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A Decade of Digital Economy Research in Education: A Bibliometric and Systematic Review of Trends, Gaps, and Future Directions

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ABSTRACT

The intersection of digital economy and education has gained significant academic attention over the past decade, particularly with the increasing influence of artificial intelligence, big data, and platform-based learning. However, a comprehensive understanding of the field's evolution remains limited. This study conducts a bibliometric and systematic review of 201 peer-reviewed journal articles published between 2014 and December 2024, retrieved from the Scopus database. The PRISMA framework guided the selection process. Bibliometric performance analysis and science mapping were carried out using VOSviewer, RStudio, Excel, and OpenRefine to explore publication trends, key themes, influential authors, and emerging research fronts. Findings reveal three dominant thematic clusters: technological innovation (e.g., economic growth, energy efficiency), advanced technologies (e.g., AI, big data, e-learning), and human-centered education (e.g., equity, curriculum design, sustainability). The number of publications peaked between 2020 and 2022, correlating with global shifts due to COVID-19 and increased digital adoption. Despite strong research output, underexplored areas remain, such as Industry 4.0, ethical AI use, and smart mobility in education. This study identifies critical gaps and suggests future research directions, including the need for inclusive digital infrastructure, ethical governance of educational AI, and sustainable models of digital transformation. A conceptual framework is proposed to guide interdisciplinary inquiry at the intersection of education and the digital economy.

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1. INTRODUCTION

Digital transformation has fundamentally altered nearly all aspects of human life, and education is no exception. In recent years, the intersection between the digital economy and educational systems has

become a central topic in academic discourse, highlighting how economic digitalization reshapes learning processes, institutional management, and access to educational opportunities. The digital economy not only introduces new technologies but also creates new educational markets, reshapes labor demands, and promotes the development of digital competencies as key learning outcomes. This phenomenon encompasses the implementation of digital economy driven technologies, particularly those that enable data monetization, platformization, and automation in education such as artificial intelligence (AI) and big data analytics, rather than treating each technology in isolation (Latifah et al., 2022; O'Doherty et al., 2018). The rapid development of these innovations presents new opportunities for global education but also raises challenges related to equity, infrastructure readiness, and policy alignment.

The COVID-19 pandemic intensified the digital transformation of education, accelerating the adoption of digital platforms for teaching, assessment, and administration (Aguilera-Hermida, 2020). This acceleration demonstrated how the digital economy operates as both a driver and a constraint, while it expanded access to online learning, it also revealed stark inequalities in digital infrastructure and skills (Almusharraf & Khahro, 2020; Alkhowailed et al., 2020). As the two main pillars of digital transformation, AI and big data have emerged as key tools in creating data driven and adaptive educational ecosystems, facilitating deeper learning analytics and personalized instruction to improve efficiency and inclusiveness (Duan et al., 2019; Shihomeka, 2023).

However, despite these advancements, the digital divide remains a critical economic and educational issue, encompassing limited access to technology, unequal digital literacy, and disparities in the economic capacity to adopt educational innovations. This divide is especially visible in developing countries, where uneven participation in the digital economy translates into unequal educational outcomes (Hulsen, 2021; Zhang et al., 2023). Addressing this issue requires a holistic understanding of how the digital economy shapes, enables, and constrains educational transformation.

Previous reviews have tended to discuss educational technologies separately, for instance by focusing on AI, big data, or blockchain, without systematically mapping the broader intellectual and thematic landscape that connects digital economy principles with education. Few bibliometric studies have specifically examined how digital economy concepts such as digital platforms, innovation ecosystems, and Industry 4.0 intersect with educational research. To the best of our knowledge, no comprehensive bibliometric and systematic review has yet explored this intersection over a decade long period. This study fills that gap by offering an integrated analysis of trends, research fronts, and knowledge structures in digital economy research within educational contexts from 2014 to 2024.

Bibliometric analysis provides an effective approach to quantitatively assess publication performance, research collaboration networks, and thematic evolution over time (Wang, 2020; Awdziej et al., 2023). It allows scholars to visualize intellectual structures, detect emerging clusters, and identify invisible colleges that shape the field. Through this method, the study uncovers how educational systems integrate into the digital economy, ranging from digital learning markets to AI enabled governance and data driven policy.

Based on this background, the study addresses two central research questions:

1. What are the dominant research themes and publication trends in digital economy related educational research between 2014 and 2024?
2. What conceptual and methodological gaps exist in the literature on the relationship between the digital economy and education, and which areas require further exploration?

Through bibliometric and systematic analysis, this study aims to provide a clearer understanding of how digital economy research has evolved within the educational domain, exploring the key actors, trends, and emerging knowledge frontiers. In doing so, it contributes to both academic and policy discourses by offering a conceptual framework to advance future research and by supporting the development of inclusive, equitable, and sustainable digital transformation in education.

2. METHODS

2.1 Research Approach

This study employs a bibliometric approach to assess the trends, hotspots, and intellectual structure within the field of digital economy and education (Zhou et al., 2023; Mishra, 2023; Kumar, 2023; Ladewi, 2023). Bibliometrics enables both quantitative and qualitative evaluations of scientific literature, offering insights into research performance and knowledge mapping (Putro, 2023; Tsilika, 2023; Desai & Patel, 2023; Jamaludin et al., 2023; Simion, 2023). The focus is on how digital economy concepts and transformations influence educational practices and policies. Key search terms such as "Digital Economy," "Digital Transformation," "Economic Growth," and "Technological Change" were combined with education-related keywords like "Education," "E-Education," "Online Education," and "Educational Technology." Terms related to economic impacts—such as "Economic Impact," "Economic Policy," and "Innovation"—were also used to ensure relevant studies were captured. The search period was set from 2014 to December 3, 2024.

The Scopus database was selected as the primary data source because it offers the most comprehensive coverage of multidisciplinary peer-reviewed journals in both education and economic domains, surpassing alternatives such as Web of Science (which tends to emphasize older citation networks) and ERIC (which is narrower and education-specific). Scopus also integrates advanced citation indexing, consistent metadata, and broader international journal representation, which are critical for capturing the intersection between the digital economy and educational research.

A targeted search within the Scopus database yielded 745 documents after applying filters for article titles, abstracts, and keywords**.** Additional manual screening through citation tracking and relevance checks was performed to ensure that key and highly cited studies were not omitted.

2.2 Inclusion and Exclusion Criteria

The inclusion and exclusion criteria were designed to ensure the review only included relevant studies (Table 1). Only journal articles published in English and finalized in their publication stages were considered, excluding conference proceedings, preprints, and other non-peer-reviewed documents. Although conference papers are often important in fast-evolving fields like digital transformation, they were excluded to maintain methodological rigor, as their peer-review standards, citation indexing, and metadata consistency are often limited in Scopus. This decision prioritizes data reliability, reproducibility, and citation accuracy over short-term topicality.

Articles were also required to fall under subject areas like "Social Science," "Economics, Econometrics, Finance," "Business, Management and Accounting," "Engineering," and "Computer Sciences," which align with the study's focus on digital economy and educational transformation (Nichols et al., 2023; Saltali & Aslanlar, 2023; Ergin, 2023; Iman et al., 2023; Evanthi, 2023). After applying these filters, 201 articles met the eligibility criteria, ensuring that only the most relevant studies were included. These criteria follow bibliometric best practices to ensure the study's reliability and relevance (Zhou et al., 2023; Mishra, 2023; Yilmaz, 2023).

Nevertheless, the exclusion of conference papers and non-English publications is acknowledged as a limitation, as these may contain region-specific innovations or preliminary findings not yet formalized in journal publications. This limitation is discussed further in the conclusion as part of the study’s boundary conditions.

Table 1. Results of inclusion criteria based on PRISMA and SPAR-4-SLR approaches

Phase(s)	Consideration	Results for Systematic Literature Review
Assembling/ Identification	Search focus	The Evolution of Digital Economy Research in Education
	Search (keyword) string	("Digital Economy" OR "Digital Transformation" OR "Economic Growth" OR "Economic Development" OR "Digitalization" OR "Technological Change") AND ("Education" OR "E-Education" OR "Online Education" OR "Educational Technology" OR "Digital Learning" OR "Learning Technologies") AND ("Research" OR "Study" OR "Analysis" OR "Investigation" OR "Evaluation") AND ("Economic Impact" OR "Economic Influence" OR "Economic Policy" OR "Policy Implications") AND ("Innovation" OR "Curriculum Development" OR "Technology Integration" OR "Educational Innovation")
	Search period	2014 up to December 3, 2024
	Search database	Scopus
	Search field	Article title, abstract, keywords
	Search results	745 documents found
Arranging/ Screening and Eligibility	Document type	Include "Article"
	Language	Include "English"
	Publication stage	Include "Final"
	Source type	Include "Journal"
	Subject (research) areas	Include "Social science" AND "Economics, Econometrics, Finance" AND" Business, Management and Accounting" AND "Engineering" AND "Computer Sciences"
	Filtered results	201 document found
Assessing/ Inclusion	Analysis method	Bibliometric - Performance analysis - Science mapping
	Agenda proposal method	Trend analysis and gap spotting

Notes: Table presentation refers to Lim et al. (2024)

2.3 Procedure

The bibliometric analysis followed a systematic approach involving multiple stages: data collection, preprocessing, analysis, and visualization. This structured sequence was guided by PRISMA standards and bibliometric protocols to ensure transparency and replicability. Initially, search results from Scopus were exported to Excel for data cleaning, removing duplicates, correcting inconsistencies, and standardizing author names and article titles. This step is crucial to maintaining data integrity (Zhou et al., 2023; Mishra, 2023). Further refinement was done using OpenRefine, a tool used to standardize data (Putro, 2023). This preprocessing ensured uniformity across metadata fields and improved the reliability of subsequent network analyses.

For the analysis, two primary techniques were employed: performance analysis and knowledge mapping. Performance analysis quantitatively assessed scientific output and impact, including publication trends, citation metrics, and the contributions of institutions and countries, providing insights into the scientific influence within this domain (Saltali & Aslanlar, 2023; Iman et al., 2023; Ergin, 2023). This analysis tracked publication volumes, citation counts, and the influence of key researchers and institutions in shaping the field's development. Such evaluation also facilitated the identification of prolific authors and high-impact journals, offering a clearer picture of how research productivity has evolved globally.

Knowledge mapping was conducted using VOSviewer and R Studio to visualize the relationships between keywords, co-citations, and co-authorships. VOSviewer was used to generate visual networks that illustrate how research topics are interconnected, particularly focusing on keyword co-occurrence and citation links (Putro, 2023; Tsilika, 2023; Toseef, 2023). The generated maps enabled the clustering of thematic structures that revealed dominant and emerging research areas. R Studio facilitated advanced statistical analysis, such as frequency analysis and regression models, to reveal deeper trends and relationships between research themes (Zhou et al., 2023; Putro, 2023; Tsilika, 2023). The integration of VOSviewer and Biblioshiny (R package) allowed simultaneous exploration of descriptive and inferential bibliometric indicators, strengthening internal validity through complementary analytical perspectives.

Additionally, trend analysis and gap analysis were used to understand how research has evolved over time. Trend analysis tracked the shift in research topics, while gap analysis identified underexplored areas in the literature based on publication trends and keyword analysis (Mishra, 2023; Kumar, 2023; Desai & Patel, 2023; Jamaludin et al., 2023; Simion, 2023; Liu, 2023). This combined approach supported the identification of underrepresented subfields such as Industry 4.0 education and digital ethics, providing directions for future research agendas.

To strengthen analytical validity, a triangulation step was introduced, applying cross-verification between visualization outcomes (from VOSviewer) and statistical patterns (from R Biblioshiny). This procedure ensured the consistency of findings between thematic clustering, bibliometric performance indicators, and keyword dynamics, minimizing interpretive bias and enhancing robustness.

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines were rigorously followed to ensure transparency and consistency in the systematic review process. The PRISMA flowchart (Moher et al., 2015) illustrates the process of article selection, starting with an initial set of documents (745) and following through with screening, eligibility checks, and inclusion criteria. In the end, 201 articles were selected for further analysis (Figure 1). The figure provides a visual summary of inclusion–exclusion stages, emphasizing data transparency and procedural clarity.

The final dataset, comprising 201 articles, was analyzed through network analysis to further explore how research topics are interconnected. Tools like VOSviewer and R Studio facilitated the mapping of research evolution and the identification of key authors, institutions, and trends. These analyses collectively revealed the intellectual structure and conceptual progression of digital economy research within educational contexts.

Although Scopus provided strong coverage, the study acknowledges the limitation that bibliometric mapping may underrepresent regional or emerging literature not indexed in major databases. Therefore, future research is encouraged to conduct cross-database comparisons using sources such as Web of Science or ERIC and to consider grey literature inclusion to enhance comprehensiveness and mitigate publication bias.

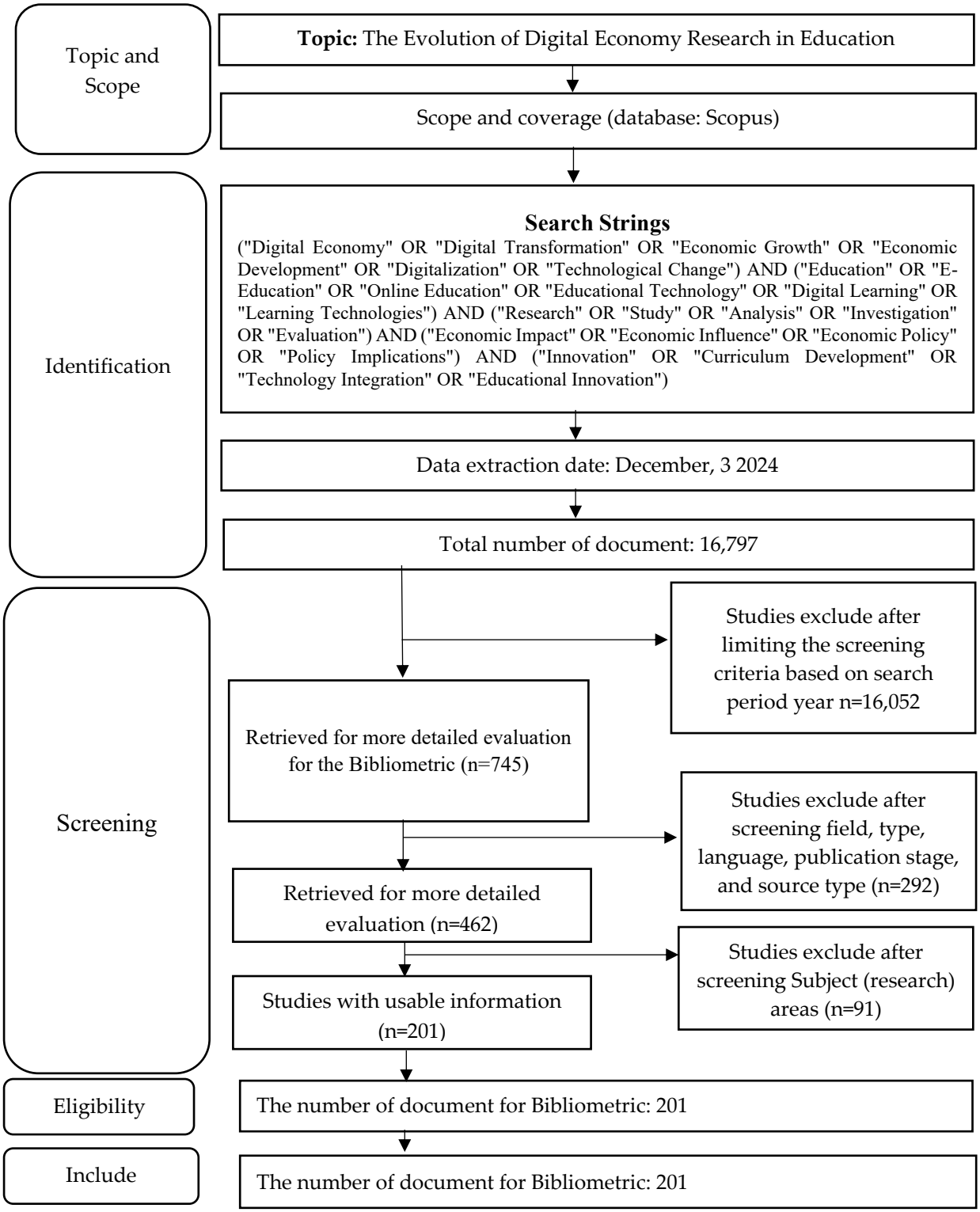


Figure 1. PRISMA Diagram
Referring to the framework Page et al. (2021) and Zulkifli and Hamzah (2024).

3. FINDINGS AND DISCUSSION

3.1 Performance Analysis

3.1.1 Key information of relevant sources

This study examines digital economy research in education from 2014 to 2025, analyzing 201 documents from 160 publications by 684 authors. Collaboration dominates, averaging 3.41 authors per paper, with 20.4% involving international co-authorship. The research shows strong influence, with 13.23 citations per document and 11,273 references, supported by 886 unique keywords that highlight diverse themes.

Publication and citation trends fluctuate alongside global education policies and funding shifts. The 2020–2023 period saw increased activity driven by post-COVID-19 recovery and AI adoption in education, followed by a decline after 2023 as focus moved toward applied AI implementation. The findings emphasize strong collaboration and the relevance of research in understanding the transformation of the digital economy in education, while providing insights into trends, impacts, and opportunities for further exploration.

3.1.2 Productivity and impact are evaluated through publication and citation trends

From 2014 to 2024, the productivity and impact of digital economy research in education showed fluctuating patterns. As shown in Panel A (Figure 2), publications increased steadily from 2014 to 2018, driven by national digital learning strategies and EdTech investments. The number rose sharply between 2019 and 2022, peaking at 22 publications in 2022 during post-pandemic recovery and large-scale digital transformation. A drop to six publications in 2024 indicates reduced activity or shifting research priorities. Continued support is needed to maintain momentum in this field.

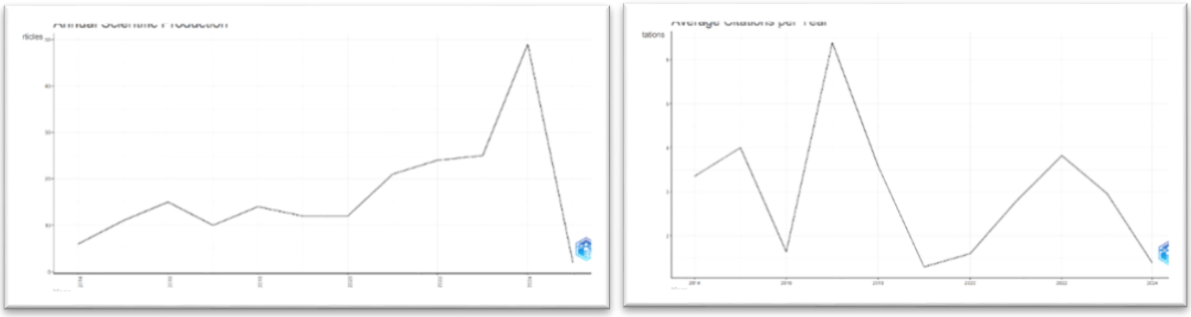
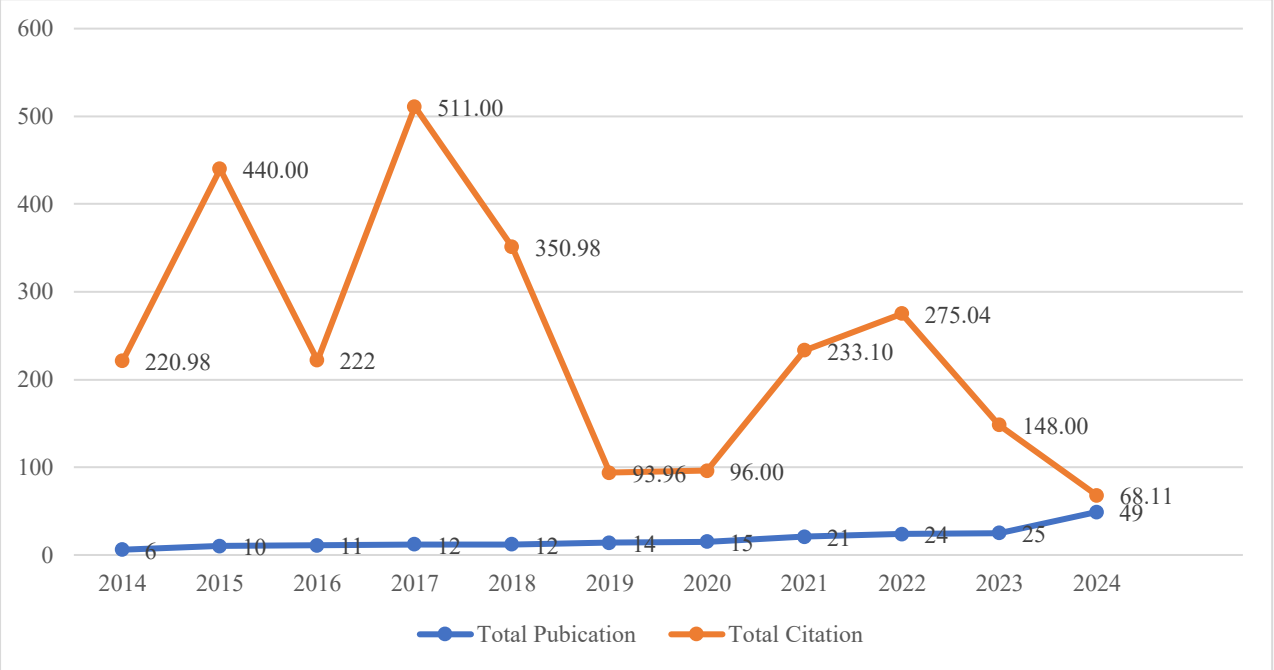


Figure 2. Panel A**:** Publication and citation trend of digital economy research in education generated through Bibliometrix's Biblioshiny (Aria & Cuccurullo, 2017; Lim et al., 2024).

Citation analysis in Panel A also shows a peak in 2017 with 511 citations, reflecting the strong influence of early studies. The subsequent decline suggests citation lag for recent works and saturation in foundational digital transformation research. Future studies should focus on innovative areas such as ethical AI governance, digital equity, and sustainability frameworks to regain academic and policy relevance.



Panel B. Publication and citation trends of digital economy research in education generated through Excel

Figure 3. Productivity and impact of digital economy research in education. Panel A. Publication and citation trends of digital economy research in education generated through bibbliometrix's bibblioshiny (Aria & Cuccurullo, 2017; Lim et al., 2024). Panel B. Publication and citation trend of digital economy research in education generated through Excel.

Panel B presents cumulative publication and citation trends from 2014–2024. Total publications rose gradually, while total citations peaked in 2017 before declining steadily. This imbalance suggests a shift from theoretical to applied research, narrowing citation networks. To address this, researchers should strengthen interdisciplinary collaboration and align studies with global challenges to improve both visibility and long-term impact.

3.1.3 Key readings informed by highly cited research

Based on Table 2, highly-cited studies on the digital economy in education explore key themes such as university–industry collaboration, innovation capacity, technology-driven entrepreneurship, and digital transformation in teaching. These works, published in leading journals like *European Planning Studies*, *Journal of Intellectual Capital*, and *International Journal of Innovation Studies*, were selected for their strong academic influence measured by Total Citations Per Year (TCPY).

Among them, Rantala and Ukko (2019) (TCPY = 2.33) focus on performance evaluation in university–industry partnerships. Kashyap and Agrawal (2020) (TCPY = 2.60) emphasize intellectual property creation in higher education. Abdelfattah et al. (2023) (TCPY = 6.50) highlight technology adoption and e-entrepreneurship, while Chai et al. (2024) (TCPY = 8.00) discuss eco-efficiency in China's ecological zones. Feng (2017) and Yip et al. (2022) (both TCPY = 1.00) explore digital teaching methods and smart campus models. Together, these papers reflect the diversity and depth of digital economy research in education.

Across these influential works, several traits stand out: methodological rigor through advanced quantitative or mixed methods, a strong focus on practical innovation, clear regional contexts (Europe, China, GCC), and interdisciplinary integration of management, education, and technology. These

qualities demonstrate that impactful studies in this field effectively bridge theory and policy, advancing the global digital transformation agenda in education.

Table 2. Highly-cited of digital economy research in education

Rank	Author (S) And Years	Article Title	Journal Title	Total Citations	Tcpy
1	Rantala and Ukko (2019).	Performance Evaluation To Support European Regional Development–A University–Industry Perspective	European Planning Studies	14	2,333
2	Kashyap and Agrawal (2020).	Scale Development And Modeling Of Intellectual Property Creation Capability In Higher Education	Journal of Intellectual Capital	13	2,6
3	Abdelfattah et al. (2023)	Cognitive Style And Fostering Of Technological Adaptation Drive E-Entrepreneurial Of New Mature Business	International Journal Of Innovation Studies	13	6,5
4	Chai et al. (2024)	The Road To Eco-Efficiency: Can Ecological Civilization Pilot Zone Be Useful? New Evidence From China	Journal Of Environmental Planning And Management	8	8
5	Feng, X. (2017).	An English Teaching Method Based On Network Technology Platform	Boletin Tecnico/Technical Bulletin	8	1
6	Syed et al. (2023).	Entrepreneurship Development In Universities Across Gulf Cooperation Council Countries: A Systematic Review Of The Research And Way Forward	Journal Of Enterprising Communities	7	3,5
7	Rantala et al. (2021)	The Role Of Performance Measurement In University-Industry Collaboration Projects As A Part Of Managing Triple Helix Operations	Triple Helix	6	1,5
8	Chowdhury et al. (2024).	Generative Artificial Intelligence In Business: Towards A Strategic Human Resource Management Framework	British Journal Of Management	3	3
9	Yip et al. (2022).	A Hybrid Assessment Framework For Human-Centred Sustainable Smart Campus: A Case Study On Covid-19 Impact	Iet Smart Cities	3	1
10	Liu et al. (2021).	New Characteristics And Trend Of Regional Innovation Capacity In China	Bulletin Of Chinese Academy Of Sciences	3	0,75

This research not only reflects global trends but also provides regional insights, such as university–industry development in Europe, technological innovation in China, and entrepreneurship initiatives in GCC countries. These findings contribute significantly to advancing theories of digital education

transformation while offering practical guidance for educational institutions and policymakers. However, further research is needed to explore the long-term impact of digital transformation on equitable access to education and the sustainability of innovation across different regional contexts.

3.1.4 Key contributions identified from the most prolific journals, authors, institutions, and countries

Based on Table 3, digital economy research in education is driven by a concentrated network of leading journals, scholars, and institutions with strong international participation. Journals such as *Sustainability (Switzerland)* and *IEEE Access* dominate publication output, serving as central platforms that shape both thematic directions and methodological approaches in this field. Their consistent publication of high-quality studies reflects the growing academic attention to the intersection between digital transformation and education.

Among the authors, Rantala, Tero and Ukko, Juhani stand out for their multiple contributions, signaling a core group of influential researchers shaping theoretical and empirical developments. This pattern of productivity highlights a focused yet mature research community that continually drives discourse on digital transformation in education.

Table 3. Most prominent contributions of digital economy research in education

Panel A. Journals	Art	Panel B. Authors	Art	Panel C. Institutions	Art	Panel D. Countries	Art
Sustainability (switzerland)	9	Rantala, Tero	2	Ankara University	7	China	85
Ieee access	4	Ukko, Juhani	2	Internasional Centre of Insect Physiology And Ecology (Icipe)	7	Mexico	42
Technological forecasting and social change	4	Abdelfattah, Fadi	1	FPT University	6	India	36
Applied mathematics and nonlinear sciences	3	Abdijabar, Zeana	1	School Of Engineering And Sciesnces	6	UK	36
Australasian journal of educational technology	3	Abdildayeva, Assel	1	The University Of Queensland	6	USA	26
Ieee transactions on engineering management	3	Abusorrah, Abdullah	1	University Of Aveiro	6	Italy	25
Journal of cleaner production	3	Adeoti, John	1	University Of Sheffield	6	Australia	23

Noted: Art = Articles

Institutionally, Ankara University and the International Centre of Insect Physiology and Ecology (ICIPE) lead with the highest publication counts, followed by FPT University, The University of Queensland, and The University of Sheffield. These universities play a critical role in advancing interdisciplinary collaboration and reinforcing the global reach of this research area.

At the national level, China leads with 85 articles, reflecting its major investment in educational digitalization and knowledge-based growth. Other key contributors include Mexico, India, the UK, and the USA, representing both emerging and advanced economies actively shaping the field. This distribution underscores the global nature of digital economy research and the shared recognition of its transformative role in modern education.

Collectively, the findings demonstrate a well-established and internationally connected research ecosystem. The prominence of leading journals, influential authors, and globally distributed institutions highlights the strength and maturity of this field, while also indicating the need for continued cross-regional studies to understand the diverse pathways of digital transformation in education.

3.2 Science Mapping

3.2.1 Uncovering the knowledge produced by the field through a tree field plot, a tree map, keyword co-occurrence analysis, and bibliographic coupling

Bibliometric visualization in Figure 3 presents the structure of research on the digital economy in education. Using four analytical views, namely Tree Field Plot (Panel C), Tree Map (Panel D), Keyword Co-occurrence Network (Panel E), and Bibliographic Coupling Map (Panel F), the analysis explains how authors, topics, and publication sources interact within the field. Together, these panels show how research develops through collaboration, thematic focus, and methodological diversity.

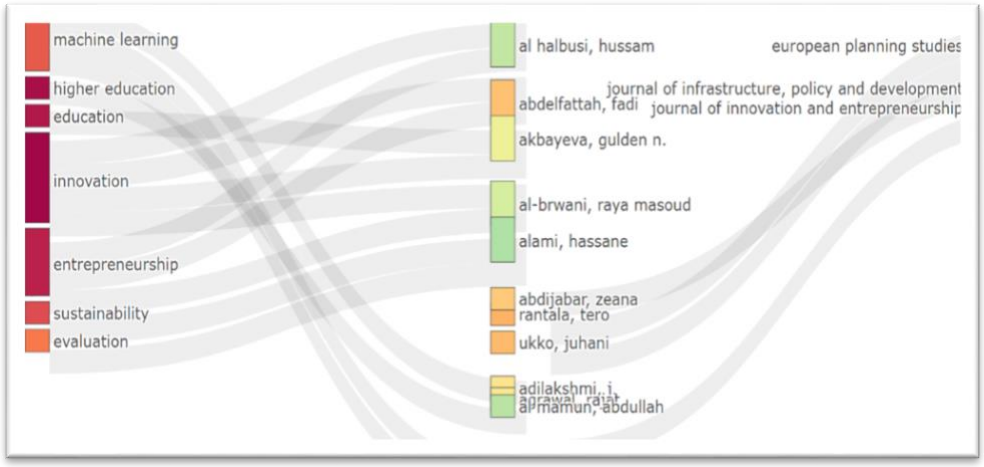


Figure 4. Tree Field Plot

As shown in Panel C, collaboration between major topics, authors, and journals reflects a strong interdisciplinary network. Themes such as innovation, education, and entrepreneurship dominate, supported by significant contributions from Al Halbusi, Hussam and Abdelfattah, Fadi. Their publications in *European Planning Studies* and *Journal of Innovation and Entrepreneurship* highlight the central role of collaborative and cross-disciplinary research in advancing digital transformation in education.

The Tree Map (Panel D) visualizes the proportion of main research themes, showing that innovation and sustainable development are the most prominent. Emerging topics such as artificial intelligence, machine learning, and e-learning indicate growing attention to technological integration in education. This visualization confirms that digital transformation is not only technological but also supports the creation of inclusive and sustainable learning systems.

Figure 5. Panel D: Tree Map

The Keyword Co-occurrence Network (Panel E) identifies three interlinked clusters summarized in Table 4. The *Technological Innovation* cluster focuses on innovation, energy efficiency, and technology transfer. The *Advanced Technologies* cluster includes artificial intelligence, big data, and e-learning for adaptive education. The *Human-Centered Education* cluster highlights curriculum design, sustainability, entrepreneurship, and equality, reflecting the rapid expansion of online learning during COVID-19. These clusters together form a connected ecosystem where innovation enables technology use and technology strengthens human-centered education.

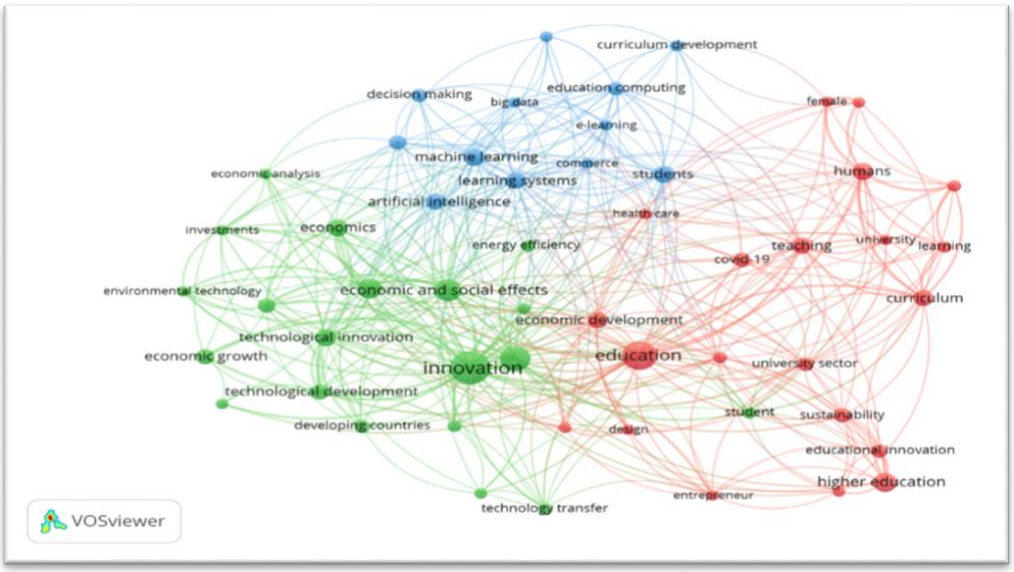


Figure 6. Panel E: Network of Keyword Co-occurance

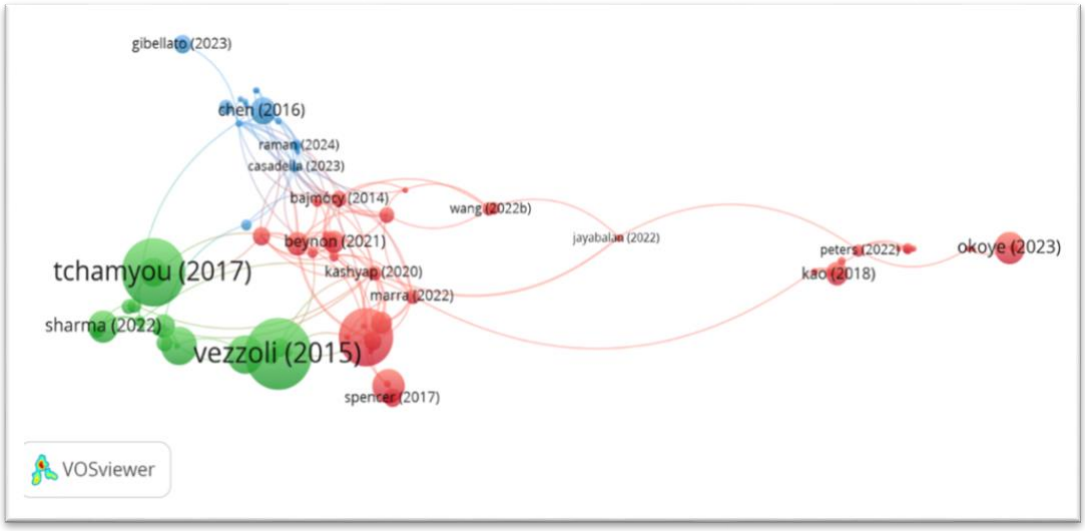
These interlinked clusters can be interpreted through theoretical lenses such as the Technology Acceptance Model (TAM) and the SAMR framework, which explain how technological innovation and pedagogical adaptation evolve in digital education. The human-centered emphasis observed in the red cluster aligns with digital equity principles and critical education theory, emphasizing inclusive access, fairness, and social justice in technology integration. This theoretical reflection positions the

bibliometric patterns within broader educational policy discourses and strengthens the interpretation of the science mapping as a holistic and integrated framework.

Table 4. Cluster and keywords of digital economy research in education revealed through keyword co-occurrence analysis.

Color (Cluster)	Keywords (Cluster Name)
Green (Technological Innovation)	innovation, economic and social effects, economic growth, technological development, investments, economic analysis, environmental technology, technological innovation, developing countries, energy efficiency, technology transfer
Blue (Advanced Technologies)	machine learning, artificial intelligence, big data, learning systems, decision making, curriculum development, education computing, e-learning, students, commerce, health care
Red (Human-centered Education)	education, humans, teaching, curriculum, university learning, university sector, higher education, sustainability, educational innovation, student, design, COVID-19, entrepreneur, female

The Bibliographic Coupling Map (Panel F) visualizes how thirty-seven influential articles are connected through shared references. The green cluster, led by *Vezzoli (2015)* and *Tchamyou (2017)*, focuses on technology integration for learning improvement. The red cluster, represented by *Okoye (2023)* and *Wang (2022b)*, discusses policy frameworks supporting digital education. The blue cluster, led by *Chen (2016)* and *Gibellato (2023)*, explores the use of artificial intelligence and big data to evaluate educational performance. Strong links between *Vezzoli (2015)* and *Wang (2022b)* show how theoretical foundations evolved into policy and applied research, marking a shift toward practical solutions addressing digital equity, access, and readiness for the digital workforce.



Panel F: Bibliographic Coupling Map

Figure 7. Uncovering the knowledge produced by the field. Panel C. Tree Field Plot. Panel D. Tree Map. Panel E. Network of Keyword Co-occurance. Panel F. Bibliographic Coupling Map

3.2.2 Mapping Research Themes and their Relationship

The thematic structure of research on the digital economy in education, shown in Figure 4, organizes topics based on their relevance (centrality) and level of development (density). In the basic themes quadrant, innovation, economic and social effects, and education appear as core areas that underpin the study of digital transformation and its societal impact. The motor themes quadrant

features teaching, learning systems, and students, indicating mature and influential topics that drive advancements in adaptive learning and instructional technology.

The niche themes quadrant includes human, humans, and curriculum, representing specialized yet less-connected studies focusing on personalized and human-centered learning. The emerging or declining themes quadrant includes Industry 4.0, competition, and mapping, which link education to industrial competitiveness and automation. Although these themes are still underdeveloped, they show strong potential for future research directions. Overall, Figure 4 demonstrates that the field is dynamic, with solid foundational themes coexisting with new areas that are beginning to attract scholarly attention.

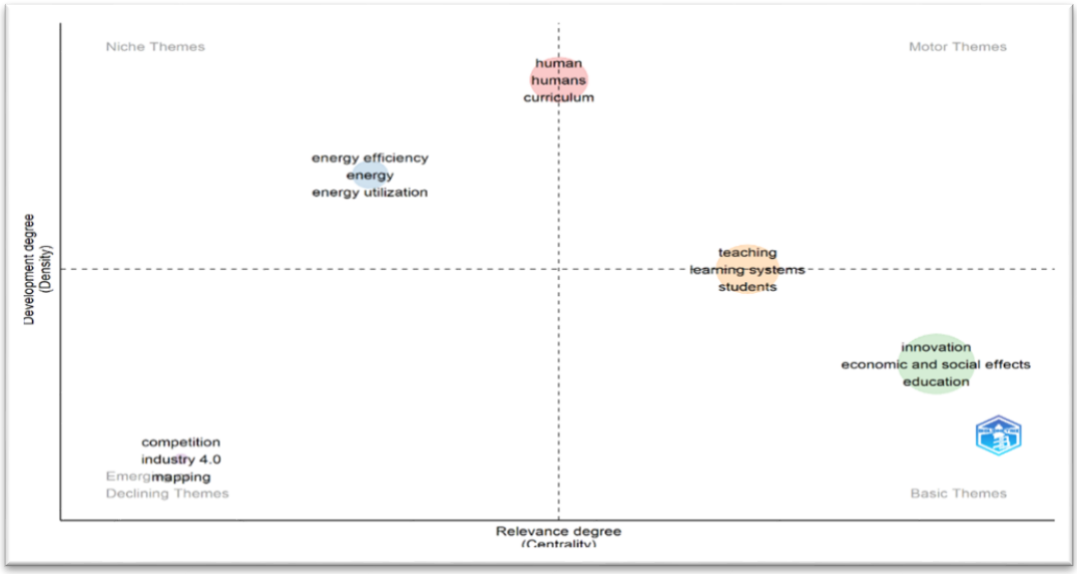


Figure 8. Thematic Map

3.2.3 Unveiling the future Directions of the Field

The Topical Trend Map (Panel G) highlights innovation as the unifying concept connecting education, economics, technology, and social development. In education, key topics such as higher education, teaching, curriculum design, and e-learning show growing integration of artificial intelligence and machine learning to improve teaching and learning quality. The yellow tones in the visualization (2020–2023) reflect the surge of these studies during and after the COVID-19 pandemic. Earlier trends from 2018–2019, shown in blue, focused more on technology development and big data. Over time, these themes shifted toward sustainability and energy efficiency, linking innovation with economic growth and social well-being, especially in developing countries.

From the social perspective, the inclusion of topics such as humans, females, and health care emphasizes the importance of inclusion, gender equity, and global welfare. Research has increasingly evolved from exploring technological foundations to applying innovation for societal transformation, making education a key driver of inclusive and sustainable progress.

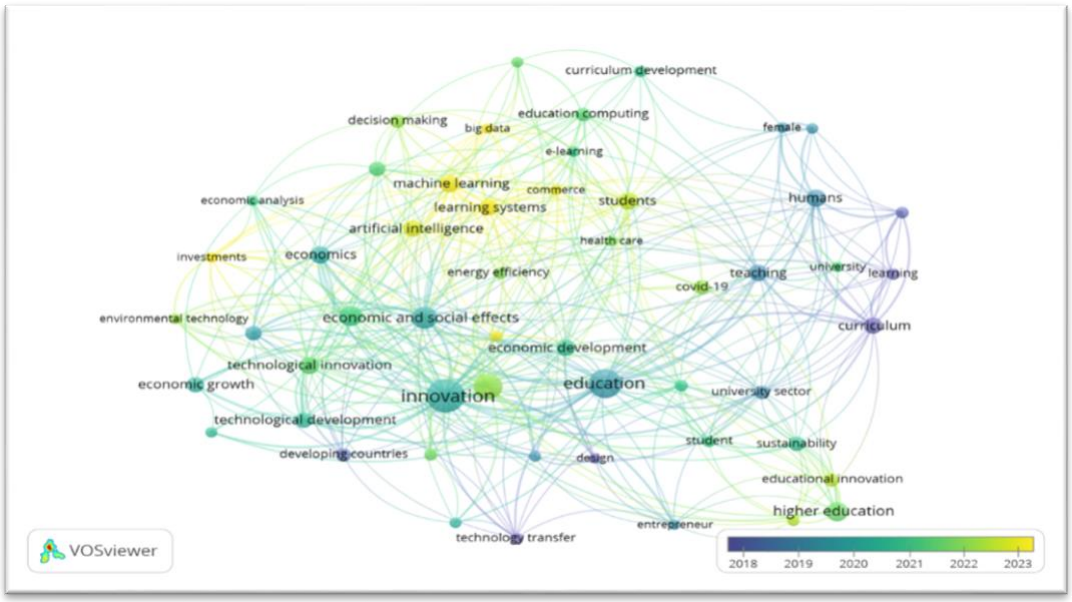
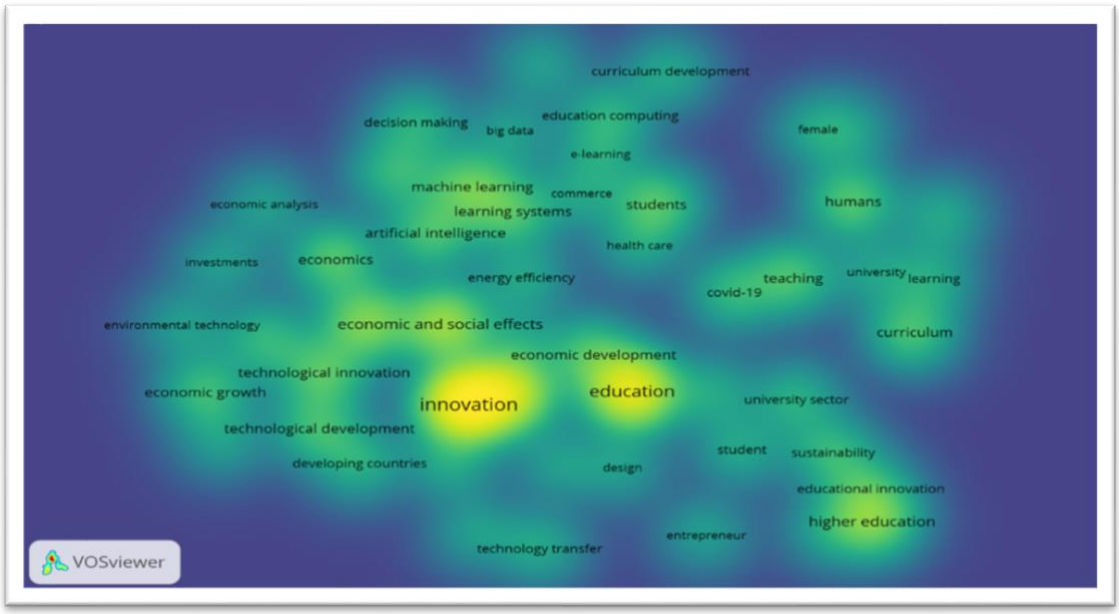


Figure 9. Panel G: Topical trend of digital economy research in education

The Density Visualization (Panel H) further highlights innovation and education as the most intensive research themes. These clusters appear in bright yellow, symbolizing their central role as hubs connecting other interdisciplinary topics. Innovation acts as a catalyst for technological progress and economic growth, while education serves as a bridge that integrates these innovations into teaching and learning systems. This reflects a strong global effort to modernize education through artificial intelligence, machine learning, and e-learning.

The map also illustrates the growing role of higher education institutions, represented by the density around students and the university sector, in advancing adaptive and sustainability-oriented curricula. The proximity of sustainability to education themes signals a commitment to aligning digital transformation with global development goals. Meanwhile, research on developing countries, health care, big data, and COVID-19 shows a rising focus on equity, resilience, and responsiveness to global challenges. The inclusion of human-centered themes such as humans and female demonstrates a consistent concern for inclusion and justice in digital learning. Collectively, these findings confirm that innovation and education remain the driving forces in shaping an equitable, sustainable, and technology-empowered future for education.



Panel H. Density Visualization

Figure 10. Unveiling the Future Directions of the Field. Panel G. Overlay Visualization. Panel H. Density Visualization

3.2.4 Mapping Thematic Findings of Digital Economy Research In Education and Its Implications for Theory, Practice, and Future Research Direction

The consolidated findings indicate that the digital economy in education has evolved from conceptual debates to practical, policy-relevant applications. The field integrates theoretical models such as the Technology Acceptance Model (TAM) and SAMR framework, emphasizing how innovation and technology adoption reshape learning ecosystems. The growing attention to themes like *humans*, *female*, and *university sector* highlights an increasing commitment to equity and inclusion.

Future research should focus on three key areas: expanding digital infrastructure in underdeveloped regions, addressing ethical issues in AI and data governance, and developing sustainable, inclusive models for digital transformation. Strengthening collaboration between academia, policymakers, and industry will be essential for ensuring that digital innovation continues to drive equitable and resilient education systems worldwide.

4. CONCLUSION

This study maps the evolution of digital economy research in education over the past decade, revealing critical intersections between technological innovation and inclusive curriculum design. Key themes, including innovation, teaching, learning systems, and students, demonstrate the integration of machine learning, artificial intelligence, and e-learning, driving adaptive and efficient educational practices. The research trajectory has shifted from foundational topics such as economic and social effects to applied areas like sustainability and network optimization, reflecting the global influence of digital transformation on education. At the same time, emerging themes such as Industry 4.0, competition, and smart mobility remain underexplored, highlighting opportunities for future research.

Building on these findings, there are clear implications for both policy and research. Educational policymakers should prioritize investments in data infrastructure to reduce regional disparities in digital learning access and support equitable technology adoption. Researchers are encouraged to

examine ethical considerations of AI and big data, integrate human-centered approaches into curriculum design, and develop sustainable digital education models that promote inclusivity and address global challenges. This approach ensures that future studies advance both theory and practice, fostering a more resilient, equitable, and innovative digital education ecosystem.

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