Emerging Research Fronts in the Digital Educational Ecosystem: A Systematic Qualitative and Quantitative Analysis

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ABSTRACT

The digital educational ecosystem has undergone rapid evolution through the integration of modern digital technologies, transforming teaching, learning, and research practices within higher education. This study conducts a systematic qualitative and quantitative analysis of emerging research fronts in this dynamic field, utilizing bibliometric data from Scopus spanning the years 2019-2023. Key research fronts identified include Digital Assessment, Blockchain, Artificial Intelligence, Lifelong Learning, and Online Learning, each demonstrating significant growth and influence on educational practices. The study introduces innovative metrics, including Growth Rate (R), the gap between the publication years of published and citing papers (ΔT), and the Emerging Factor (EF), to assess the prominence and immediacy of these research areas. Findings reveal that Digital Assessment and Blockchain are the most rapidly emerging topics, driven by their increasing growth rates (R) and the proximity of average publication years (T) between published and citing papers. The geographical analysis highlights substantial contributions from leading institutions in the United States, China, and Europe, underscoring the global nature of research in the digital educational ecosystem. This study provides critical insights for educators, policymakers, and researchers, offering a comprehensive overview of the current landscape and future directions in digital education research.

Keywords: Digital Educational Ecosystem, Emerging Research Fronts, Bibliometric Analysis, Digital Assessment, Blockchain in Education, Growth Rate, Emerging Factor Growth

1. Introduction

In recent years, the higher education sector has undergone a profound transformation driven by the integration of digital technologies across teaching, learning, research, and administration. This transformation has given rise to what is now known as the digital educational ecosystem, where tools such as artificial intelligence, blockchain, virtual reality, and online platforms converge to reshape pedagogical practices and institutional strategies (Nguyen & Tuamsuk, 2022; Chinchua et al., 2022). As universities adapt to this shift, it becomes increasingly important to identify which digital technologies and scholarly domains are emerging most rapidly, drawing academic attention and influencing future educational paradigms.

Research fronts, defined as clusters of thematically linked scholarly activities, serve as vital indicators of these dynamic developments. Initially conceptualized by Garfield (1955) and further refined by Price (1965), research fronts illustrate how new ideas disseminate and gain momentum across academic communities. Their application in science and technology foresight is well established, particularly through Clarivate Analytics' use of bibliometric indicators to identify "hot" and "emerging" fronts (Research Fronts, 2024). For higher education institutions, such knowledge can inform strategic planning, policy formulation, and investment in innovation.

Despite the growing relevance of the digital educational ecosystem, most existing studies address individual technologies in isolation - such as artificial intelligence (Kaur et al., 2020; Hashim et al., 2022; Guo et al., 2024), virtual reality (Rojas-Sánchez et al., 2023), online teaching (Bao et al., 2020), educational technology (Bedenlier et al., 2020), gamification (Kummanee et al., 2020; Chinchua et al., 2022), and digital literacy (Wang & Jing, 2021; Yong, 2024). However, few have attempted to holistically map how these areas converge into broader research fronts that shape the digital transformation of higher education. This creates a significant gap in understanding the structure and trajectory of emerging knowledge in this domain. In particular, limited attention has been given to identifying and evaluating emerging research fronts those that may become the next major drivers of academic and institutional innovation.

To address this gap, the present study conducts a systematic bibliometric analysis using Scopus data from 2019 to 2023 to identify key emerging research fronts in digital education. By understanding how these research fronts evolve, universities and higher education institutions can better align their research strategies, curricular design, and digital transformation efforts. In particular, this study emphasizes scientific and geographical mapping at both institutional and national levels**,** identifying which universities and countries are leading contributors to these emergent domains. While the final discussion elaborates on these institutional implications, this paper also integrates this perspective throughout the analysis. Specifically, the study aims to answer the following questions: (i) How can quantitative metrics be formulated to determine emerging research fronts? (ii) What are the most prominent emerging research areas within the digital educational ecosystem? (iii) Which countries and institutions are the leading contributors to scholarly output in this field?

2. Literature Review

Concept of Research Front

The notion of research fronts emerged from Garfield's (1955) pioneering work on citation indexing. These fronts are structured around two key elements: core papers that are frequently cited, forming the foundational knowledge base, and citing papers that further develop and expand these ideas (Small & Griffith, 1974). This framework enables the tracking of established knowledge, as well as the dynamic progression of research innovations. Zheng et al. (2016) demonstrated the application of keyword co-occurrence analysis in identifying research fronts, emphasizing the effectiveness of bibliometric approaches in monitoring their development. Advanced techniques such as co-citation analysis and co-word analysis play a vital role in exploring these domains (Li & Chu, 2016). Mazov et al. (2020) offered a modern interpretation, describing research fronts as clusters of recently published works with shared topical interests, distinguished by dense internal citation links and relatively sparse external connections.

Existing Frameworks and Limitations

Research fronts are typically grouped into three primary categories: Emerging research fronts, which signal novel areas of investigation driven by innovative methodologies or unresolved issues; Hot research fronts, characterized by heightened academic engagement and rapidly increasing citations and outputs; and Impactful research fronts, which have a lasting impact on scholarly discourse, policy decisions, and industry practices. To classify and analyze the most influential research fronts, indicators and formulas, integrating key bibliometric parameters is commonly introduced.

Traditionally, hot research fronts have been identified primarily using Clarivate's CPT indicator, which is based on metrics such as the number of core papers and the volume of citing articles (e.g., Research Fronts, 2024; Chung & Cam, 2024). In such a study, the CPT indicator, which is defined as the ratio of the average citation impact of a research front to the age/occurrence of its citing papers and is calculated as follows:

$$CPT = \left(\frac{P_{citing}}{P_{core}}\right)/T_{citing} = \frac{P_{citing}}{(P_{core} \times T_{citing})} \quad (1)$$

where:

- P_{core} is the number of foundational core papers, i.e., the highly cited papers that are explicitly defined as papers that rank in the top one percent in terms of citations within the same Essential Science Indicator field and publication year. In studies analyzing research fronts within a specific field (e.g., digital education) (Chung & Cam, 2024), P_{core} has also been determined using the Hirsch index (H-index) (Hirsch, 2005).

- P_{citing} represents the number of citing articles, i.e., the total of articles citing the core papers;

- T_{citing} indicates the age of citing articles, which is the number of citing years, from the earliest year of a citing paper to the latest one.

In this case, the higher the CPT number, the hotter or more impactful the topic.

CPT is the ratio of the average citation (P_{citing}/P_{core}) of a research front to the age/occurrence of its citing papers (T_{citing}), meaning the higher the average citation, the hotter or more impactful the topic. It measures the extent and immediacy of a research front and can be used to explore the developing aspects of research fronts and to forecast future possibilities. The degree of citation impact can also be

seen from CPT, which considers the average publication years of citing papers and demonstrates the trend and extent of attention on specific research fronts over time.

This CPT approach emphasizes the core number of published articles (P_{core}) and their citations (P_{citing}). It does not account for the growth rate (R) and the interaction between published (or core) and citing publications. Notably, the growth rate (R) of both published and citing articles is absent, which is crucial for understanding extensive and immediate trends. To identify impactful research trends, it is essential also to consider publication productivity (S). Specifically, examining the gap between the average publication years of published and citing papers, T_{pub} and T_{citing}, respectively, can offer valuable insights. A narrower gap ($\Delta T = T_{citing} - T_{pub}$) indicates emerging trends and suggests stronger alignment with global research directions.

Toward a New Analytical Framework for Digital Education

To address the gaps mentioned above, recent work by Chung & Cam (2025) proposed an Impact Factor (IF) for evaluating research fronts in the digital educational ecosystem by incorporating the total productivity (S_{pub}) and growth rate (R_{pub}) of published publications. Building on this, the present study introduces an Emerging Factor (EF) that incorporates three key bibliometric components: the growth rate of published papers, the growth rate of citing papers, and the time gap between the average publication years of the published and citing papers. This framework is specifically designed to capture emerging relevance—how quickly and extensively new research areas gain scholarly traction. The current study applies this enhanced framework to higher education-focused literature within the digital educational ecosystem.

Research fronts, when applied to digital education, do more than trace scholarly attention. They help identify the institutions and nations at the forefront of educational innovation. By mapping bibliometric indicators to affiliated universities and countries, one can assess not only the thematic evolution of digital education but also the geographic diffusion and institutional leadership driving that change. Despite the increasing volume of research on emerging technologies in education, prior bibliometric studies have rarely linked these trends back to organizational-level insights, such as which universities produce the most influential core papers or which national systems demonstrate leadership across research fronts. This study addresses that gap by integrating a geospatial lens into the analysis, enabling insights into both scientific concentration (research productivity and citation growth) and institutional strategy alignment within higher education ecosystems.

3. Methodology

Data Source and Keyword Selection

To address the research questions, bibliometric data were collected from the Scopus database, covering all publication types (journal articles and conference papers) from 2019 to 2023. The selection of high-frequency keywords was informed by a triangulated approach comprising: (i) a review of previous systematic reviews and bibliometric studies in the field of digital education; (ii) expert consultation with scholars and practitioners specializing in educational technology, instructional design, and digital pedagogy; and (iii) a pilot keyword frequency analysis using preliminary Scopus data from 2019–2023 to identify terms with consistently high relevance and citation linkage. This multifaceted process ensured that the selected keywords reflect both influential and emerging themes within the digital

educational ecosystem, aligning with historical research trends and forward-looking innovations. Ultimately, 17 keywords were selected for analysis based on the criterion that each exhibited either a total number of published or citing papers exceeding 1,000, or a publication/citation growth rate greater than 1.25. These keywords reflect key themes and technological trends shaping modern education, including Artificial Intelligence, Blockchain, Cloud Computing, Collaborative Learning, Digital Assessment, Digital Literacy, Educational Technology, Gamification, Hybrid Learning, Learning Analytics, Learning Management Systems, Lifelong Learning, Massive Open Online Courses (MOOCs), Mobile Learning, Online Learning, Personalized Learning, and Virtual Reality (see table 1). Each keyword represents a distinct domain within the digital education landscape, contributing to the formation of research fronts by addressing critical challenges and advancements.

The search syntax was formulated as follows: TITLE-ABS-KEY [("synonyms keyword terms") AND ("higher education" OR "university*" OR "college*")] (see also Table 1). This approach was carefully designed to ensure both the validity and reliability of the data collection process. After a thorough manual review, the results, along with all available bibliometric information, were exported in CSV format for further analysis.

Table 1: Research fronts and keywords using synonyms in the search string. The total number of published (P_{pub}) and citing (P_{citing}) papers from the period of 2019-2023 is included.

No	Research front	Keywords and Synonyms terms	P_{pub}	P_{citing}
1.	Artificial Intelligence	"Artificial Intelligence" OR "Machine Learning"	11572	15848
2.	Blockchain	"Blockchain"	737	1883
3.	Cloud Computing	"Cloud Computing" OR "Internet-based computing"	1020	1880
4.	Collaborative Learning	"Collaborative Learning" OR "Cooperative Learning"	1933	3571
5.	Digital Assessment	"Digital Assessment" OR "Online Assessment"	557	2192
6.	Digital Literacy	"Digital Literacy" OR "Digital Competence" OR "Digital Skill"	1447	2356
7.	Educational technology	"Learning technology" OR "Educational technology"	2135	4541
8.	Gamification	"Gamification"	1347	2105
9.	Hybrid Learning	"Hybrid Learning" OR "Blended Learning" OR "Hyflex Learning"	2499	3816
10.	Learning Analytics	"Learning Analytics" OR "Academic Analytics" OR "Learning Data Analysis"	1094	3045
11.	Learning Management Systems	"Learning Management Systems" OR "LMS"	1372	2604
12.	Lifelong Learning	"Lifelong Learning" OR "Lifelong Education"	555	1420
13.	Massive Open Online Courses	"Massive Open Online Courses" OR "MOOC"	1109	1907
14.	Mobile Learning	"Mobile Learning" OR "M-learning"	1081	3117
15.	Online Learning	"Online Learning" OR "E-learning" OR "Distance Education"	17675	17350
16.	Personalised Learning	"Personalised Learning" OR "Individualised Learning"	310	945
17.	Virtual Reality	"Virtual Reality"	3221	4752

Instrumentation and Analytical Tools

To extract publication and citation statistics, this study primarily utilized Scopus's built-in analytics features, including the Document Search, Analyze Search Results, and Citation Overview tools. These were used to determine the total and annual number of publications (P_{pub}) and citations (P_{citing}) for each research front, as well as to calculate the average publication year (T_{pub}) and average citation year (T_{citing}) across the period from 2019 to 2023. Subsequent metrics, such as growth rates (R_{pub}, R_{citing}), the time gap (ΔT), and finally, the Emerging Factor (EF), were computed in Microsoft Excel using

standardized formulas. The combination of Scopus's validated citation data and transparent Excel-based computation ensured both accuracy and replicability in the analysis.

Scopus's built-in Citation Overview and Analyze Search Results tools were utilized to extract institutional affiliation data and country-level contributions, enabling scientific and geographical mapping at two levels.

- Institution-level: Identifying top universities contributing to core publications in each emerging research front (e.g., the University of Illinois Urbana-Champaign in Digital Assessment; Universitas Raharja in Blockchain).
- Nation-level: Mapping national scientific output (e.g., U.S., China, South Africa) in terms of publication volume and core contribution to emerging areas.

In total, 122,899 papers, including 49,664 published (P_{pub}) and 73,335 citing (P_{citing}) papers, were retrieved from Scopus between 2019 and 2023 across the 17 identified research fronts. The total number of published and citing papers for each research front is included in Table 1.

Metric Formulation

Figure 1 illustrates the search string and analysis process, outlining the various steps involved in the process. The source data consists of Scopus's annual number of published papers at year y ($S_{pub}(y)$). At the first output level (Output 1), the growth rate (R_{pub}) is calculated according to the following equation:

$$R_{pub} = \frac{S_{pub}(y=2023)}{S_{pub}(y=2019)} \quad (2)$$

Additionally, the average published year (T_{pub}) is calculated based on the annual published papers in year y ($S_{pub}(y)$):

$$T_{pub} = \frac{\sum_{y=2019}^{2023} y \times S(y)}{\sum_{y=2019}^{2013} S(y)} \quad (3)$$

At the second output level (Output 2), the step involves determining the annual number of citing articles at year y ($S_{citing}(y)$), i.e., the number of articles citing the published papers, and determining the growth rate (R_{citing}) and the average citation year (T_{citing}) using similar formulas to eq. (1) and (2), respectively:

$$R_{citing} = \frac{S_{citing}(y=2023)}{S_{citing}(y=2019)} \quad (4)$$

$$T_{citing} = \frac{\sum_{y=2019}^{2023} y \times S_{citing}(y)}{\sum_{y=2019}^{2013} S_{citing}(y)} \quad (5)$$

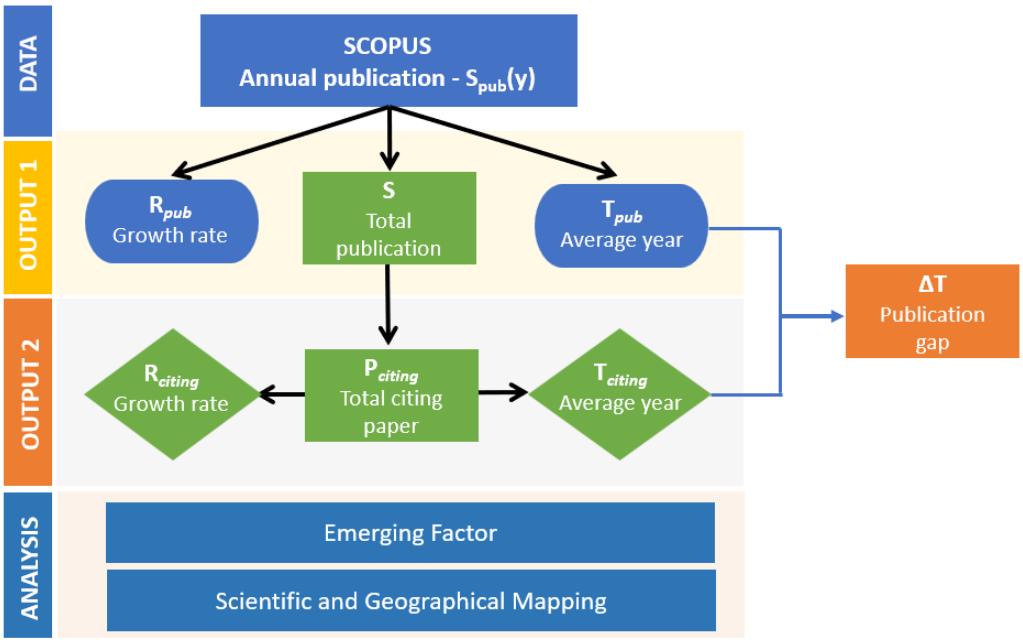

Figure 1. The search string and analysis process

Regarding emerging aspects, the immediacy of the published papers is a priority, which is why they are characterized as "emerging." To identify emerging specialties, the growth rates of R_{pub} and R_{citing} are key indicators. Additionally, the average year of publication of the papers (Tpub) and those cited (T_{citing}) offer valuable insights. The closer T is to the present, the more it reflects emerging trends. In particular, the narrower gap between the publication years of published and citing papers (ΔT) suggests a stronger resonance with global research trends.

ΔT is evaluated as a consequence of the first and second output levels (Fig. 1):

$$\Delta T = T_{citing} - T_{pub} \quad (6)$$

The analysis process also includes the calculation of the Emerging Factor (EF) along with Scientific and Geographical Mapping. The EF is determined using the following formula:

$$EF = \frac{R_{pub} \times R_{citing}}{\Delta Y} \quad (7)$$

4. Results and Discussion

Emerging Research Fronts

Table 2 presents the number of annual published $S_{pub}(y)$ and citing papers $S_{citing}(y)$ for various research fronts within the digital educational ecosystem, collected from the Scopus database from 2019 to 2023. Artificial Intelligence has the highest number of both published and citing papers, indicating its leading position in terms of research impact and academic activity. Online Learning ranks second in both published and citing papers, reflecting the significant attention it received, particularly during the pandemic years. Virtual Reality shows consistent growth, indicating its increasing relevance in digital

education. Educational Technology and Hybrid Learning also have substantial numbers of citing papers, suggesting they are prominent areas of ongoing research.

Table 2: The number of annual published papers – $S_{pub}(y)$ and citing papers – $S_{citing}(y)$ collected from Scopus database from 2019 to 2023

No	Topic keyword	Published papers - $S_{pub}(y)$					Citing Papers – $S_{citing}(y)$				
		2019	2020	2021	2022	2023	2019	2020	2021	2022	2023
1	Artificial Intelligence	1256	1740	2435	2731	3410	744	4021	10573	19053	29261
2	Blockchain	70	109	145	181	232	27	234	508	1054	1516
3	Cloud Computing	187	188	254	235	156	102	364	873	1360	1664
4	Collaborative Learning	357	449	376	375	376	125	814	1866	3061	3987
5	Digital Assessment	37	73	143	156	148	16	160	665	1232	1399
6	Digital Literacy	158	244	301	360	384	62	459	1105	1880	2729
7	Educational technology	492	457	382	400	404	234	987	2221	3297	4404
8	Gamification	196	215	272	311	353	89	471	974	1405	2070
9	Hybrid Learning	375	437	562	589	536	112	706	1933	3385	4414
10	Learning Analytics	187	232	210	217	248	117	586	1146	1879	2544
11	Learning Management Systems	249	272	303	269	279	89	511	1285	2043	2796
12	Lifelong Learning	88	93	110	117	147	16	175	486	841	1160
13	Massive Open Online Courses	219	246	254	214	176	73	366	927	1501	1782
14	Mobile Learning	224	203	232	215	207	97	567	1199	1928	2676
15	Online Learning	2003	2812	4501	4455	3904	616	3411	10439	18285	23770
16	Personalized Learning	52	48	68	66	76	16	128	266	489	711
17	Virtual Reality	481	477	703	706	854	184	1138	2546	4442	6167

Regarding the emerging research fronts, key metrics such as the growth rates (Rpub and Rciting), the average publication year of published papers (Tpub) and citing papers (Tciting), the gap between the publication years of published and citing papers (ΔT) and Emerging Factor (EF), as defined in equations (2-7), are determined and listed in Table 3. The results indicate that the most emerging topics, as determined by the formula (6), are as follows: Digital Assessment (with EF = 627.0), Blockchain (EF = 310.1), Artificial Intelligence (RF = 158.4), Lifelong Learning (EF = 154.8), Online Learning (EF = 142.9), Digital Literacy (EF = 97.1), Virtual Reality (EF = 79.1), Personalized Learning (EF = 74.3), Hybrid Learning (EF = 64.0), and Gamification (EF = 62.2). Among these, Digital Assessment and Blockchain rank first and second, respectively, due to the convergence of the five key indicators (Rpub, Rciting, Tpub, Tciting, and ΔT), all of which are within the top five. Although Artificial Intelligence is ranked as the top impactful hot research topic (Tran Ai & Chung, 2025), it places third in emerging topics because its Rciting does not fall within the top five.

For better visualization of the variation in these key metric values across research fronts, the normalized data on R_{pub}, R_{citing}, ΔT and EF are presented in Figure 2. It also includes trendlines illustrating the relative influence and growth of these metrics across the topics.

The growth rate of citing papers (R_{citing}), shown by the orange bars, is consistently higher than that of core published papers (R_{pub}), indicated by the blue bars, across all topics. This imbalance highlights the significant impact and influence of these core published papers in driving new research. Topics such as Digital Assessment, Blockchain, and Artificial Intelligence have notably high Rciting values, further confirming their strong influence within the academic community.

Table 3: The values of the growth rates R_{pub} and R_{citing}, the average year of the published papers T_{pub} and citing papers T_{citing}, the gap between the publication years of published and citing papers ΔT and the Emerging Factor (EF) for the investigated research fronts

No	Topic keyword	Published papers		Citing papers		ΔT	EF
		R_{pub}	T_{pub}	R_{Citing}	T_{citing}		
1	Digital Assessment	4.000	2.548	87.438	3.105	0.558	627.0
2	Blockchain	3.314	2.537	56.148	3.137	0.600	310.1
3	Artificial Intelligence	2.715	2.458	39.329	3.132	0.674	158.4
4	Digital Literacy	2.430	2.393	44.016	3.083	0.691	154.8
5	Lifelong Learning	1.670	2.256	72.500	3.103	0.847	142.9
6	Online Learning	1.949	2.308	38.588	3.082	0.774	97.1
7	Virtual Reality	1.775	2.303	33.516	3.055	0.752	79.1
8	Personalized Learning	1.462	2.213	44.438	3.088	0.875	74.3
9	Hybrid Learning	1.429	2.190	39.411	3.069	0.880	64.0
10	Gamification	1.801	2.304	23.258	2.977	0.673	62.2
11	Learning Management Systems	1.120	2.042	31.416	3.033	0.991	35.5
12	Learning Analytics	1.326	2.098	21.744	2.980	0.882	32.7
13	Collaborative Learning	1.053	1.981	31.896	3.012	1.031	32.6
14	Mobile Learning	0.924	1.980	27.588	3.008	1.028	24.8
15	Massive Open Online Courses	0.804	1.894	24.411	2.979	1.086	18.1
16	Educational technology	0.821	1.891	18.821	2.956	1.065	14.5
17	Cloud Computing	0.834	1.985	16.314	2.944	0.959	14.2

The publication gap (ΔT), depicted by green bars, shows the average time difference between the publication of core papers and their subsequent citations. Topics such as Cloud Computing, Educational Technology, and Massive Open Online Courses display the largest ΔT values, indicating that these core publications took longer to be recognized and cited. In contrast, Digital Assessment, Blockchain, and Artificial Intelligence have shorter time gaps, suggesting quicker integration into ongoing research. Indeed, during the investigated period (2019-2023), the average year of publication of the papers ranged from 2020 to 2021, making them approximately more than one and a half years old. In contrast, the average year of the citing papers was slightly more recent, ranging from 2021,94 to 2022,14, indicating that the citing papers are relatively young, being less than a year old. Despite their youth, the growth rate of the citing papers is significantly higher, approximately 20 times greater, compared to that of the published papers. It reflects the high impact of the published papers in each research front on the global research community.

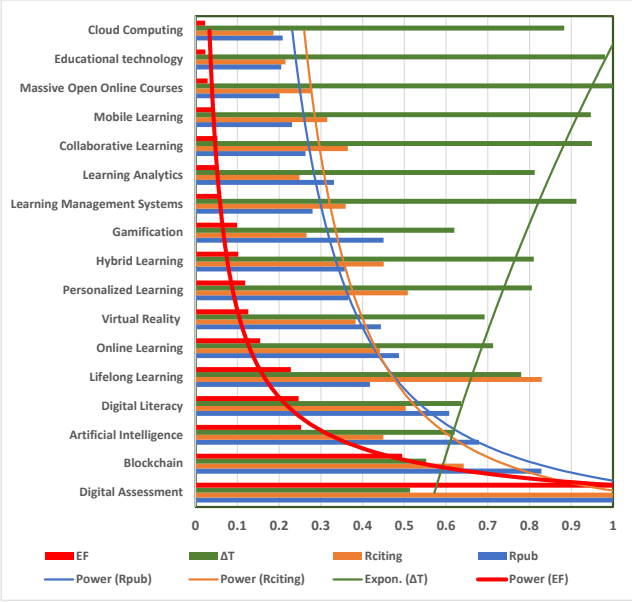

Figure 2. The normalized data on R_{pub}, R_{citing}, ΔT and EF across 17 research fronts in the digital educational ecosystem

For the first two emerging topics, Digital Assessment and Blockchain, the detailed data can be listed as follows. Digital Assessment: R_{pub} = 4.0, T_{pub} = 2021.55; R_{citing} = 87.438, Y_{citing} = 2022.11; ΔT = 0.56. Blockchain: R_{pub} = 3.314, T_{pub} = 2021.54; R_{citing} = 56.148, T_{citing} = 2022.14; ΔT = 0.600. The publication trends for Digital Assessment and Blockchain in higher education have shown remarkable growth from 2019 to 2023, reflecting increasing research interest and citation impact in these areas. Indeed, for the Digital Assessment, in 2019, there were only 37 published papers. This number increased significantly to 148 papers in 2023. Among 558 total published papers, the number of most highly cited core papers, which the H-index determines, is 32 (Hirsch, 2005; Tran Ai & Chung, 2025). The number of citing papers exhibited massive growth from 16 papers (in 2019) to 1339 papers (in 2023). Similarly, for the Blockchain, in 2019, initially, there were 70 published papers. This grew to 232 papers in 2023. The number of core papers is 40. The citing papers experienced substantial growth, increasing from 27 in 2019 to 1,516 in 2023. These trends underscore the growing importance of both Digital assessment and Blockchain technology in educational research, with a significant rise in both the volume of publications and the academic impact as measured by citations. The increase in citing papers for both digital assessment and Blockchain technology highlights their growing significance in academic discourse, positioning them as key emerging research fronts within the digital educational ecosystem. This trend suggests that these topics are not only gaining attention but are also likely influencing new studies and applications in higher education. As these fields continue to evolve, they are expected to play a crucial role in shaping the future of digital education, making them critical areas for ongoing and future research.

The Emerging Factor (EF), represented by the red bars. It shows that Digital Assessment has the highest EF at 627, followed by Blockchain and Artificial Intelligence, indicating that these topics have significantly driven follow-up research. The power curve for EF shows a decreasing trend, with only a few topics exhibiting extremely high EF values, while the majority show lower values. The trendlines illustrate the relative growth and impact of these metrics. The power trendline for R_{pub} shows a gradual increase in core publications, while the power trendline for R_{citing} reflects a steeper growth in citing papers. The exponential curve for ΔT, however, shows a decreasing time gap for more recent topics, indicating that newer research fronts are being adopted more rapidly by the research community. As a result, and consistent with the EF equation formulated in Eq. (6), these opposite trends between Rpub, Rciting, and ΔT strongly enhanced the emerging levels of Digital Assessment, Blockchain, and Artificial Intelligence, among others.

Overall, the figure highlights that recent topics, such as Digital Assessment, Blockchain, and Artificial Intelligence, have had a faster and more significant impact on ongoing research compared to older topics, like Cloud Computing and Educational Technology. The Emerging Factor metric highlights the disproportionate growth of citations for specific key research areas, reflecting their global influence and importance in the academic landscape. This ranking is highlighted below in connection with the obtained values of the key metrics.

Scientific and Geographical Mapping

Digital Assessment

Digital and online assessments utilize technology and internet platforms to evaluate student learning, replacing traditional paper-based methods (Heil & Ifenthaler, 2023; Redecker & Johannessen, 2019; Nicol, 2021). These assessments include various formats such as quizzes, essays, and interactive tasks,

typically administered through Learning Management Systems (LMS) like Moodle or Canvas (Gikandi et al., 2021).

Key components of this approach involve technology integration, with LMSs playing a central role in assessment delivery and grading. The assessment types employed include formative assessments, which provide ongoing feedback; summative assessments, used for final evaluations; adaptive assessments, which tailor difficulty to individual students (Bennett, 2019); and peer assessments, where students evaluate each other's work (Yousef & Sumner, 2021). Design considerations are crucial, focusing on ensuring validity, reliability, security, and accessibility in the creation and execution of these assessments.

Table 4: Top 5 countries and institutions producing core published papers in the research front on Digital and Online Assessment

Top-Contributing Institutions				Leading Countries		
Rank	**Affiliated institution**	**Country**	**Paper**	**Rank**	**Country**	**Paper**
1	University of Illinois Urbana-Champaign	USA	7	1	USA	60
2	University of South Africa	South Africa	7	2	Australia	47
3	University of Alberta	Canada	6	3	UK	41
4	University of Johannesburg	South Africa	6	4	South Africa	33
5	King Abdulaziz University	Saudi Arabia	6	5	Spain	31

The benefits of digital and online assessments include efficiency, as automated grading and quicker feedback streamline the evaluation process (Baird et al., 2017). These assessments also offer flexibility, as they can be accessed from any location, making them particularly useful in remote learning environments. Additionally, they provide valuable data analytics, offering insights into student performance and helping to identify areas where students may need additional support. However, challenges exist, such as technical issues related to connectivity and software reliability (Khan & Khan, 2019), inequities in access to technology (the digital divide), and concerns about academic integrity, which necessitate robust anti-cheating measures (Lancaster & Cotarlan, 2021).

Ultimately, the studies underscored the increasing importance of blockchain across various sectors. They emphasized the need for continued research, particularly in areas where blockchain intersects with emerging technologies like AI and big data. It is recommended that future research should focus on addressing existing challenges, such as scalability and regulatory issues, to fully leverage the potential of blockchain technology (Kuzior & Sira, 2022).

The geographical mapping data presented in Table 3 clearly shows that the University of Illinois Urbana-Champaign in the USA stands out as the leading institution in the research front of Digital and Online Assessment, contributing 7 papers. This highlights the university's significant role and leadership in advancing research within this field. Similarly, the University of South Africa and the University of Alberta have each produced 7 papers, highlighting their active roles in this area of research. The University of Johannesburg follows closely with 6 papers, further solidifying South Africa's growing presence and influence in digital assessment research.

From a country perspective, the United States is the most prolific contributor, with 60 papers, far surpassing other nations. This dominance indicates the substantial investment and prioritization of digital and online assessment research in the US, reflecting the country's leadership in educational innovation. Australia, with 47 papers, and the UK, with 41, also demonstrate significant engagement, highlighting their academic and research priorities in this evolving field. The core papers from Australia (6) and the UAE (5) are particularly notable, as they suggest these countries are not only contributing to the volume of research but also influencing foundational aspects of digital assessment practices.

South Africa's contribution of 33 papers is particularly noteworthy, given the presence of two universities, the University of South Africa and the University of Johannesburg, among the top five institutions in the country. This highlights South Africa's emerging role as a significant player in digital assessment research, particularly within the African context. Spain, with 31 papers, remains a key player in the global research landscape, demonstrating its significant strides in this field.

These results demonstrate a diverse geographical distribution in the research on Digital and Online Assessment, with significant contributions from institutions across multiple continents. The prominence of both established and emerging research institutions highlights the global significance of this field, indicating that digital and online assessments are being increasingly prioritized in various educational and technological contexts. The core papers from countries like Australia and the UAE emphasize the impact of their research on shaping foundational theories and practices in digital assessment, which may guide future developments and standardization efforts in this increasingly critical area of education.

Blockchain

Recent research on blockchain in the digital educational ecosystem underscores the growing interest in utilizing blockchain technology to enhance educational processes, particularly in areas such as credentialing, record-keeping, and data security (Raimundo & Rosário, 2021). These studies highlight blockchain's potential to create decentralized and tamper-proof systems for storing educational credentials, which facilitates easier verification by employers and institutions (Bhaskar et al., 2021). Furthermore, research has explored the ability of blockchain to support more transparent and efficient management of student data, thereby enhancing privacy and giving individuals greater control over their personal information (Juricic et al., 2019).

There is also significant attention to blockchain's role in fostering lifelong learning through the accumulation of verifiable micro-credentials across various educational platforms (Alsobhi et al., 2023). Scholars argue that blockchain could revolutionize traditional learning models by providing a framework for recognizing and validating informal and non-traditional learning experiences (Verma, 2022). Despite these promising applications, challenges such as scalability, regulatory concerns, and the necessity for widespread adoption are frequently noted (Loukil et al., 2021). The importance of overcoming these obstacles to fully realize blockchain's potential in education is emphasized by current research (El Koshiry, 2023).

Table 5: Top 5 countries and institutions producing published and core papers in the research front on Blockchain

Top-Contributing Institutions				Leading Countries		
Rank	**Affiliated institution**	**Country**	**Paper**	**Rank**	**Country**	**Paper**
1	Universitas Raharja	Indonesia	16	1	China	191
2	Bina Nusantara University	Indonesia	12	2	India	155
3	Bucharest University of Economic Studies	Romania	9	3	US	63
4	Kraków University of Economics	Poland	8	4	Indonesia	42
5	University Politehnica of Bucharest	Romania	6	5	UK	33

China leads the field in terms of overall publication productivity, with 191 papers, reflecting its strong focus on and investment in blockchain technology. China's dominance in this research area is further emphasized by its core contributions, positioning it as a global leader in advancing blockchain research. India and the United States also play significant roles, with 155 and 63 papers, respectively, showcasing their substantial involvement in the development and exploration of blockchain applications.

European institutions, such as the Bucharest University of Economic Studies in Romania and the Kraków University of Economics in Poland, also feature prominently, with 9 and 8 papers, respectively. This highlights Europe's growing interest in blockchain research, particularly in countries like Romania and Poland. The presence of institutions like the Politehnica University of Bucharest, which contributed 6 papers, further underscores Romania's active participation in this field.

These results suggest a diverse and widespread interest in blockchain research, with significant contributions coming from both established and emerging economies. The leadership of countries like China and the United States, along with the active participation of Indonesia and various European nations, points to a dynamic and rapidly evolving research landscape. The prominence of core papers from the United States and the United Kingdom suggests that these countries are not only producing a large volume of research but also significantly influencing the foundational theories and practices within the blockchain domain.

5. Conclusion

This study offers a comprehensive examination of emerging research trends within the digital educational ecosystem, utilizing both qualitative and quantitative methodologies. Through the analysis of bibliometric data from 2019 to 2023, key research fronts, including Digital Assessment, Blockchain, Artificial Intelligence, Lifelong Learning, and Online Learning, were identified as pivotal areas driving innovation in higher education. The introduction of metrics such as Growth Rate (R), the gap between the publication years of published and citing papers (ΔT), and the Emerging Factor (EF) enabled a nuanced assessment of the prominence and immediacy of these topics.

Digital Assessment and Blockchain emerged as the most rapidly evolving areas, underscoring their growing significance in educational practices. The geographical analysis revealed substantial contributions from institutions in the United States, China, and Europe, reflecting the global nature of research in this field. These findings underscore the pivotal role that emerging technologies and

practices play in shaping the future of education, offering valuable insights for educators, policymakers, and researchers.

As the digital educational ecosystem continues to evolve, ongoing research is essential to address existing challenges and to explore the potential intersections with other emerging technologies, such as Artificial Intelligence and Big Data. This study not only maps the current landscape but also sets the stage for future research that can further enhance the integration of digital technologies in education, ultimately improving educational outcomes and fostering innovation worldwide.
Finally, the findings of this study offer actionable insights for researchers, institutions, and policymakers. Identifying fast-growing research fronts, such as Digital Assessment, Blockchain, and artificial intelligence, not only reflects current academic attention but also highlights areas of innovation that are likely to shape the future of digital education. These results can inform strategic decisions related to funding allocation, research agenda development, and the integration of educational technology. Additionally, the geographical and institutional mapping sheds light on global research dynamics. Countries such as the USA, China, South Africa, and Romania, and institutions like the University of Illinois and Universitas Raharja, are emerging as key contributors. Understanding these patterns supports global benchmarking, capacity-building initiatives, and the formation of transnational research partnerships in digital education.

Conflict of Interest

The author declares that there is no conflict of interest.

Ethics approval and consent to participate

The author has reviewed the manuscript and has provided his consent for its publication.

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