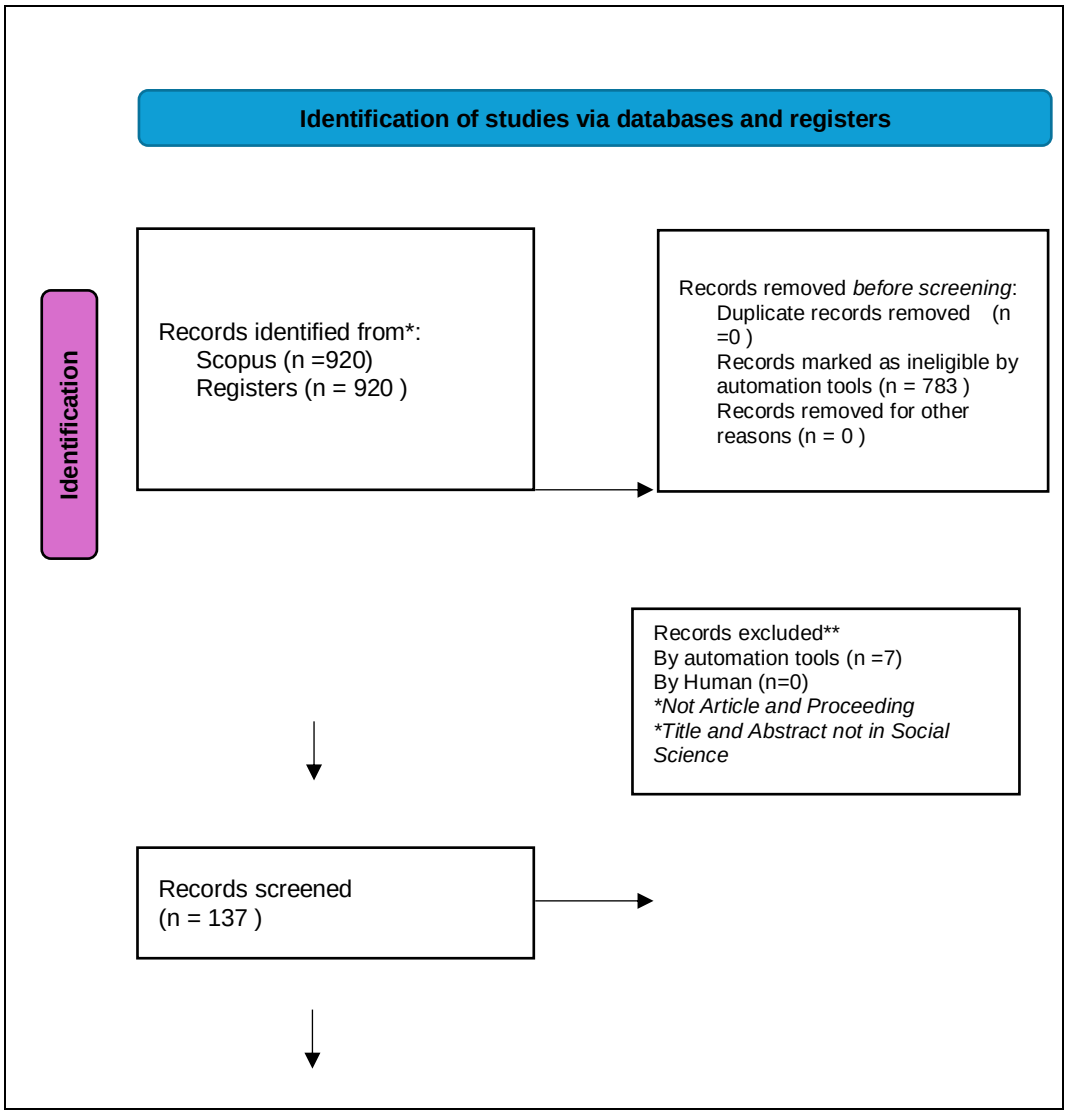
Search strategy

We adopted the modified PRISMA guidelines (Page et al., 2021) for conducting systematic research reviews. The search string (("educational technolog*" OR "instructional technolog*" OR "edtech") AND ("pre-service teacher*" OR "preservice teacher*" OR "teacher candidate*" OR "teacher education") AND ("course*" OR "curriculum" OR "program*" OR "instruction*")) was entered into the Scopus advanced search engine. Scopus subject filters were applied to refine the search. The scope of the research was defined by limiting the results to

specific search fields, source types, and document types, thereby excluding irrelevant papers. This search yielded 920 documents (see Fig. 1).

Based on Figure 1, articles were screened through multiple stages to ensure that only relevant studies were included in the final analysis. Out of the 920 documents initially identified in Scopus, 783 were flagged as ineligible by automated tools prior to manual screening， as the database filters were configured to include only studies within the Social Sciences subject area and open-access articles, while excluding Gold, Green, Bronze, and Hybrid Gold access types. Subsequently, 137 articles underwent further scrutiny. Of these, seven (7) were removed for not being academic articles or conference proceedings, and two (2) reports could not be retrieved for evaluation. After a comprehensive eligibility assessment of the remaining 128 reports, 18 were excluded based on the following criteria: non-English, not in the final publication stage, or Title and Abstract not related to pre-service teachers who are none of educational technology or computer-related majors, or Title and Abstract not related to EdTech Course.

To maintain data quality and relevance, the research meticulously applied systematic inclusion and exclusion criteria. The inclusion criteria focused on publications explicitly related to EdTech course design for PSTs, indexed in Scopus from 2020 to 2025, written in English, and utilising bibliometric, systematic, or empirical approaches. On the other hand, the exclusion criteria removed non-educational studies, non-English documents, non-peer-reviewed content, editorials, book chapters, duplicate records, and entries with incomplete metadata. This structured approach ensures a comprehensive, transparent, and reliable bibliometric analysis of research in the field of Educational Technology Course Design for Pre-Service Teachers. Following this strict screening procedure, a final selection of 110 articles was included in the study, ensuring that only high-quality and relevant research contributed to the analysis.



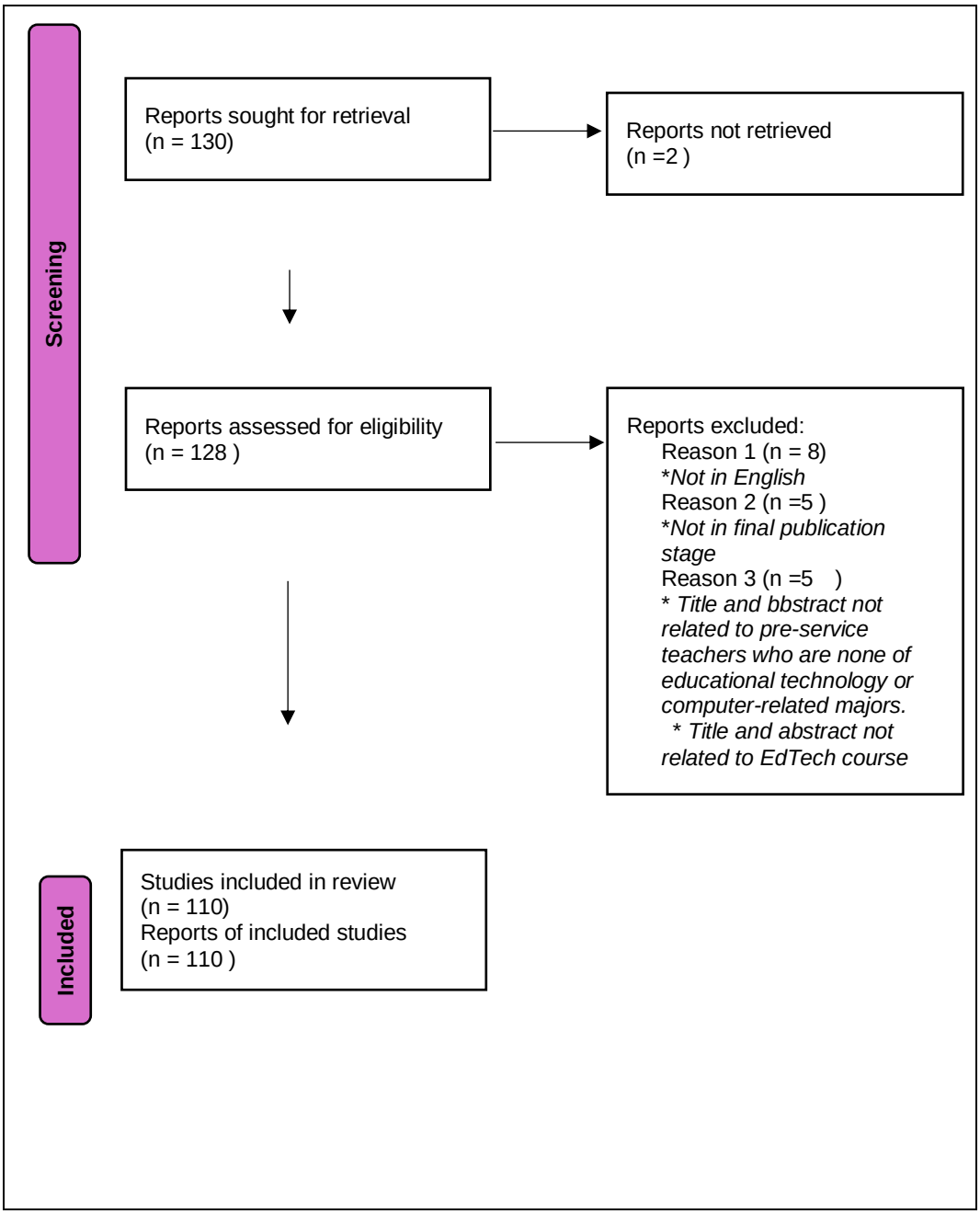


Fig. 1 PRISMA steps

Data cleaning and harmonisation

Data cleaning and harmonisation play crucial roles in bibliometric analysis, which is essential for the accuracy and reliability of the results. This research applied biblioMagika® and OpenRefine (Ahmi, 2023) to refine and align bibliographic data, including author names, affiliations, keywords, and other key details. These tools were very useful for achieving data precision and consistency, particularly given the diversity of research outputs and the potential for dataset discrepancies. The download of Scopus data in CSV format was needed as the first step, and then the selected files were targeted for cleaning. Specific columns, such as keywords, author names, and affiliations, were chosen for amendments using various methods and functions provided by the clustering tools. biblioMagika® was used for advanced bibliometric assessments. This tool supported analyses across key metrics, including Total Publications (TP), Number of Contributing Authors (NCA), Number of Cited Publications (NCP), Total Citations (TC), along with Citations per Publication (C/P), Citations per Cited Publication (C/CP), Citations per Author (C/A). It also calculated ratios including Authors per Publication (A/P), Citations per Year (C/Y), alongside indicators such as Citable Year, h-index, g-index, m-index, and Citation Sum within the h-Core. These assessments were applied to various categories, such as years, source titles, individual authors, institutions, and countries. Additionally, biblioMagika® helped identify missing data, and

allowed the researchers to manually fill in missing information for facilitating the data cleaning and harmonisation process. By leveraging these specialized tools, the researchers ensured the integrity and reliability of their analyses and findings. The cleaning and harmonisation processes enhanced the detail and clarity of the research dataset, making it a comprehensive foundation for exploring the complex field of EdTech course design for PSTs.

Data analysis

The data analysis was conducted to address the RQs. The authors mapped the current landscape of research on EdTech course design for PSTs, focusing on aspects such as document type, source type, languages, subject areas, and citation metrics. The authors presented the findings based on various criteria, including annual publication volume, contributions from top authors and institutions, prominent countries, and influential source titles. This approach helped identify the major contributors and current trends within the discipline. To thoroughly evaluate the impact and significance of publications, the authors applied bibliometric indicators such as Total Publications (TP), Number of Cited Papers (NCP), Total Citations (TC), Citations per Publication (C/P), Citations per Cited Publication (C/CP), h-index, g-index, m-index, and Citation Sum within the h-Core. Additionally, to explain the principal themes and concepts prevalent in this area, the authors applied techniques such as co-occurrence network analysis, thematic mapping, and factor analysis to visualise the authors' keywords. These visualisations enable us to identify clusters of related topics, reveal potential patterns, and explore the connections among different research subfields.

Tools

The authors utilised several specialised tools, such as Microsoft Excel, biblioMagika®, OpenRefine, and VOSviewer, to ensure a rigorous bibliometric analysis, each tool of them played its role in enhancing the data accuracy and interpretability. Microsoft Excel was used for initial data cleaning and organisation, such as sorting and structuring of the data from Scopus. Then biblioMagika® standardised the metadata, fixing inconsistencies in author names, institutional affiliations, and country attributions. OpenRefine was used to harmonise authors' keywords to ensure consistency in co-occurrence analysis. VOSviewer generated visualizations of bibliometric networks, mapping trends in keywords, author collaborations, and citation relationships. In fact, these tools were not used in a certain sequence but are selected specifically based on actual needs.

RESULTS

In this section, the authors will analyse the current research status of EdTech course design for PSTs. This detailed analysis will address the Research Questions (RQs), to provide a detailed and insightful overview of the domain and deliver valuable knowledge for scholars, practitioners, and policymakers.

Current Status of Research regarding the design of EdTech course for PSTs

In response to the initial RQ 1, which aims to map the current status of research in EdTech course design for PSTs, the authors will evaluate various factors of the distribution of publications, including document type, source type, languages, and subject areas. In addition, the authors will evaluate the overall citation metrics to ascertain the impact and significance of these works in the field of EdTech course design for PSTs. Initially, the collected data were categorized by document type, covering formats such as articles and conference papers. It is noted that conference papers frequently disseminate research presented academic gatherings, with a portion subsequently appearing in published proceedings.

Between the period from 2020 to 2025, the compiled data in the table 2 provides insights into substantial research contributions in the field of EdTech course for PSTs based on the search string. Over a span of six active publication years, a total of 110 publications were produced through collaboration among 338 contributing authors. These efforts resulted in 93 cited papers, reflecting the academic relevance of the research. Collectively, the body of work accumulated 1,294 citations, with an average of 11.76 citations per publication, thereby illustrating its scholarly influence. The average citations per cited paper reached 13.91, signifying the

considerable impact of the referenced literature. With an annual citation rate of 258.80, this research maintains consistent academic engagement.

At the individual level, the total number of citations per author was 3.83, while the average collaboration density was 3.07 authors per paper. The citation sum within the h-core reached 1,134, highlighting the quality of high-impact papers. The h-index of 17 and g-index of 33 further underscore the research's sustained influence. At the same time, the m-index of 2.833 indicates progressive growth in impact over time. Collectively, these metrics demonstrate a prolific and influential research body that makes meaningful advances in its field.

Table 2. Citation Metric.

Main Information	Data
Publication Years	2020 - 2025
Total Publications	110
Citable Year	6
Number of Contributing Authors	338
Number of Cited Papers	93
Total Citations	1,294
Citation per Paper	11.76
Citation per Cited Paper	13.91
Citation per Year	258.80
Citation per Author	3.83
Author per Paper	3.07
Citation sum within h-Core	1,134
h-index	17
g-index	33
m-index	2.833

Publication trends

To address the second RQ, the authors initiated their analysis by tracking the publication growth trajectory of educational technology course design for pre-service teachers. Research on educational technology course design for pre-service teachers demonstrates significant growth, particularly since 2021, surging from 13 publications in 2020 to 23 in 2022 (Table 3, Fig. 2). Although a slight dip occurred in 2023 (21 publications), momentum was maintained in 2024 (23 publications), indicating sustained scholarly interest.

Expanding Research Collaboration:

The steady rise in the Number of Contributing Authors (NCA)—from 41 (2020) to 78 (2024)—highlights growing interdisciplinary collaboration. This trend underscores the integration of pedagogy, technology, and instructional design expertise in developing teacher-training curricula.

Maturing Research Impact:

The h-index and g-index exhibit consistent growth (Table 3), indicating an increase in the field's academic influence. However, recent declines in citation metrics (C/P and C/CP) suggest:

Early studies (2020–2022) garnered high citations (e.g., 2020: C/P = 28.85), establishing a foundational knowledge base.

Newer publications (2023–2025) exhibit lower citation rates (C/P = 7.57 in 2023; 0.75 in 2025), likely due to recency (2025 data is partial).

Focus on Innovation & Practical Application:

The peak in publications (2022–2024) aligns with post-pandemic emphasis on immersive tech integration (e.g., VR/AR). This trend reflects efforts to equip pre-service teachers with hands-on experience in emerging educational technology (EdTech) tools.

Quality and Citation Dynamics:

Fluctuations in the m-index and a decline in C/CP (from 31.25 in 2020 to 1.50 in 2025) may indicate evolving research priorities or a diversification of topics. This warrants a deeper analysis of citation practices and research quality.

The field is rapidly expanding in volume, collaboration, and scholarly impact. Trends indicate an increasing emphasis on collaborative, practice-oriented research that prepares educators for technology-enhanced classrooms. However, monitoring citation dynamics and ensuring methodological rigor remain critical for sustained growth.

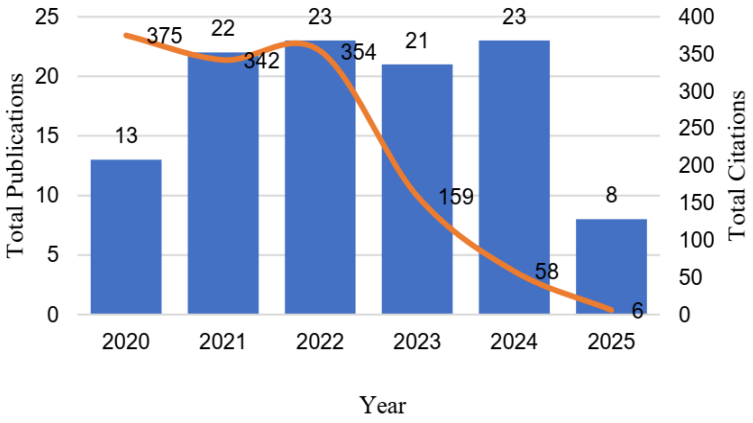


Fig. 2 Total publications and citations by year (Publication data for 2025 is only up until 10 July 2025).

Table 3. Publication by year

Year	TP	NCA	NCP	TC	C/P	C/CP	h-index	g-index	m-index
2020	13	41	12	375	28.85	31.25	10	13	1.667
2021	22	59	21	342	15.55	16.29	9	18	1.800
2022	23	75	19	354	15.39	18.63	8	18	2.000
2023	21	62	20	159	7.57	7.95	7	12	2.333

2024	23	78	17	58	2.52	3.41	4	6	2.000
2025	8	23	4	6	0.75	1.50	2	2	2.000
Grand Total	**110**	**338**	**93**	**1294**	**11.76**	**13.91**	**40**	**69**	**6.667**

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

* Publication data for 2025 is only up until 10 July 2025.

Publications by source titles

Fig. 3 and Table 4 identify the most productive scholarly sources that publish research on educational technology course design for pre-service teachers, highlighting journals with two or more publications. Cogent Education leads in productivity with a TP (Total Publications) of 6, reflecting its prominent role in disseminating foundational research. It also demonstrates substantial academic influence with a TC (Total Citations) of 33 and an h-index of 3. The International Journal of Emerging Technologies in Learning follows closely with five (5) publications and the highest citation impact in its cohort (TC=38, C/P=7.60), underscoring its relevance for innovative pedagogical approaches.

Education Sciences and Education and Information Technologies emerge as key contributors. While both focus on teacher preparation frameworks, the latter exhibits a more substantial citation impact (TC = 37, C/P = 9.25) compared to the former (TC = 16, C/P = 2.67). Sustainability (Switzerland), though publishing fewer documents (TP=3), achieves high scholarly recognition with a TC of 56 and the highest C/P (18.67), indicating its influential role in sustainable technology integration research.

Notably, the Australasian Journal of Educational Technology (h-index= 4) and Contemporary Educational Technology (h-index = 3) demonstrate a consistent impact through rigorous scholarship. Newer sources such as the Journal of Metaverse (C/CP = 12.00), show early traction in exploring immersive learning designs.

Comprehensive bibliometric indices (C/P, C/CP, h-index, g-index, m-index) collectively affirm where high-impact research on pre-service teacher technology training is curated and cited. This analysis helps academia and institutions navigate collaborations and publication avenues in the evolving field of educational technology pedagogy.

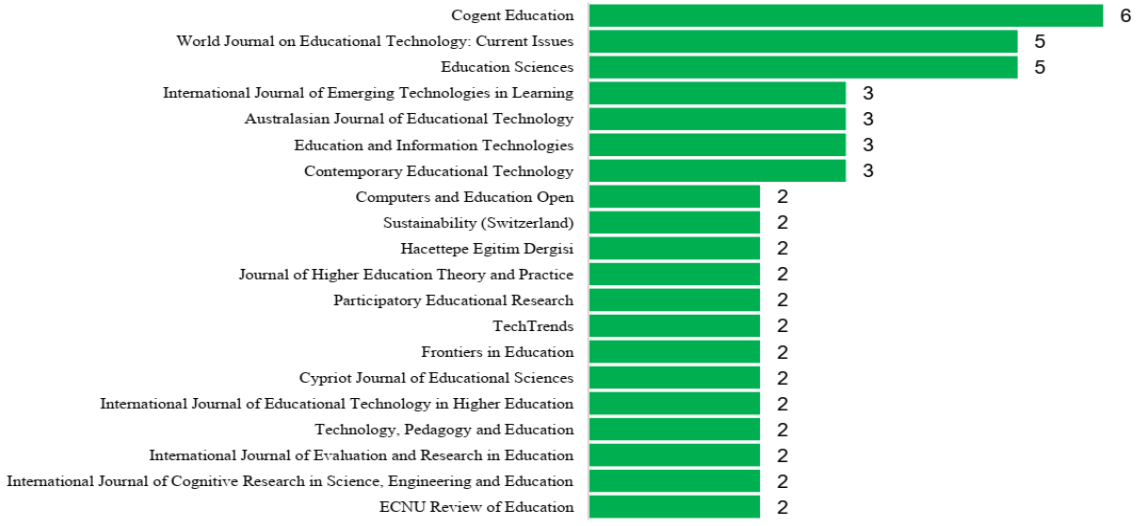


Fig. 3. Top 20 Most Productive Source Titles.

Table 4. Most active source titles that have published two (2) or more documents.

Source Title	TP	NCA	NCP	TC	C/P	C/CP	h	g	m
Cogent Education	6	21	6	33	5.50	5.50	3	5	0.750
World Journal on Educational Technology: Current Issues	6	24	3	14	2.33	4.67	2	3	0.333
Education Sciences	6	22	4	16	2.67	4.00	2	4	0.400
International Journal of Emerging Technologies in Learning	5	28	5	38	7.60	7.60	3	5	0.500
Australasian Journal of Educational Technology	5	9	5	126	25.20	25.20	4	5	0.667
Education and Information Technologies	4	17	4	37	9.25	9.25	3	4	1.000
Contemporary Educational Technology	4	11	4	34	8.50	8.50	3	4	0.750
Computers and Education Open	4	14	3	16	4.00	5.33	2	4	0.500
Sustainability (Switzerland)	3	7	3	56	18.67	18.67	2	3	0.400
Hacettepe Egitim Dergisi	3	6	3	11	3.67	3.67	2	3	0.500
Journal of Higher Education Theory and Practice	3	6	2	7	2.33	3.50	2	2	0.333
Participatory Educational Research	3	6	2	24	8.00	12.00	2	3	0.333
TechTrends	3	5	3	27	9.00	9.00	3	3	0.600
Frontiers in Education	2	7	2	24	12.00	12.00	1	2	0.200
Cypriot Journal of Educational Sciences	2	12	1	1	0.50	1.00	1	1	0.250
International Journal of Educational Technology in Higher Education	2	3	2	23	11.50	11.50	2	2	0.500
Technology, Pedagogy and Education	2	3	2	18	9.00	9.00	1	2	0.167
International Journal of Evaluation and Research in Education	2	9	1	12	6.00	12.00	1	2	0.200

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

Highly cited documents

In addressing RQ5 "What landmark papers have significantly shaped the theory, practice, and discourse around designing educational technology courses for pre-service teachers?", Table 5 identifies the top 10 highly cited articles that have profoundly influenced this domain. These publications represent foundational works that have redirected academic discourse and pedagogical approaches in teacher preparation.

The paper by Nazaretsky et al. (2022) is the most cited work with 231 citations, explored how teachers trust AI-powered educational technology. and developed professional development frameworks to build that trust. Their work has reshaped discourse on technology acceptance in teacher education, highlighting the critical role of psychological readiness and technological skills.

The second most influential paper by Backfisch et al. (2020) is cited 131 times, they investigated whether professional knowledge or motivation more significantly influenced pre-service teachers' ability to design technology-enhanced lesson plans. Its findings have stimulated the revision of curriculum design to balance pedagogical knowledge (PK) with motivational scaffolding.

The paper by Bereczki and Kárpáti (2021) with 118 citations, ranks third, the authors conducted a study on how technology enhances creativity through case studies of expert teachers. Their study demonstrates how digital tools can transform creative pedagogy and directly influence the curriculum design of pre-service teachers.

Overall, these articles, as well as the others in Table 5, reveal three main themes that influence EdTech courses. The first theme is the integration of trust and artificial intelligence, as emphasized by Nazaretsky et al. on psychological disorders. The second one is the interaction between knowledge and motivation. Backfisch et al. have provided evidence for training that focuses on these two aspects. The third theme is creative practices related to technology, such as the digital creative model proposed by Bereczki and Karpati.

Citation metrics (TC and C/Y) highlight their impact, particularly the paper by Nazaretsky et al. has counted 57.75 citations per year, reflecting the urgent academic involvement of AI in teacher development. This bibliometric analysis emphasizes how landmark papers have shifted curricular priorities toward human-centred technology adoption, evidence-informed motivation strategies, and creative digital pedagogies in pre-service teacher education.

Table 5. Top 10 highly cited articles.

No.	Author(s)	Title	Source Title	TC	C/Y
1	Nazaretsky T., et al. (2022)	Teachers' trust in AI-powered educational technology and a professional development program to improve it	British Journal of Educational Technology	231	57.75
2	Backfisch I., et al. (2020)	Professional knowledge or motivation? Investigating the role of teachers' expertise on the quality of technology-enhanced lesson plans	Learning and Instruction	131	21.83
3	Bereczki E.O.; Kárpáti A. (2021)	Technology-enhanced creativity: A multiple case study of digital technology-integration expert teachers' beliefs and practices	Thinking Skills and Creativity	118	23.60
4	Ledger S.; Fischetti J. (2020)	Micro-teaching 2.0: Technology as the classroom	Australasian Journal of Educational Technology	72	12.00

5	García-Vandewalle García J.M., et al. (2023)	Analysis of digital competence of educators (DigCompEdu) in teacher trainees: the context of Melilla, Spain	Technology, Knowledge and Learning	48	16.00
6	Zhao L.; Liu X.; Su Y.-S. (2021)	The differentiate effect of self-efficacy, motivation, and satisfaction on pre-service teacher students' learning achievement in a flipped classroom: A case of a modern educational technology course	Sustainability (Switzerland)	39	7.80
7	Saubern R., et al. (2020)	Describing increasing proficiency in teachers' knowledge of the effective use of digital technology	Computers and Education	39	6.50
8	Garcia-Esteban S.; Villarreal I.; Bueno-Alastuey M.C. (2021)	The effect of telecollaboration in the development of the Learning to Learn competence in CLIL teacher training	Interactive Learning Environments	26	5.20
9	Kobayashi M. (2020)	Does anonymity matter? Examining quality of online peer assessment and students' attitudes	Australasian Journal of Educational Technology	26	4.33
10	Starčič A.I.; Lebeničnik M. (2020)	Investigation of university students' perceptions of their educators as role models and designers of digitalised curricula	Human Technology	25	4.17

Notes: TC = Total Citations: C/Y = Average Citations by Year

Publications by authors

Table 6 identifies the most prolific scholars (≥2 publications) in educational technology course design for pre-service teachers, analysed through bibliometric indicators. The research landscape is dominated by:

Lachner, Andreas (University of Tübingen, Germany): Co-leading in total citations (TC=133) with colleague Backfisch, Iris, reflecting influential work on technology integration in teacher education.

Kulaksiz, Taibe (Heidelberg University of Education, Germany): Highest productivity (TP=3) and strongest sustained impact (m-index=0.750), signalling consistent contributions to pedagogical frameworks for EdTech courses.

Institutional and Pedagogical Insights

German Research Hub:

University of Tübingen researchers (Lachner, Backfisch) dominate in citation impact (C/P = 44.33–66.50), suggesting rigorous studies on pre-service teacher competency development.

Kulaksiz's work exemplifies high knowledge transfer (h-index = 3), likely addressing practical implementation challenges.

Spanish Pedagogical Innovation Cluster (University of Granada):

Four authors (García-Vandewalle, García-Carmona, Trujillo Torres, Moya Fernández) share identical high-impact metrics (TC = 62, C/P = 31.00, m = 0.500), indicating collaborative studies on structured EdTech curricula or assessment models.

Emerging International Scholarship:

Phillips, Michael (Australia): Focus on critical digital pedagogy (TC = 44, C/P = 22.00).

Atabek, Oguzhan (Turkey) and Anas Thohir, M. (Indonesia): Exploring culturally responsive course designs (C/CP = 11.00 - 12.00).

Bibliometric Implications for Teacher Education

High-impact works (e.g., Backfisch's C/P=66.50) likely address core challenges:

Technology integration in practicum settings

Scaffolding digital literacy for pre-service teachers

Moderate m-indices (e.g., Kulaksiz: 0.750; García-Carmona: 0.500) denote accelerating scholarly influence in this emerging niche.

Lower citation rates (e.g., Eren: TC = 8) may represent innovative but nascent frameworks that are awaiting broader validation.

This analysis maps the active research fronts in pre-service EdTech course design, revealing a German-Spanish dominance in high-impact studies and growing contributions from the Asia-Pacific region. Institutional collaboration (e.g., Granada) appears vital for scalability.

Table 6. Most productive authors who published more than two (2) documents.

Full Name	Current Affiliation	Country	TP	NCP	TC	C/P	C/CP	h	g	m
Lachner, Andreas	University of Tübingen	Germany	3	2	133	44.33	66.50	2	3	0.333
Kulaksız, Taibe	Heidelberg University of Education	Germany	3	3	27	9.00	9.00	3	3	0.750
Backfisch, Iris	University of Tübingen	Germany	2	2	133	66.50	66.50	2	2	0.333
Phillips, Michael	Monash University	Australia	2	2	44	22.00	22.00	2	2	0.333
Atabek, Oguzhan	Akdeniz University	Turkey	2	1	11	5.50	11.00	1	2	0.167
García, José Manuel García-Vandewalle	University of Granada	Spain	2	2	62	31.00	31.00	2	2	0.500

Istenic, Andreja	University of Primorska	Slovenia	2	2	23	11.50	11.50	1	2	0.200
Rosanda, Violeta	State High School	Italy	2	2	23	11.50	11.50	1	2	0.200
McGarr, Oliver	University of Limerick	Ireland	2	2	18	9.00	9.00	1	2	0.167
García-Carmona, Marina	University of Granada	Spain	2	2	62	31.00	31.00	2	2	0.500
Anas Thohir, M.	Universitas Negeri Malang	Indonesia	2	1	12	6.00	12.00	1	2	0.200
Torres, Juan Manuel Trujillo	University of Granada	Spain	2	2	62	31.00	31.00	2	2	0.500
Moya Fernández, Pablo	University of Granada	Spain	2	2	62	31.00	31.00	2	2	0.500
Eren, Esra	Eskisehir Osmangazi University	Turkey	2	2	8	4.00	4.00	2	2	0.500

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

Publications by institutions

Table 7 highlights institutional research productivity in educational technology course design for pre-service teachers, featuring institutions with at least three publications. The University of Tübingen (Germany) demonstrates significant scholarly impact with a TP of 13 and an exceptionally high TC of 133, yielding a C/P of 44.33 and C/CP of 66.50 – the highest citation efficiency in the dataset.

The University of Granada (Spain) achieves the highest h-index (3) and g-index (3) among institutions with three (3) publications, coupled with a robust TC of 69 and C/P of 23.00. Similarly, Heidelberg University of Education (Turkey) stands out with a perfect h-index/g-index (3/3) and a high C/P of 9.00 from 3 publications.

Other notable contributors include:

University of Primorska (Slovenia): High TC (48) and C/P (16.00) despite a modest TP (3).

Universitas Negeri Malang (Indonesia): Strong citation impact (C/CP = 8.50) with TC of 17.

L.N. Gumilyov Eurasian National University (Kazakhstan): Moderate output (TP=3, TC=10) with an h-index of 2.

Institutions such as Abai Kazakh National Pedagogical University (h-index=0) and Near East University (h-index=1) reflect emerging engagement, albeit with limited current citation impact.

Collectively, these institutions reveal a geographically diverse research landscape advancing pre-service teacher technology education. Metrics like C/CP (citations per cited publication) and g-index underscore variations in research influence, with European institutions leading in citation efficiency.

Table 7. Most productive institutions with a minimum of three (3) publications.

Institution Name	Country	TP	NCA	NCP	TC	C/P	C/CP	h	g	m
Abai Kazakh National Pedagogical University	Kazakhstan	4	5	1	1	0.25	1.00	1	1	0.200
Heidelberg University of Education	Turkey	3	3	3	27	9.00	9.00	3	3	0.750
L.N. Gumilyov Eurasian National University	Kazakhstan	3	5	2	10	3.33	5.00	2	3	0.333
Universitas Negeri Malang	Indonesia	3	4	2	17	5.67	8.50	2	3	0.400
University of Granada	Spain	3	10	3	69	23.00	23.00	3	3	0.750
University of Tübingen	Germany	3	13	2	133	44.33	66.50	2	3	0.333
Near East University	Cyprus	3	4	3	4	1.33	1.33	1	2	0.167
University of Primorska	Slovenia	3	4	3	48	16.00	16.00	2	3	0.333
Kazan Federal University	Russian Federation	3	4	3	16	5.33	5.33	1	3	0.167

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

Publications by countries

Table 8 (below) summarises the research output of countries contributing three or more publications in the domain of educational technology course design for pre-service teachers, based on bibliometric data analysis. Turkey leads in publication volume (TP = 23), though its citation impact (C/P = 5.22) is moderate. The United States follows with 16 publications and a more substantial influence (TC = 154; C/P = 9.63), alongside a high h-index of 7. Spain stands out with exceptional citation metrics, achieving the highest C/P (13.09) and C/CP (14.40) among major contributors, despite having only 11 publications.

The United Kingdom, despite having only three publications, dominates in total citations (242) with an extraordinary C/P ratio of 80.67. Australia's eight publications yield a high C/P of 17.25, while Germany's six publications generate the highest number of citations (TC = 166) and the highest C/P (27.67) in the dataset. Slovenia similarly shows a high per-publication impact (C/P: 16.00) with three (3) publications.

Countries like Kazakhstan (TP = 10) and Indonesia (TP = 4) contribute volume but exhibit lower citation traction (C/P: 1.80 and 5.00, respectively). Metrics such as the h-index (measuring productivity and citation impact), g-index (weighting highly cited papers), and m-index (normalising h-index by time) reveal scholarly influence and collaboration patterns. For example, Kazakhstan's high NCA (51 authors for 10 publications) suggests extensive collaboration. Figure 4 visually maps the global distribution of research in this field.

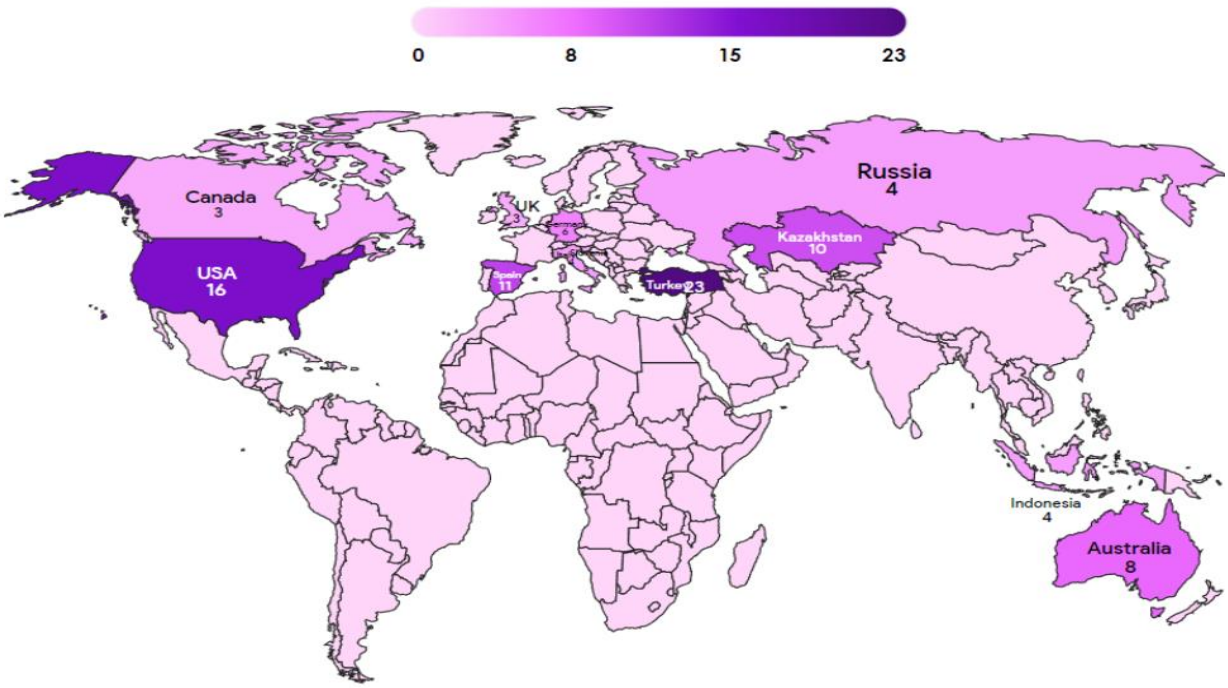


Fig. 4. Visualisation of Global Distribution of Research Publications

Table 8. Countries that contributed three (3) or more publications.

Country	TP	NCA	NCP	TC	C/P	C/CP	h	g	m
Turkey	23	47	19	120	5.22	6.32	6	10	1.000
United States	16	34	15	154	9.63	10.27	7	12	1.167
Spain	11	34	10	144	13.09	14.40	7	11	1.400
Kazakhstan	10	51	7	18	1.80	2.57	2	4	0.333
Australia	8	18	7	138	17.25	19.71	5	8	0.833
Germany	6	21	5	166	27.67	33.20	4	6	0.667
Italy	4	6	4	15	3.75	3.75	2	3	0.500
Indonesia	4	16	3	20	5.00	6.67	3	4	0.600
Russian Federation	4	14	4	29	7.25	7.25	2	4	0.333
United Kingdom	3	3	3	242	80.67	80.67	2	3	0.500
Canada	3	5	3	4	1.33	1.33	1	2	0.200
Slovenia	3	7	3	48	16.00	16.00	2	3	0.333

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

Co-occurrence analysis

The final RQ is, “What are the pivotal research themes and knowledge domains underpinning the scholarship on educational technology course design for pre-service teachers?”. To answer this RQ, the co-occurrence network (Fig. 5) maps author keywords with at least four occurrences, revealing pivotal research themes in educational technology course design for pre-service teachers. This analysis identifies interconnected clusters that reflect current scholarly priorities, technological integrations, and pedagogical approaches shaping the field of teacher education.

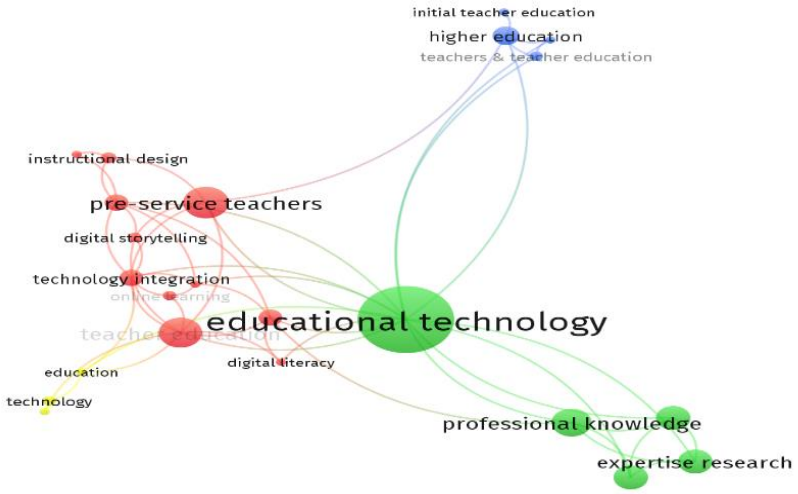


Fig. 5. Co-occurrence network of the author’s keywords with at least four occurrences.

Cluster 1: Teacher Education Core

(Keywords: initial teacher education, teachers & teacher education, pre-service teachers, teaching education)

This central cluster underscores the foundational focus on teacher preparation. Keywords like "pre-service teachers" and "initial teacher education" dominate, highlighting research dedicated to equipping future educators with essential competencies. The strong linkage between "teachers & teacher education" and "teaching education" reinforces iterative professional development frameworks. This cluster anchors the network, signifying that pedagogical training remains the bedrock of educational technology integration.

Cluster 2: Technology Integration in Learning Environments

(Keywords: educational technology, technology integration, online learning, digital storytelling, digital literacy)

Adjacent to the teacher education core, this cluster reveals robust connections between technological tools and instructional delivery. "Technology integration" and "educational technology" co-occur with "online learning", reflecting post-pandemic shifts toward hybrid/digital classrooms. "Digital storytelling" and "digital literacy" further demonstrate evolving pedagogies that leverage immersive, narrative-driven tools to enhance engagement. This synergy highlights efforts to bridge technical skills with creative teaching methodologies.

Cluster 3: Institutional Contexts and Design Frameworks

(Keywords: higher Education, instructional-design, professional knowledge, expertise research)

Positioned at the network’s periphery, this cluster links systemic structures to curricular design. "Higher education" is closely tied to "instructional design", indicating research on optimising course architecture within universities. Meanwhile, "professional knowledge" and "expertise research" intersect with design principles, stressing evidence-based strategies to cultivate pedagogical expertise. This theme addresses scalability challenges in institutional adoption of technology-enhanced curricula.

Cross-Cluster Synergies and Implications

Technology-Pedagogy Nexus: "Instructional-design" bridges Clusters 2 and 3, illustrating how digital tools (e.g., digital storytelling) are systematically embedded in teacher training programs.

Equity and Access: The prominence of "online learning" raises questions about resource disparities, echoing concerns in the broader XR/AI literature regarding infrastructure barriers for marginalised educators.

Future Directions: The new connection with "digital literacy" and "professional knowledge" marks a shift towards a framework of key digital capabilities. However, ethical considerations, such as data privacy in online practicums and balancing virtual and face-to-face training, require further study.

This co-occurrence network identifies three interdependent pillars in EdTech for PSTs, the pedagogical foundations (teacher identity development), the technological fluency (tools and literacy), and the system design (curriculum scalability). The analysis underscores a transformative trajectory: technology is no longer ancillary but central to reimagining teacher education. Future research must address the issue of digital equity while ensuring that immersive tools, such as simulations and AI-driven platforms, complement human-centered pedagogy. As these clusters evolve, they will continue to shape resilient, adaptive frameworks for preparing educators in a digitally mediated world.

DISCUSSION

Through bibliometric analysis, we map trends in Educational Technology (EdTech) course design for pre-service teachers (PSTs). Our findings indicate a significant expansion in scholarly output since 2020, driven by global collaboration among institutions in Germany, Spain, Turkey, the United States, and Australia. This growth highlights the escalating recognition of technology's transformative role in teacher preparation, particularly post-COVID-19, in which intensified focus on digital competencies and immersive learning tools (García-Vandewalle García et al., 2023; Nazaretsky et al., 2022). Although the samples covered major databases, non-English literature was not included, which may affect the universality of the conclusion. Additionally, the temporal scope of the analysis (2020-2025), while capturing the most recent trends, necessarily excludes earlier seminal work that shaped the foundational trajectory of the field. A longitudinal comparison including pre-2020 research would be valuable to fully contextualize post-pandemic transformations. And the reliance on the Scopus database, though comprehensive, may have resulted in the omission of relevant studies from regions or journals not covered by it.

The co-occurrence analysis identified three dominant thematic clusters. 1) Teacher Education Core (e.g., "pre-service teachers," "initial teacher education"), emphasising foundational pedagogical training. 2)Technology Integration (e.g., "educational technology," "digital literacy"), highlighting strategies to bridge technical skills with classroom application. 3) Institutional Design Frameworks (e.g., "higher education," "instructional-design"), addressing the issues of system scalability and evidence-based curriculum development. These clusters illustrate the development of the field from technological proficiency to holistic pedagogical reasoning, which is consistent with the emphasis of the TPACK framework on the integration of contextualized knowledge (Mishra & Koehler, 2006; Scherer et al., 2021). A large number of cited studies have further confirmed this transformation. Nazaretsky et al. (2022) have believed that trust in AI is a key factor in its adoption, while Backfisch et al. (2020) have demonstrated the interaction between professional knowledge and motivation in designing technology-enhanced courses. Bereczki and Karpati (2021) have emphasized the role of creative digital pedagogy, urging the curriculum to cultivate innovation beyond the mastery of tools.

Although these clusters reflect the intellectual structure, the key interpretation of the bibliometric data reveals potential dynamics and gaps. The dominance of countries such as Germany, Spain and the United States in research output (as shown in Table 8) can be attributed to the combined effect of various factors, including strong national research funding, established policy priorities in digital education, and the presence of influential research institutions that set the academic agenda. This geographic concentration may create a hegemonic discourse in EdTech course design, potentially marginalizing context-specific challenges and solutions from developing regions. Furthermore, the discussion around emerging technologies like AI and VR in the literature

often remains descriptively optimistic, focusing on their potential rather than critically examining their pedagogical necessity, ethical implications, or the practical challenges of implementation at scale. For instance, while AI promises personalized learning, its integration requires a critical discussion of data privacy, algorithmic bias, and the risk of de-professionalizing teachers by outsourcing pedagogical decisions.

Despite these advancements, three key challenges still exist. Firstly, the gap between theory and practice remains prominent. EdTech courses often fail to integrate theoretical frameworks such as TPACK into real classroom practice (Tondeur et al., 2017). Secondly, the disparity in institutional resources has widened the gap between equity and access. For instance, the high-impact research in Germany contrasts with the emerging contributions of Kazakhstan and Indonesia, which may widen the digital gap (Kimmons et al., 2020). Thirdly, it is difficult for courses to keep up with the rapid pace of technological development, especially with tools like AI and virtual platforms (Kopcha et al., 2020).

Emerging trends also bring many opportunities for innovating EdTech course design. First, AI integration: personalised learning pathways and AI-driven mentorship models (e.g., Nazaretsky et al., 2022) could enhance adaptive instruction, but such applications require ethical guarantee measures for data privacy. Secondly, in the field of immersive technology, such as VR/AR applications (e.g., Journal of Metaverse), provide experiential practical environments for learners; however, the high cost has become a major obstacle to its wide popularization (García-Vandewalle García et al., 2023). Thirdly, in the cultivation of key digital citizenship literacy, the critical assessment of tools and the integration of ethical digital practices remain relatively weak. (Tondeur et al., 2018).

Implications for Course Design and Teacher Education

The findings of this bibliometric review, particularly the identified thematic clusters and influential studies, have had specific impacts on curriculum designers and teacher educators. To translate these insights into practice, there is a need to make changes to the content and delivery methods of EdTech courses for pre-service teachers.

The first implication is from tool literacy to pedagogical reasoning. Course objectives should be reframed to develop strong pedagogical reasoning with technology, rather than focusing exclusively on technological skills. This can be achieved by embedding the use of digital tools within authentic, content-specific teaching tasks. For example, PSTs might be tasked with using VR to create immersive historical simulations, thereby contextualizing technological knowledge within specific pedagogical and content domains.

To support this shift, course design can benefit from adopting a cross-framework approach that moves beyond a sole reliance on TPACK. Integrating insights from complementary models can create a more dynamic and actionable curriculum. Learning outcomes can be aligned with the detailed, competency-based descriptors of the DigCompEdu framework, while the SAMR model can be used as a self-evaluation tool for PSTs to critique and redesign their lesson plans, pushing them towards transformative uses of technology.

Concurrently, the rising influence of AI demands dedicated curriculum components on AI ethics in education. PSTs must learn to critically evaluate AI-powered tools, understand data privacy issues, and mitigate algorithmic bias to ensure equitable learning experiences. This directly addresses the ethical and equitable design frameworks highlighted as a strength of the field.

Finally, a critical step in bridging the theory-practice gap involves the translation of high-impact research findings into practical guidelines. For instance, the work on teacher trust in AI (Nazaretsky et al., 2022) can be applied to classroom activities on evaluating AI-powered educational tools, while research on technology-enhanced creativity (Bereczki & Kárpáti, 2021) can directly inform the design of assignments that use digital storytelling for critical expression and student engagement.

Implications for Stakeholders：

Educators should prioritize pedagogical reasoning over tool-oriented training, and cultivate the adaptability for integrating technologies by leveraging design thinking models (Kopcha et al., 2020). Institutions need to increase

investment in teacher development programs and promote cross-institutional cooperation, such as the research network model of the University of Granada in Spain, to promote replicable EdTech practices globally. For policymakers, key initiatives include increasing funding for digital infrastructure development in underdeveloped regions and establishing ethical norms for emerging technologies like AI and XR in teacher education to ensure equitable implementation (UNESCO, 2023).

Future Research Directions:

Three priority areas demand scholarly attention to promote the innovative development of teacher education. Firstly, there should be longitudinal studies on how pre-service teachers integrate technology in various internship settings. Such research will effectively bridge the gap between theory and classroom practice, providing empirical support for improving teacher training models. Secondly, it is necessary to develop AI ethical norms specifically tailored to the teacher education. This is crucial for addressing data privacy issues. Thirdly, it is necessary to develop immersive modelling tools that are both cost-effective and practical, such as VR and AR, such tools should be mainly provided to educational institutions with limited resources. This will ensure the equitable and effective application of advanced teaching tools, thereby promoting the balanced development of education.

CONCLUSION

This bibliometric analysis provides a detailed overview of research trends and landscape on EdTech course design for PSTs, highlighting its transformative potential and challenges. The research adopts the co-occurrence network analysis method to draw the topic clustering map. Through this analysis, it identifies three core elements that are key to preparing pre-service teachers for digital teaching environments. The first is the teaching foundation, such as teacher identity development and TPACK integration. The second is technological literacy, such as developing digital literacy and using AI tools. The third is institutional design, involving systemic support measures, such as creating scalable curricula and establishing collaborative frameworks (Mishra & Koehler, 2006; Tondeur et al., 2018). These elements support each other. They not only enhance the ability of pre-service teachers to connect theory with practice, but also promote their flexible application of technology and innovative practice in diverse K-12 settings (Kopcha et al., 2020).

However, there are still several key shortcomings in this field that need to be addressed urgently. the disconnection between theory and practice still exists. For instance, it is often difficult to effectively transform theoretical frameworks such as TPACK into teaching practices in real classrooms for course design, which directly limits the ability of PSTs to deal with actual teaching challenges (Polly et al., 2010; Tondeur et al., 2012). Additionally, the imbalance in the distribution of institutional resources is significant, for example, in the global distribution of high-impact research, there is a notable gap between countries like Germany and Spain and emerging contributing countries such as Kazakhstan and Indonesia, this imbalance may further widen the digital education gap (Kimmons et al., 2020). At the same time, the rapid iteration of technologies such as AI and immersive platforms has continuously reduced the curricular relevance, this requires the curriculum system to be continuously updated and optimized to avoid losing practical value due to outdated content (Nazaretsky et al., 2022).

Emerging trends are showing us a landscape that the frontiers of education are full of hope but complex. Although the deep integration of AI provides learners with highly personalised learning paths and mentorship models, it has also raised ethical concerns about data privacy and the risk of algorithmic bias (Nazaretsky et al., 2022). Immersive technologies, such as VR and AR, have successfully created immersive practical experience environments, transforming abstract knowledge into perceivable and operable concrete practices. However, the high cost of equipment and infrastructure requirements have led to significant accessibility barriers in their popularization (García-Vandewalle García et al., 2023). Meanwhile, the cultivation of ethical tool evaluation and inclusive practices for critical digital citizenship is still underdeveloped in existing curriculum systems, despite it is urgent in countering misinformation and inequity (Tondeur et al., 2018).

To promote the design of EdTech courses, stakeholders should prioritize teaching adaptability rather than tool-centric training, such as cultivating PSTs' critical reasoning skills through design-thinking models (Kopcha et al., 2020). At the same time, digital equity gaps require targeted solutions, such as cross-institutional collaborations

and funding for underrepresented regions, to help bridge resource disparities (UNESCO, 2023). And we also need to concern the ethical frameworks for emerging technologies, it must be deeply integrated into the curriculum system, to ensure that the application of AI and immersive tools is always aligned with the core goal of people-oriented education.

From this bibliometric review on Edtech course design for PSTs, future research and practice should focus on the following three core directions. The first one is conducting longitudinal studies on technology integration in teaching environment for PSTs; the second one is developing cost-effective simulations for resource-constrained educational institutions; the third one is formulating systematic AI ethical guidelines specifically for the field of teacher education. With placing equity, ethics and adaptability at the same position as educational technology in Edtech course design for PSTs, EdTech courses can truly empower the educators, enabling them to master and shape the digital future of teaching and learning.

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