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Journal of Educational Computing Research

Thematic Evolution of Educational Technology Research: A Large-Scale Topic Modeling Perspective

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Keywords:	topic modeling, educational technology, latent dirichlet allocation, thematic evolution

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Running Head: Thematic Evolution of Educational Technology Research

Thematic Evolution of Educational Technology Research: A Large-Scale Topic Modeling Perspective

Alper ASLAN[1], Seda AKTI ASLAN[2], Yiğit Emrah TURGUT[3], Jordan ALLISON[4], Özcan ÖZYURT[5]

Abstract

This study aims to reveal the thematic evolution of the educational technology field by analyzing 17,393 articles published between 2000 and 2024 in ten leading journals using the Latent Dirichlet Allocation (LDA) based topic modeling. Based on the analysis of title, abstract, and keywords, 20 themes were identified and grouped under seven broader meta-themes such as "Teacher Professional Competence and Technology Adoption", "Digital and Disciplinary Literacy Development", and "Immersive and Experiential Learning Technologies". The model achieved its highest coherence at K = 20 (c_v = 0.4091), and the stability of the thematic structure was supported through additional runs with alternative hyperparameter configurations and expert validation. The findings show that there has been a significant increase in themes such as "Technology Integration", "Teacher Roles in Online Learning Design", and "Technology Acceptance and Self-Efficacy" in recent years. Temporal trend and growth analyses indicate that these themes will continue to shape the research landscape in the upcoming years. This holistic approach, which overcomes the contextual limitations of traditional bibliometric analysis, makes a significant contribution to the literature by mapp ing the last 25 years of scholarly accumulation in educational technology.

Keywords

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topic modeling, educational technology, latent dirichlet allocation, thematic evolution

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Introduction

The integration of digital technologies into educational environments has radically transformed the nature of teaching-learning processes and created a new paradigm in education. Computer-based instructional technologies have been at the center of this digital transformation process, profoundly affecting both students' individual learning experiences and teachers' pedagogical practices as well as institutions' digital infrastructures (Helbig et al., 2021; Timotheou et al., 2023). In addition, research in areas such as artificial intelligence systems, mobile applications, digital games, online learning platforms and learning analytics has made the field of educational technology increasingly complex and multidimensional. To make sense of the rapidly developing research trends in the field and to trace the direction in which it is likely to evolve, comprehensive analyses that encompass multiple prestigious journals rather than focusing on a single outlet are required (Zawacki-Richter & Latchem, 2018). Previous studies have often examined individual

journals or applied bibliometric approaches with limited semantic depth, but such approaches fall short of capturing the broader thematic structures that shape the field (Bond et al., 2019; Torres-Vergara et al., 2025). Leading journals such as *Computers & Education*, *British Journal of Educational Technology* (BJET), *Education and Information Technologies* (EAIT), *Interactive Learning Environments* (ILE), and several others serve as critical platforms for understanding the evolution of educational technology research. Collectively examining these journals enables researchers to identify dominant research orientations, trace thematic shifts over time, and reveal both continuities and emerging research gaps. In this respect, conducting a multi-journal, large-scale, and longitudinal analysis provides a more holistic perspective on the thematic development of the field over the past 25 years, offering deeper insights into its scientific accumulation and future directions. Beyond offering a descriptive mapping of research trends, the thematic structures identified in educational technology research can also be meaningfully interpreted through established theoretical perspectives on learning and pedagogy. For instance, themes related to teacher roles in technology-mediated learning environments resonate with sociocultural approaches that emphasize mediation, interaction, and the social construction of knowledge. Similarly, the prominence of technology acceptance and self-efficacy reflects key assumptions of social cognitive theory, while the increasing focus on immersive and experiential learning technologies aligns closely with constructivist and experiential learning paradigms.

To understand the ever-expanding range of topics in the field of educational technology, retrospective analyses are often conducted on prestigious journals in the field. In this context, there are studies that reveal publication and citation trends, the most influential authors and institutions, and research directions using different techniques. For example, Mostafa (2022) conducted a bibliometric analysis of 995 articles published in *Interactive Learning Environments* between 1990

and 2020, examining citation patterns, collaboration networks, influential authors, institutions, and nationalities. Similarly, in the 25th anniversary of *Education and Information Technologies*, two different studies were conducted: Tatnall and Fluck (2022) analyzed 1511 articles between 1996 and 2020 using historical methods, while Ozyurt and Ayaz (2022) examined 1841 articles between 1996 and 2021 through bibliometric analysis and topic modeling techniques. It is observed that some long-established journals in educational technology publish special issues for anniversaries, while others publish studies in which such retrospective analyses are included (Bond et al., 2019; Chen et al., 2019; Torres-Vergara et al., 2025). However, there is still a lack of large-scale, systematic, and semantic analyses that holistically examine the thematic transformation of the educational technology field across multiple journals. Particularly after COVID-19 and with the rise of generative AI, the nature of educational technology has dramatically shifted. Therefore, a broader and more comprehensive investigation is needed to capture the thematic evolution of the field over the last 25 years.

Bibliometric analyses are widely used in the literature to provide an overview of journals and research topics. In bibliometric analysis studies, scientific publications are mapped by using certain indicators such as year and number of publications, keywords, citations, author, institution and country information (de Oliveira et al., 2019). However, bibliometric analyses are limited in providing in-depth information as they do not include semantic analysis of the content of the publications (Douard et al., 2025). Recent work demonstrates that semantic patterns can be revealed by using content analysis techniques to address this limitation of bibliometric analysis (Arıcı et al., 2019; Bayrak Karsli et al., 2024; Goksu et al., 2022). Both bibliometric analysis and systematic review methods in which a limited number of publications are manually analyzed are insufficient to reveal the hidden semantic patterns of research (Gurcan et al., 2021; Ozyurt et al.,

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2024). Topic modeling, which was developed to overcome the limitations of these traditional analysis types, stands out as a revolutionary method in the field of text mining. This method, which is one of the natural language processing techniques, enables the discovery of implicit themes and semantic relationships in large text sets (Kherwa & Bansal, 2020). The most widely and effectively used technique in topic modeling analysis is the Latent Dirichlet Allocation (LDA) model, which treats documents as topic mixtures and represents each topic with specific word distributions (Blei, 2012). For this reason, LDA-based topic modeling, which has a wide range of applications, has been frequently used in recent years to make sense of the content of academic journals, to reveal latent structures in the content and to identify research gaps (Aslan & Ozyurt, 2025; Nylander et al., 2022). This technique, which offers valuable insights into the field, is one of the most appropriate methods for analyzing long-term, large-scale, and thematically coherent corpora covering multiple leading journals in educational technology.

In addition to its increasing use within educational research, LDA-based topic modeling has been successfully employed across diverse disciplinary domains, further demonstrating its methodological robustness and generalizability. For example, large-scale thematic analyses based on LDA have been conducted to map fifty years of domestic violence research (Basilio et al., 2021), to systematically explore the evolution of policing strategies through the integration of bibliometric analysis and topic modeling (Basilio & Pereira, 2022), and to support complex analytical processes in management and decision-support systems by combining LDA with multi-criteria modeling approaches (Basilio et al., 2020). These studies illustrate that LDA is not domain-specific but rather constitutes a flexible and reliable analytical framework for uncovering latent thematic structures in large scholarly corpora, thereby reinforcing the methodological relevance of its application in the present study.

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In this study, the aim is to reveal the thematic trends in the 25-year publication history of the educational technology field by analyzing research articles published in ten leading journals using the topic modeling method. Within the scope of the study, the LDA method was employed to discover implicit themes based on the title, abstract, and keyword information of the articles, and the distribution of these themes over time was analyzed. In this way, the study contributes to the field by both making sense of the long-term development of educational technology research and revealing how research orientations towards digital and computer-assisted learning technologies have transformed. In this context, the following research questions were addressed:

RQ1. What are the prominent themes and meta-themes in prestigious educational technology journals between 2000 and 2024?

RQ2. How have these themes and meta-themes changed over time?

RQ3. What kinds of relationships and interaction networks exist among the prominent themes in the field?

RQ4. What research gaps and emerging topics can be identified in educational technology over the past 25 years?

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Method

Research Design

This study aims to identify the thematic orientations of the educational technology field by analyzing research articles published between 2000 and 2024 in ten leading journals: *Computers & Education*, *British Journal of Educational Technology* (BJET), *Computer Assisted Language Learning* (CALL), *International Journal of Computer-Supported Collaborative Learning* (ijCSCL), *Education and Information Technologies* (EAIT), *Interactive Learning Environments*

(ILE), *Educational Technology Research & Development* (ETR&D), *Australasian Journal of Educational Technology* (AJET), *Journal of Educational Computing Research* (JECR), and *Journal of Computer Assisted Learning* (JCAL). In total, 17,393 research articles were included in the analysis. Minor differences from raw Scopus counts (17,856) were due to unavailable abstracts, incomplete metadata, and data-cleaning steps such as duplicate removal. For this purpose, the LDA algorithm, which is widely used to discover contextual patterns in large text collections (Blei, Ng, & Jordan, 2003), was utilized. The LDA-based topic modeling analysis examines co-occurrence structures in texts, assuming that each document can belong to more than one theme (Jelodar et al., 2019).

The methodological framework was inspired by previous LDA-based publication analyses (Syed & Spruit, 2017). Analysis based on titles, abstracts, and keywords was preferred for both time efficiency and semantic representation. The themes obtained were interpreted by the research team, considering their contextual consistency and semantic density. This process was carried out by a five-member research team, all of whom are experienced academics with prior work in similar studies. Expert opinions were also sought to ensure that the themes were labeled in accordance with the academic context. Finally, theme distributions by year were analyzed using the topic-document probability matrix. This analysis sheds light on the contextual transformation of the literature by revealing both dominant themes and trends that change over time (Ozkose et al., 2023). The methodological stages of this process were structured in four main steps, starting with data collection and preprocessing, and concluding with LDA modeling, theme naming, and time series analysis. This holistic approach is summarized in Figure 1.

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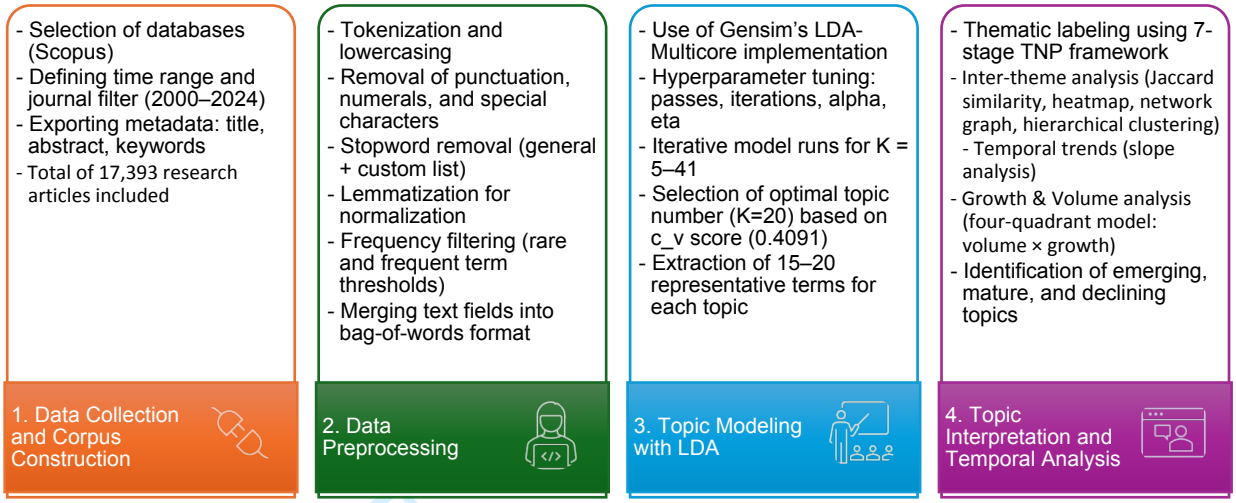

Figure 1. LDA-based Topic Modeling Process and Analysis Stages

Data Collection and Scope

In this study, a comprehensive dataset covering research articles published between 2000 and 2024 in ten leading educational technology journals was created. The Scopus database was used as the primary source due to its advanced filtering and querying capabilities, which are widely preferred in large-scale LDA-based topic modeling analyses (Ozkose et al., 2023). A total of 17,393 articles were included in the corpus. The slight difference from the Scopus query totals (17,856) was due to unavailable abstracts, incomplete metadata, and cleaning procedures such as duplicate removal. Only peer-reviewed research articles were considered, while editorials, reviews, book notices, and non-research materials were excluded.

The selection of journals followed a multi-step procedure. First, journals explicitly focusing on educational technology and not restricted to a narrowly defined subfield were considered to ensure representativeness of the broader disciplinary landscape. Priority was given to journals indexed in major international databases such as Scopus and Web of Science, with a long-standing publication

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history and high academic visibility. Based on these criteria, ten journals were selected: Computers & Education, British Journal of Educational Technology (BJET), Computer Assisted Language Learning (CALL), International Journal of Computer-Supported Collaborative Learning (ijCSCL), Education and Information Technologies (EAIT), Interactive Learning Environments (ILE), Educational Technology Research and Development (ETR&D), Australasian Journal of Educational Technology (AJET), Journal of Educational Computing Research (JECR), and Journal of Computer Assisted Learning (JCAL). The joint analysis of these journals is therefore assumed to provide a comprehensive representation of the thematic evolution of educational technology research.

Data Preprocessing

Prior to the topic modeling analysis, a comprehensive preprocessing process was performed to make the texts statistically meaningful and semantically parsable. This is a step that directly affects the accuracy and efficiency of the model, especially in natural language processing applications (Aggarwal & Zhai, 2013; Jelodar et al., 2019). The preprocessing procedures were applied to the entire corpus of 17,393 research articles collected from ten educational technology journals.

The pre-processing steps applied in this study included:

- **Tokenization:** All texts are parsed into words to be used as units of analysis.
- **Lowercase conversion**: All words have been converted to lower case to avoid differences in word matches.
- **Punctuation and special character cleaning**: Numbers, punctuation and special characters have been removed from the texts.

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- **Stopword removal:** Frequently used words without semantic contribution such as "the", "and", "of" were removed. In addition, excessively frequent terms outside the scope of the analysis, such as "technology", "acceptance", "model", etc., were also specially filtered.
- **Lemmatization**: Words are reduced to their root or canonical forms to preserve unity of meaning.
- **Rare and common word filtering**: Terms appearing in more than 50% of all documents or less than 1% of all documents were eliminated. This reduced semantic noise and improved the thematic discrimination of the model.

Preprocessing was performed using Python programming language and libraries such as spaCy, NLTK and Gensim. Finally, a document-term matrix was created by combining the title, abstract and keywords of each study and this structure was provided as input to the LDA model.

LDA-based Topic Modeling

Following data preprocessing, the LDA algorithm was applied to discover implicit themes in the text collection. The LDA-based topic modeling was implemented in Python with the multicore version of the Gensim library (Řehůřek & Sojka, 2010). The hyperparameters of the model were determined in the direction recommended in the literature and an iterative approach was adopted:

- **passes** = 15
- **iterations** = 100
- **alpha** = 'symmetric'
- **eta (beta)** = 'symmetric'
- **random_state** = 42

To determine the number of topics, the model was trained with different K values ranging between K = 5 and K = 41 and the c_v coherence score was calculated for each model (Röder,

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Both & Hinneburg, 2015). The highest coherence value of 0.4091 was obtained for K = 20; therefore, 20 thematic structures were used in the analysis. Each topic obtained from the model was defined through 15-20 representative terms with the highest probability and made sense according to their semantic content. This process enabled the creation of thematic structures based on both statistical and contextual integrity in line with similar LDA studies (Jacobi et al., 2016).

To assess model robustness and reproducibility, additional exploratory runs were conducted using alternative topic numbers and hyperparameter configurations. Across these configurations, the overall thematic structure remained largely consistent and core themes were preserved. This suggests that the findings are not dependent on a single parameter setting but reflect a stable underlying structure in the corpus.

Topic Interpretation and Labeling

Each theme extracted by the LDA model was subjected to a multi-layered evaluation process based on representative term lists, contextual integrity, conceptual context, and consistency with the literature. To this end, a 7-stage Theme Naming Process (TNP) was applied as a systematic approach in the study. This process aims not only to label semantic clusters but also to understand and interpret the contextual structure of themes in a holistic way.

In order to enhance the credibility of the theme interpretation process, expert validation was employed. Three independent academics holding doctoral degrees in educational technology and instructional technology reviewed the topic outputs, representative keywords, and sample documents. The experts conducted the evaluation independently, and themes for which consensus was achieved were directly accepted. For a limited number of themes where minor discrepancies

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emerged, consensus was reached through discussion, ensuring conceptual consistency across the final theme set.

The TNP consists of the following steps:

1. **Selection of Key Terms and Frequency Analysis:** The most frequently used terms in the dataset were identified, listed as thematic candidates and priority keywords were clarified.
2. **Conceptual Coding and Thematic Classification:** These terms were interpreted conceptually and those with similar meanings were grouped and thematic clusters were formed.
3. **Creating a Thematic Profile:** The scope, focus and content of each cluster were determined and thematic profiles were created.
4. **Alternative Theme Names:** Multiple naming options have been developed for each thematic profile.
5. **Consistency with Literature:** The proposed names were compared with the existing literature and conceptual consistency was ensured.
6. **Simplify and Focus:** Theme names are simplified and focused to avoid confusion.
7. **Theme Naming:** In the final stage, the final names of the themes were determined based on all analyses and evaluations.

The transparency and scientific basis of this process enhance both the methodological reliability and interpretability of the topic modeling analysis. Furthermore, to provide readers with a transparent overview of how themes were constructed, an example of a theme naming process for a theme is presented in tabular form below (Table 1):

Table 1. Development of a Sample Theme in the Scope of TNP

1. Selection of Key Terms and Frequency Analysis
Key Terms: literacy (3.45%), digital (2.97%), skills (1.82%), information (1.61%), media (1.40%), critical (1.21%), competence (1.18%), technology (1.14%), education (1.12%),

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access (1.01%), communication (0.95%), online (0.91%), learning (0.86%), internet (0.80%), development (0.79%), evaluation (0.73%), knowledge (0.72%), reading (0.69%), writing (0.63%), usage (0.61%)

2. Conceptual Coding and Thematic Classification

Conceptual Group	Keywords
Core Concepts of Digital Literacy	literacy, digital, skills, competence, critical
Educational Contexts	education, learning, development, evaluation
Information & Media Dimension	information, media, communication, knowledge
Technological Access & Usage	technology, internet, online, access, usage
Literacy Practices	reading, writing

3. Thematic Profile Creation

This theme covers how digital literacy is conceptualized as a set of critical skills and competences in using information, media, and technology. It emphasizes educational practices, technological access, and the integration of literacy into learning environments.

4. Alternative Theme Names

- Critical Skills and Digital Literacy in Education
- Information, Media, and Technology Competences
- Educational Practices for Developing Digital Literacy

5. Literature Alignment

This theme reflects common areas in the literature such as:

- Developing students' digital competences for 21st-century skills
- The role of critical media literacy in education
- Integrating digital literacy practices into formal and informal learning

6. Simplification and Focus

The most central and frequently recurring concepts are literacy, digital, and skills. The most straightforward and representative name is:
Digital Literacy

7. Final Theme Naming

Digital Literacy

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Temporal Trends, Inter-theme Relations, and Growth Analysis

In the first stage, temporal analysis was conducted by transforming the thematic distributions of articles published between 2000 and 2024 into annual ratios. Based on these ratios, trend curves were created for each theme, and slope coefficients were calculated using linear regression methods. These slope values quantitatively indicate whether themes follow an upward, stable, or downward trajectory (Syed & Spruit, 2017).

In the second stage, inter-theme analysis was carried out to reveal conceptual relationships among themes. For this purpose, Jaccard similarity indices were calculated, and the results were visualized through heatmaps, network graphs, and hierarchical clustering. This process enabled the identification of conceptual proximities, overlaps, and structural relations across the thematic landscape (Jacobi et al., 2016).

In the third stage, growth and volume analysis was applied to identify emerging, saturated, and declining research areas. Publication volumes and slope values were combined in a four-quadrant model, positioning themes according to both their cumulative size and growth momentum. This approach highlights which themes represent mature research domains, which ones are rapidly gaining prominence, and which are losing attention over time (Aslan & Ozyurt, 2025).

FINDINGS

Prominent Themes and Meta-Themes in the Field of Educational Technology (RQ1)

The first research question aimed to identify the prominent themes and meta-themes in educational technology journals over the past 25 years. In this context, themes were created using data obtained from LDA-based topic modeling analysis. The terms used in creating the themes and their conceptual profiles are shared in Table 1. The naming of the themes considered the frequency

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values of the key terms, the academic context of the themes, and their conceptual equivalents in the literature. Thus, the resulting themes are presented not only as technical outputs but also as conceptual frameworks reflecting the research areas they represent within the literature. Table 2 provides the name of each theme, its conceptual profile, the key terms that constitute that theme, and its percentage (Pt %) within the total publication volume of the dataset.

Table 2. Discovered themes, terms constituting the themes, and volume ratios

Theme	Theme Profile / Theme Terms	n	P_t (%)
Modeling and Data-Driven Approaches	This theme addresses data-driven modeling and artificial intelligence-supported approaches in education. Students' learning processes are monitored and evaluated through learning analytics, adaptive systems, and smart teaching technologies.	1390	7.99
	model-data-web-educational-research-adaptive-learner-process-environment-analytics-assessment-design-support-machine-intelligence-intelligent-tutoring-artificial-technology-decision		
Teacher Competencies	This theme covers teachers' professional competencies and classroom practices. Teaching skills, pedagogical knowledge, technology integration, and professional development processes are highlighted.	1303	7.49
	teacher-teaching-skill-thinking-development-school-classroom-ict-professional-competence-service-practice-information-computational-training-tool-knowledge-activity-curriculum-pedagogical		
Technology Integration	This theme examines the integration of technology in educational settings. It addresses ways in which teachers incorporate technology into lesson design through pedagogical approaches, adopt innovative practices, and enhance teaching processes.	1224	7.04
	technology-educational-teacher-research-integration-teaching-practice-school-development-framework-pedagogical-innovation-factor-context-adoption-design-support-technological-educator-experience		
Teacher Roles in Online Learning Design	This theme addresses the roles teachers take on in online learning environments. Responsibilities such as lesson design, content development, interaction management, and pedagogical guidance are highlighted.	1142	6.57
	online-design-teacher-course-teaching-interaction-content-knowledge-environment-practice-lecture-experience-participation-instructional-learner-pedagogical-professional-development-research-instructor		
Collaborative Learning (CSCL)	This theme examines computer-supported collaborative learning processes. It addresses how students construct knowledge through interaction, feedback, and collaborative problem solving. Software tools, communication processes, and collaborative activities are highlighted as elements that enhance the effectiveness of learning environments.	1093	6.28
	collaborative-computer-feedback-collaboration-interaction-knowledge-environment-process-software-communication-cooperative-activity-tool-work-cscl-research-design-support-human-task		
Cognitive Load and Multimedia	This theme addresses the concept of cognitive load in multimedia learning processes. The design of learning materials and the relationship between the use of text, video, and images and students' cognitive capacities are examined.	1071	6.16

	cognitive-multimedia-learner-condition-load-instructional-video-knowledge-performance-design-task-text-environment-instruction-computer-participant-prior-strategy-experiment-ability		
Language Learning and Assessment	This theme examines foreign language learning and assessment processes. English language teaching focuses on reading comprehension, vocabulary, writing, and developing language skills. language-assessment-english-reading-vocabulary-efl-comprehension-teacher-text-learner-word-foreign-computer-writing-test-instruction-skill-teaching-classroom-call	958	5.51
Online Learning	This theme addresses online and blended learning models. With the COVID-19 process in higher education, the management of online courses, teaching quality, faculty roles, and student experiences have come to the fore. online-blended-higher-covid-teaching-university-course-school-instructor-pandemic-quality-management-institution-platform-perception-distance-experience-support-factor-challenge	922	5.30
Technology Acceptance and Self-Efficacy	This theme addresses the relationship between technology acceptance and self-efficacy in an educational context. Teachers' and students' intentions, perceptions, beliefs, and satisfaction regarding technology use are examined. self-efficacy-model-intention-teacher-technology-acceptance-factor-structural-belief-equation-online-influence-satisfaction-usefulness-knowledge-engagement-modeling-behavioral-ease	879	5.05
Experimental Evaluation and Assessment	This theme covers experimental evaluation and measurement processes in educational research. Tests, scales, interactive tools, and performance measurements are highlighted. test-evaluation-experimental-tool-control-scale-interactive-item-score-performance-design-effectiveness-mathematics-research-computer-post-teaching-achievement-testing-application	846	4.86
Game-Based Learning and Computational Thinking in Children	This theme examines game-based learning and computational thinking skills in children. Children's problem-solving, coding, and awareness development processes are addressed through computer-assisted activities, projects, and science-based applications. game-child-computer-project-science-educational-concept-computational-knowledge-research-intervention-team-school-design-thinking-support-awareness-activity-coding-play	841	4.84
Programming Education	This theme covers the teaching processes of programming education and their impact on student success. Teaching methods, learning styles, motivation, and strategy use are highlighted. course-programming-teaching-performance-style-motivation-learner-academic-computer-classroom-online-data-achievement-environment-class-strategy-instruction-research-traditional-impact	827	4.75
ICT Attitudes and Use	This theme examines individuals' attitudes toward and patterns of use of information and communication technologies (ICT). Technology use in school, university, and teacher contexts, internet access, gender differences, and impacts in academic settings are addressed. ict-computer-attitude-technology-internet-gender-school-factor-information-university-difference-communication-teacher-research-higher-usage-female-teaching-data-academic	825	4.74
Social Networking and Collaborative Problem Solving	This theme addresses the role of social networks and online communities in collaborative problem-solving processes. It examines how students improve their academic performance through interaction, information sharing, and joint cognitive activities. social-problem-network-online-medium-solving-community-learner-interaction-knowledge-performance-academic-map-cognitive-behavior-pattern-networking-research-presence-process	758	4.36

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Mobile Learning and Inquiry	This theme covers the use of mobile technologies in learning processes and inquiry-based education. Augmented and virtual reality applications, mobile devices, and data-driven activities support students' problem-solving, access to information, and in-class/online learning experiences. mobile-science-reality-application-knowledge-device-inquiry-problem-augmented-data-school-environment-activity-information-technology-solving-classroom-virtual-teaching-tool	748	4.30
Affective and Participatory Learning Design	This theme examines learning designs that focus on emotional dimensions and participant interaction. It addresses students' emotional experiences, participation levels, and the effects on their learning processes through virtual and video-based environments. design-engagement-research-virtual-video-educational-emotion-emotional-experience-environment-reality-user-theory-meta-world-affective-process-framework-context-impact	727	4.18
Self-Regulation and Writing	This theme addresses the relationship between self-regulation skills and writing performance. Students' motivation, strategy use, feedback reception, and academic achievement processes are examined. self-writing-motivation-performance-achievement-regulation-regulated-learner-strategy-feedback-academic-class-online-language-efficacy-classroom-data-experimental-course-control	669	3.85
Virtual and Simulated Learning Environments	This theme examines virtual and simulation-based learning environments. Students' skill development, participation, and performance are evaluated through gamified activities, interactive tasks, and role-playing applications. virtual-training-game-simulation-learner-task-reality-language-environment-skill-participant-experience-interactive-performance-immersive-second-real-role-playing-design	548	3.15
Digital Literacy	This theme addresses technological competencies in digital literacy and educational environments. It examines students' access to information, use of resources, interaction with digital materials, and skill development processes. digital-literacy-resource-medium-technology-competency-learner-material-information-research-skill-school-development-educational-knowledge-teaching-child-environment-practice-informal	336	1.93
Online Learning Strategies	This theme examines the strategies used in online learning. Synchronous and asynchronous activities, social interaction, communication, and online presence elements are highlighted. online-strategy-face-presence-environment-reading-teaching-social-synchronous-activity-communication-research-interaction-question-computer-distance-asynchronous-experience-university-instruction	286	1.64
	Total	17393	100

Table 2 shows that “Modeling and Data-Driven Approaches” ranks first in terms of publication volume, accounting for 7.99% of total publications. This is followed by the themes “Teacher Competencies” (7.49%) and “Technology Integration” (7.04%). Together, these three themes cover approximately 22.5% of the dataset. Themes with a medium publication volume include “Teacher Roles in Online Learning Design” (6.57%), “Collaborative Learning (CSCL)” (6.28%),

and “Cognitive Load and Multimedia” (6.16%). Themes with lower publication volume include areas such as “Digital Literacy” (1.93%) and “Online Learning Strategies” (1.64%).

Another step taken within the scope of the first research question was the identification of meta-themes based on the themes that emerged. These themes were grouped into broader meta-themes, considering their common characteristics and conceptual similarities. The conceptual affinities of the themes obtained through topic modeling analysis, the research contexts they represent, and their counterparts in the literature were used as the basis for the creation of meta-themes. In this process, themes with similar focuses were brought together and grouped under higher-level conceptual frameworks. Furthermore, the classification of meta-themes was supported by the opinions of subject matter experts, thereby enhancing the validity and reliability of the thematic integrity.

For example, the themes of “Teacher Competencies”, “Online Learning Roles”, and “Technology Integration” were evaluated together and classified under the meta-theme “Teacher Professional Competence and Technology Adoption.” Thus, the statistical outputs were presented within a conceptual framework, allowing the thematic development of the field to be interpreted at a higher level. This structure enables the results of the topic modeling analysis to be interpreted collectively through similar themes, thereby supporting broader and more comprehensive conclusions. The meta-themes created are shown in Figure 2.

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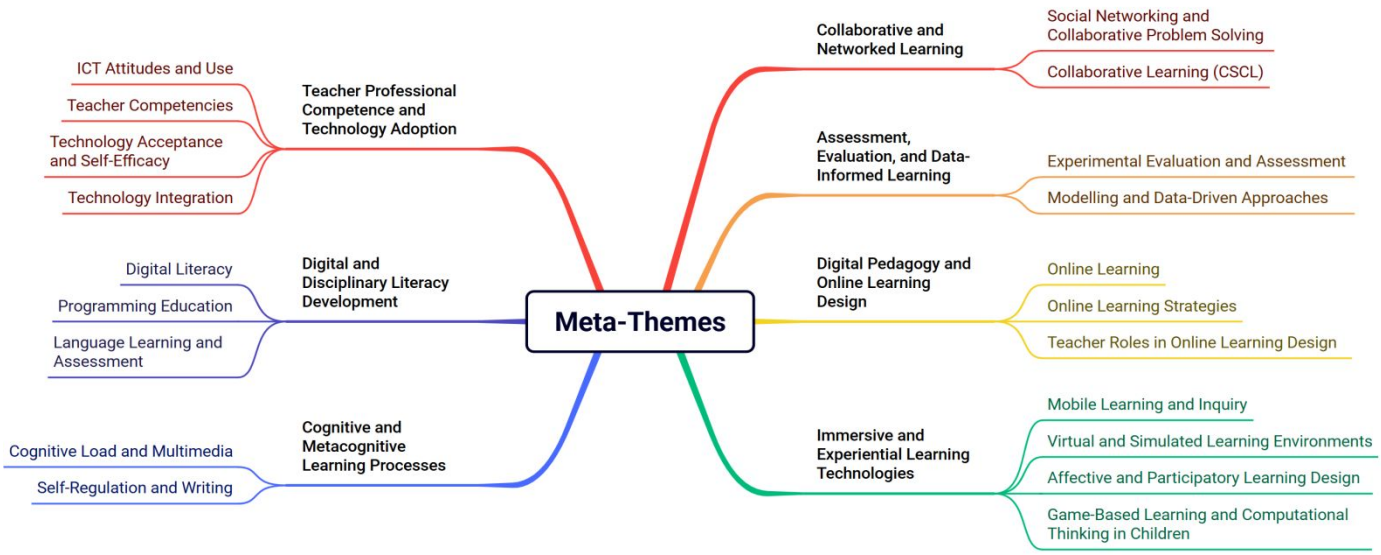

Figure 2. Meta-Themes Identified in Educational Technology Research

As shown in Figure 2, seven main meta-themes were identified in the study:

1. "Teacher Professional Competence and Technology Adoption" addressing teachers' professional competencies and technology integration.
2. "Digital and Disciplinary Literacy Development" encompassing digital literacy, programming, and language learning processes.
3. "Cognitive and Metacognitive Learning Processes" covering cognitive load, multimedia learning, and self-regulation processes.
4. "Collaborative and Networked Learning," relating to collaborative learning and problem solving through social networks.
5. "Assessment, Evaluation, and Data-Informed Learning," focusing on assessment and data-driven approaches.
6. "Digital Pedagogy and Online Learning Design," addressing online learning strategies and pedagogical designs.

In Peer Review

7. “Immersive and Experiential Learning Technologies” encompassing experiential technologies such as mobile learning, virtual/simulated environments, and game-based learning.

This structure demonstrates a comprehensive classification of the fundamental research foci of the educational technology field.

Changes in Prominent Themes and Meta-Themes in the Field of Educational Technology Over Time (RQ2)

The second research question examined the annual distribution and changing trends of prominent themes and meta-themes in the field of educational technology over the past 25 years. In this context, the number of publications for each theme was calculated, excluding 2025 (as the year was not yet complete), and the trends were visualized. This enabled a comparative analysis of the increasing or decreasing trends of themes over time and revealed their periodic intensities.

The change in the identified themes was analyzed in two different ways. The first was a heat map presenting the evolution of all themes across the years (Figure 3). The color transitions in Figure 3 display publication intensity by year: light colors indicate low intensity, while darker tones indicate higher publication intensity for the relevant theme.

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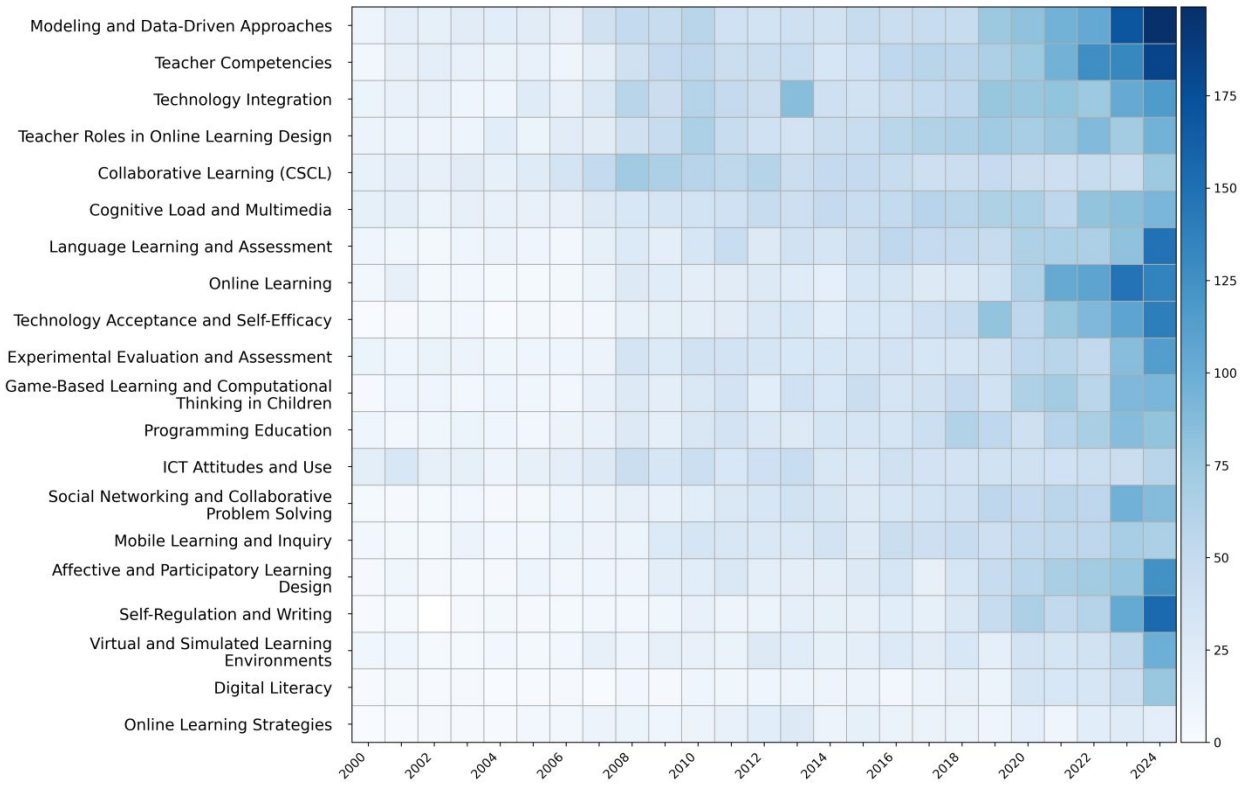

Figure 3. Distribution of Themes Over Years (Compact Heatmap)

When examining Figure 3, it is observed that the themes "Teacher Competencies" and "Modelling and Data-Driven Approaches" have consistently been focal areas of research since the early years, despite periodic declines. After 2015, a noticeable increase occurred in the themes "Technology Integration" and "Teacher Roles in Online Learning Design," which can be directly attributed to the growing digitalization of education and the global shift to online learning. Furthermore, certain themes, such as "Assessment in Digital Learning" and "Teachers' Technology Integration," have periodically risen in prominence, reflecting temporal surges in scholarly interest. The heat map therefore reveals both the continuity of long-established themes and the growing significance of emerging topics, suggesting that transformation in the field is driven by both technological advances and pedagogical demands.

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After presenting the heat map, the slopes of the themes were calculated to examine their acceleration rates over time. This approach, based on publication frequency per year, enabled the identification of long-term trends, revealing which themes were rising, stable, or declining. Figure 4 presents a comparative analysis of the rate of change in publication numbers for each theme between 2000 and 2024.

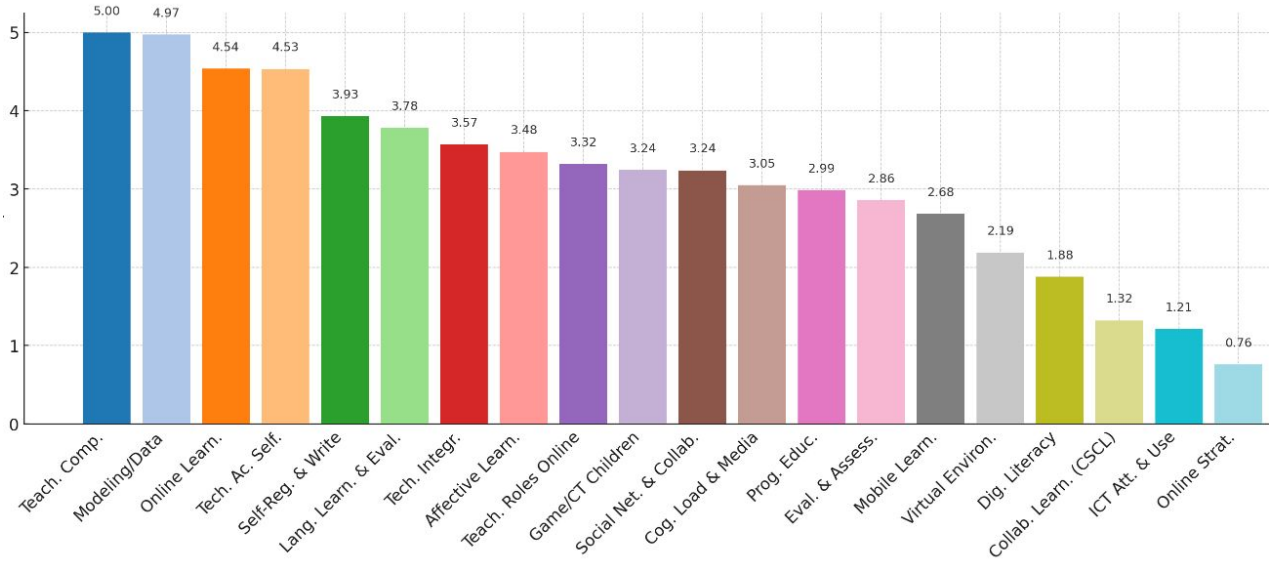

Figure 4. Slope Values of Themes

The results indicate that all themes exhibit positive slopes, reflecting an overall increase in publication activity. The themes with the highest slope values are "Teacher Competencies," "Technology Acceptance and Self-Efficacy," and "Self-Regulation and Writing," while other themes show smaller yet consistent increases. The values above each bar represent the linear slope coefficient for the respective theme.

The analysis also examined the annual change in publication numbers across meta-themes. A line graph based on publication data from 2000 to 2024 (Figure 5) illustrates these distributions.

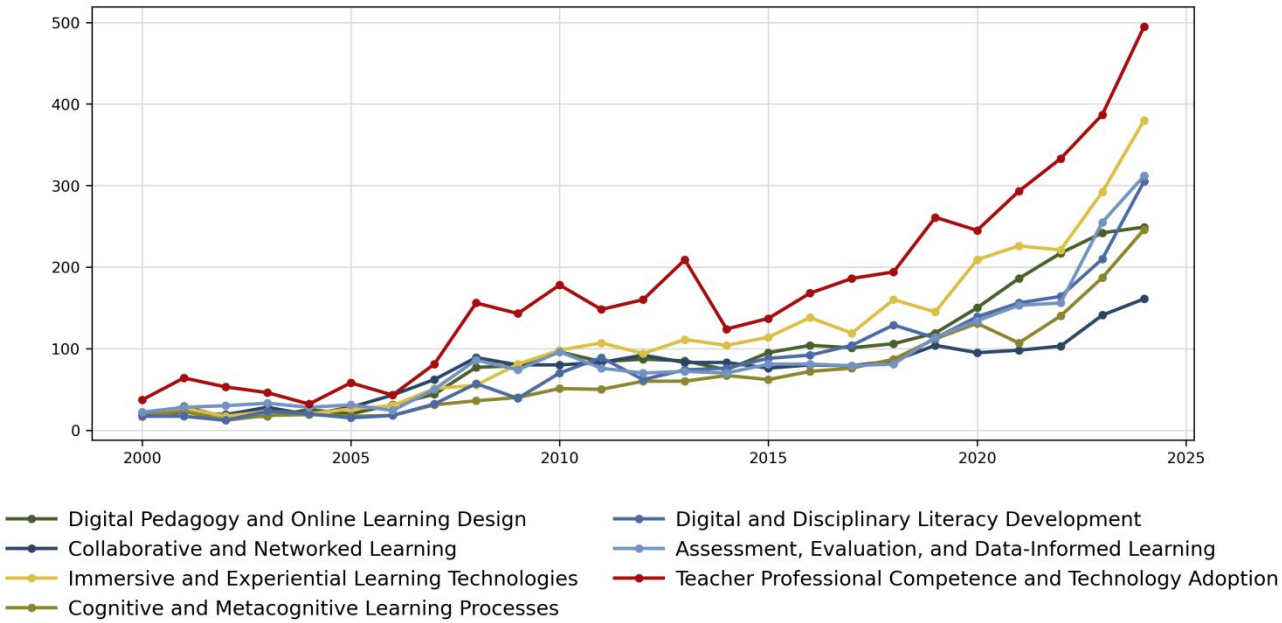

Figure 5. Number of Publications by Meta-Theme by Year

As shown in Figure 5, "Teacher Professional Competence and Technology Adoption" achieved the highest number of publications throughout the entire period, while "Immersive and Experiential Learning Technologies" and "Assessment, Evaluation, and Data-Informed Learning" have shown noticeable growth in recent years. Other meta-themes exhibit more balanced distributions, demonstrating steady upward trends over time.

Relationships and Interaction Networks Among Prominent Themes in the Field of Educational Technology (RQ3)

The third research question focused on evaluating themes that emerged in the field of educational technology not only as individual entities but also in terms of their conceptual similarity and levels of overlap. Research trends in the literature often cluster around points where certain themes exhibit high conceptual similarity, which in turn paves the way for the emergence of new subfields. Therefore, the relationships between themes were measured using the Jaccard similarity coefficient, and the results were visualized through a heat map (see Figure 6). This systematically

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revealed which themes had strong conceptual commonalities and which remained more distinct. Such visualization allows for a more interpretive understanding of the conceptual architecture of the field.

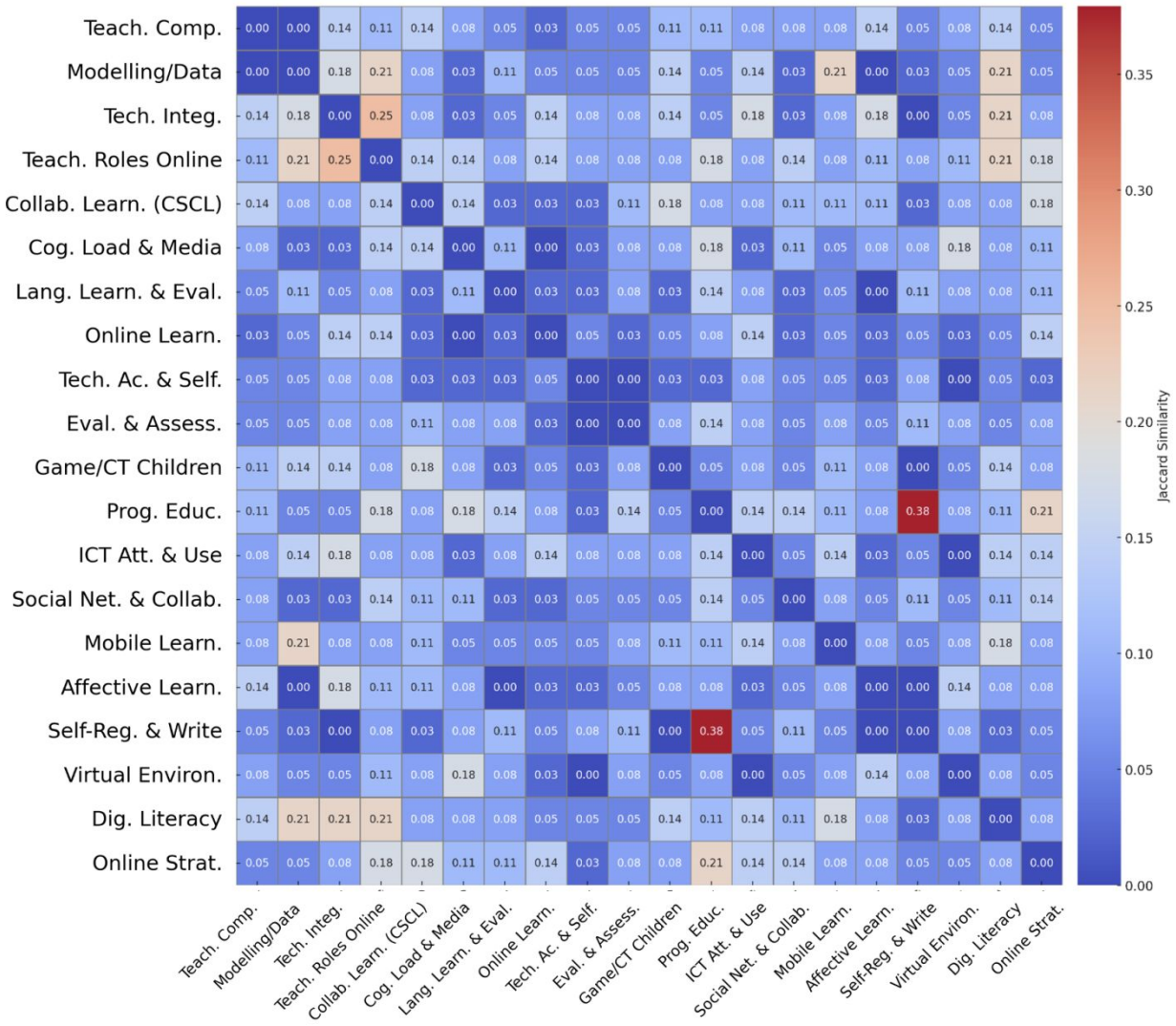

Figure 6. Heat Map of Similarities Between Themes

When examining Figure 6, it is observed that there are high levels of similarity between some themes, while in others, these similarities are limited. For example, the similarity coefficient between "Programming Education" and "Self-Regulation and Writing" shows the highest value at 0.38, while the similarities between "Technology Integration" and "Teacher Roles in Online

Learning Design" (0.25) and between "Teacher Competencies" and "Teacher Roles in Online Learning Design" (0.21) are also noteworthy. Similarly, a relatively high similarity is observed between "Collaborative Learning (CSCL)" and "Online Learning Strategies." On the other hand, it is noteworthy that some themes, such as "Digital Literacy," have lower similarity values with other themes.

The patterns in the heat map also show strong alignment with the identified meta-theme clusters. The themes under the meta-themes "Teacher Professional Competence and Technology Adoption" and "Digital Pedagogy and Online Learning Design" appear to have strong conceptual commonalities with each other. Similarly, high levels of similarity are also noticeable among the themes within the "Collaborative and Networked Learning" meta-theme. In contrast, themes that are more independently positioned, such as "Programming Education," while related to the "Digital and Disciplinary Literacy Development" meta-theme, exhibit limited connections to other clusters.

In general, the heat map reveals that similarities in themes are not evenly distributed across the field of educational technology, with more pronounced clusters in certain areas. Strong conceptual overlaps are particularly evident in areas such as teacher competencies, online learning roles, and collaborative learning strategies, while more limited commonalities emerge in areas such as programming education and digital literacy. These findings illustrate the multi-layered and interdependent nature of educational technology research, where both convergence and differentiation coexist within the thematic landscape of the field.

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Research Gaps in the Field of Educational Technology (RQ4)

The fourth research question aimed to reveal both the status of prominent themes in the field of educational technology over the past twenty-five years, and their development trajectories and potential directions for future inquiry. The literature shows that some themes have matured over time and achieved a certain stability, while others have rapidly risen or shown a decline. Therefore, research gaps and emerging topics were systematically examined by considering both the publication volumes, growth rates, and continuity of the themes. This reveals not only the field's past development trajectory but also provides insight into potential future research directions.

Figure 7 provides a visual representation of this approach, with themes positioned across four research areas: (i) high volume–high growth (mature and accelerating areas), (ii) low volume–high growth (emerging and high-potential areas), (iii) high volume–low growth (maturing areas), and (iv) low volume–low growth (niche and lagging areas). The vertical (n = 800) and horizontal (slope = 0.155) threshold lines in Figure 7 were determined based on the mean values of publication volume and growth rates across all themes, thereby providing a data-driven and balanced quadrant classification. This structure provides a comprehensive view of both current trends and strategic opportunities for scholarly development.

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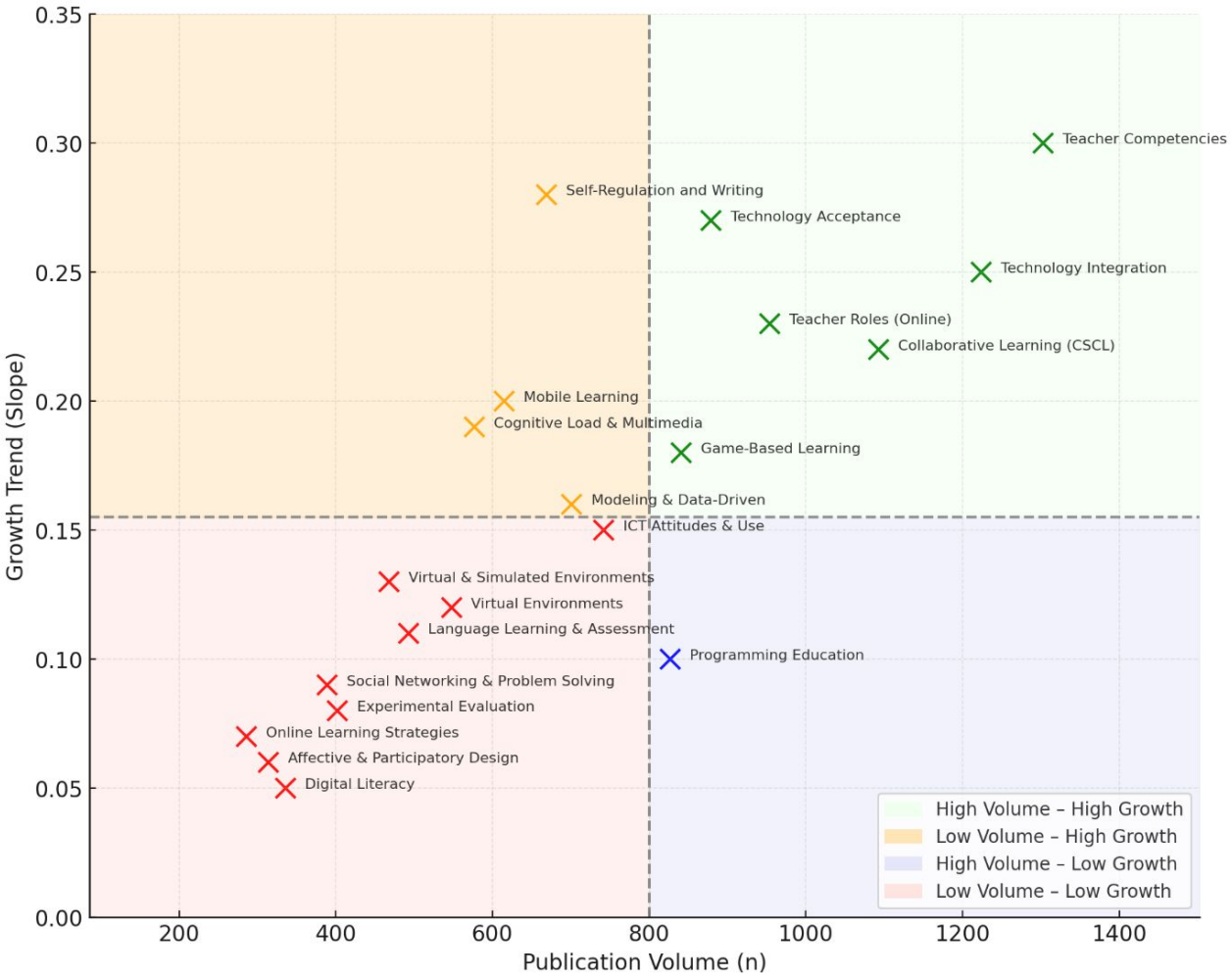

Figure 7. Four-Region Analysis Based on Publication Volume and Growth Trend of Themes

Figure 7 shows the distribution of prominent themes in the field of educational technology according to their total publication volume and growth trends. The dashed lines in the graph divide the field into four regions, using the 800-publication threshold and the median of growth values as references. The analysis revealed that five themes formed a strong cluster with high publication volume and high growth trend ("Teacher Competencies," "Technology Integration," "Collaborative Learning (CSCL)," "Teacher Roles (Online)," "Technology Acceptance"). Two themes stand out as emerging new foci, exhibiting high growth despite low publication volume; "Self-Regulation and Writing" and "Mobile Learning" are particularly noteworthy in this group.

"Programming Education," while having a high publication volume, has remained stagnant as a theme with limited growth. Finally, three themes ("Digital Literacy," "Experimental Evaluation," "Language Learning & Assessment") with low publication volume and low growth trends stand out as weaker areas of focus.

In general, the findings of the analysis show that the strongest areas of focus are forming in the high volume–high growth region, while new and rapidly developing research areas are emerging in the low volume–high growth region. This pattern reveals that both mature and emerging themes coexist in the field of educational technology, thus pointing to diverse developmental pathways and multiple potential directions for future research.

DISCUSSION

This study set out to identify and interpret the thematic evolution of educational technology research over the past twenty-five years by applying Latent Dirichlet Allocation (LDA) topic modelling to 17,393 research articles drawn from ten leading journals. The analysis revealed twenty themes clustered into seven broader meta-themes, offering a panoramic view of how the field has evolved in scope and emphasis since 2000. The most salient finding was the consistent dominance of themes related to teacher professional competence and technology adoption, coupled with an acceleration of interest in modelling and data-driven approaches. From a pedagogical perspective, this finding suggests that professional development initiatives should prioritize not only technical skill acquisition but also teachers' pedagogical reasoning, reflective practice, and adaptive technology integration capacities. At the policy level, it points to the need for systemic, long-term professional learning frameworks rather than short-term, tool-oriented training programmes. These results position the study as a significant contribution to understanding the

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intellectual trajectory of educational technology, highlighting how the field has matured from early concerns with technology integration to more data-oriented and pedagogically nuanced paradigms.

From a longitudinal perspective, the findings suggest that the conceptualization of technology in education has shifted from viewing digital tools as supplementary aids to understanding them as structuring forces within teaching and learning ecologies. Early peaks in research on teacher competencies and technology integration mirror the field's historical orientation towards implementation and acceptance studies (Bond et al., 2019; Zawacki-Richter & Latchem, 2018). However, the emergence and sustained growth of data-driven and modelling approaches signal a paradigmatic move towards evidence-based and computationally informed educational decision-making (Helbig et al., 2021; Timotheou et al., 2023). This evolution aligns with recent reviews noting the increasing convergence between educational data science, learning analytics, and instructional design (Aslan & Ozyurt, 2025; Douard et al., 2025). Moreover, the rise of themes such as immersive and experiential learning technologies demonstrates how the field has progressively broadened to include affective, cognitive, and sensory dimensions of learning, extending beyond cognitive-behavioral models prevalent in earlier research (Goksu et al., 2022; Torres-Vergara et al., 2025). In this context, recent literature reviews highlight the growing integration of augmented and virtual reality, gamification, and simulation-based environments in educational settings (Aydin & Cakir, 2025; Lampropoulos et al., 2022). This observation supports the theme's growth momentum and underscores the future potential of immersive and experiential learning. In applied terms, these findings indicate that schools and higher education institutions increasingly require investment not only in technological infrastructure but also in ethical data literacy, pedagogically grounded implementation strategies, and the development of critical awareness regarding algorithmic systems. At the policy level, the growing prominence of data-

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driven and immersive technologies underscores the importance of national strategies and regulatory frameworks that address data governance and equity of access in educational technologies. In this sense, the present analysis both confirms and refines existing meta-analytical insights, showing that while foundational concerns with pedagogy and access persist, EdTech has become increasingly hybridized, anchored in both humanistic and data-intensive epistemologies.

The findings also help clarify long-standing debates about the identity and coherence of educational technology as a research domain. Prior bibliometric studies have often highlighted fragmentation across subfields (Bond et al., 2019; Gurcan et al., 2021), suggesting that EdTech functions as a meta-field integrating diverse traditions rather than a unified discipline. The present thematic synthesis partially corroborates this view, yet the co-occurrence networks and meta-theme clusters reveal that intellectual convergence is stronger than previously assumed. For instance, the high conceptual overlap between teacher roles in online learning, technology integration, and collaborative learning implies the emergence of integrative pedagogical frameworks that transcend traditional subdomain boundaries. The sustained expansion of digital and disciplinary literacy research further demonstrates the field's growing responsiveness to global shifts in digital citizenship and competency-based education. In this regard, although digital literacy is underrepresented, its strategic importance remains high. The literature highlights that factors such as teacher education, infrastructure, and policy support are key to advancing digital literacy (Andersen et al., 2024; Liu & Xu, 2025). Hence, the lack of representation may stem not from irrelevance but from systemic barriers. Thus, rather than confirming disciplinary fragmentation, this study suggests that educational technology is undergoing a process of theoretical consolidation, where digital pedagogy, data analytics, and professional competence increasingly coalesce around shared methodological and ethical concerns.

For Peer Review

Implications for Practice and Policy

Translating these findings into practical implications, the identification of high-growth areas such as modelling and data-driven learning demonstrates the need for enhanced professional capacity-building and ethical regulation within educational systems. As the datafication of education accelerates, questions of algorithmic transparency, learner privacy, and responsible AI integration require urgent institutional attention (Helbig et al., 2021). For practitioners, the growth of research on teacher competencies and technology self-efficacy points to sustained demand for professional development programmes that integrate pedagogical innovation with digital fluency. Conversely, underrepresented areas such as online learning strategies and digital literacy may indicate either perceived maturity or insufficient innovation. Similarly, despite its strong connection to self-regulation and writing skills, programming education is notably underrepresented in publications. The literature emphasizes its role in enhancing cognitive strategy development, problem-solving, and self-management skills (Loksa et al., 2022). This suggests that programming education has not yet been fully integrated into curricula or that practitioner support remains limited, positioning it as a strategically significant area for future growth. Policymakers and research funders should therefore consider whether these domains are genuinely saturated or merely overlooked in favor of more technologically fashionable topics. Large-scale topic modelling analyses such as this can thus serve as strategic instruments for evidence-informed policy, guiding curricular reform, prioritizing research investments, and identifying where pedagogical renewal or systemic support is most needed.

Limitations and Future Research

While the methodological framework employed here offers a robust macro-level synthesis, its interpretive boundaries must be acknowledged transparently. The analysis focused exclusively on

For Peer Review

ten high-impact journals, thereby privileging mainstream English-language discourse and potentially underrepresenting regional or practice-oriented publications. This selection was deliberate, reflecting the intention to capture the field's central intellectual corpus rather than its full global diversity. Nonetheless, such corpus-based boundaries inevitably shape interpretive outcomes. Similarly, while topic modelling excels at identifying latent semantic structures and long-term thematic shifts, it cannot capture the nuanced theoretical debates, methodological innovations, or epistemic tensions that underpin individual studies (Jacobi et al., 2016; Syed & Spruit, 2017). The findings should therefore be read as interpretive generalizations that map broad intellectual trajectories rather than definitive claims about conceptual homogeneity. In this sense, computational text analysis serves as a complement, not a replacement, for qualitative synthesis and expert-driven interpretation.

Looking ahead, the results of this study provide a strategic roadmap for future inquiry in educational technology. The observed acceleration of data-intensive and immersive learning research suggests a need for cross-disciplinary integration between computer science, cognitive psychology, and educational design. Emerging areas such as self-regulation and writing, mobile learning, and AI-supported pedagogy appear particularly promising for subsequent theoretical and empirical exploration. In this context, the mobile learning theme, despite its low publication volume, demonstrates a high growth rate and holds considerable forward-looking potential, as highlighted in recent studies (Asadullah et al., 2023; Garzón et al., 2025). Furthermore, future research could expand the present approach by including a greater sample of journals to capture more diverse epistemological perspectives. In addition, future studies may enrich this line of inquiry by incorporating citation-based impact indicators and geographical dimensions, which

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could offer deeper explanatory insights into the differential influence and global distribution of themes.

CONCLUSION

In conclusion, this study demonstrates the value of using LDA based topic modeling as a tool for mapping and interpreting the long-term evolution of educational technology research. Substantively, it offers a panoramic view of how the field has diversified and consolidated over twenty-five years, tracing its movement from early implementation studies to complex, data-informed pedagogical ecosystems. Methodologically, it exemplifies how topic modelling can complement bibliometric and qualitative reviews by revealing macro-structural dynamics that are otherwise difficult to identify. Together, these contributions advance both the empirical understanding and the methodological toolkit of educational technology scholarship. By situating the field's intellectual development within its broader technological and pedagogical contexts, this study provides a foundation for more reflective, integrative, and strategically informed research in the decades to come.

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