

Online Learning for Technical Education: A Bibliometric Analysis

Wan Azani Mustafa^{1,2,3}, Norhayati Mohd Zain⁴, Nor Aniza Azmi⁵, Mohamad Nur Khairul Hafizi Rohani²

¹Advanced Computing Engineering (AdvComp), Centre of Excellence (CoE), University Malaysia Perlis, Pauh Putra Campus, 02600 Arau, Perlis, Malaysia

²Faculty of Electrical Engineering Technology, Pauh Putra Campus, University Malaysia Perlis, 02600 Arau, Perlis, Malaysia

³East Coast Environmental Research Institute (ESERI), Universiti Sultan Zainal Abidin, Kampus Gong Badak, 21300, Kuala Nerus, Terengganu

⁴Medical Imaging Department, School of Integrative Medicine & Life Sciences, KPJ Healthcare University, 71800 Nilai, Malaysia

⁵Diagnostic Imaging & Radiotherapy Program, Universiti Kebangsaan Malaysia, Jalan Raja Muda Abdul Aziz, 50300 Kuala Lumpur, Malaysia

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ABSTRACT:

Background: Online learning for technical and vocational education has transitioned from an emergency substitute to a permanent instructional model, yet understanding its scientific growth, global contributions, and structural evolution remains critical.

Aim: This paper aims to execute a bibliometric analysis mapping publication trends, impactful contributors, international collaboration structures, and thematic evolution in the online technical education literature.

Methodology: Following a systematic extraction strategy, 308 pristine English-language documents published between 1999 and 2026 were retrieved from Scopus. Data cleaning was conducted using OpenRefine, and computational network visualizations were performed via BiblioSpy® and VOSviewer.

Results: The results reveal an explosive growth peak in 2023 following the COVID-19 pandemic, with the field accumulating 5,836 total citations. While the United States and China lead in overall publication volume, the United Kingdom and Taiwan demonstrate superior citation efficiency per paper. International research collaborations remain largely clustered regionally rather than globally integrated. Keyword co-occurrence analysis revealed three distinct thematic clusters: Technology Acceptance Model (TAM), online implementation and pandemic impacts, and emerging learner-centered dimensions focusing on self-efficacy and student engagement.

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Conclusion: The field is actively shifting from a technology-centered implementation paradigm toward a holistic, learner-centered perspective. Sustainable digital integration in technical education requires enhanced international collaboration, blended instructional designs, and interactive tools like virtual laboratories to ensure practical competency development.

Keywords: Online, Technical, Education, Bibliometrics, Review

1. Introduction

Online learning for technical education has expanded from an emergency substitute for classroom teaching into a durable instructional model. However, the literature demonstrates that its value depends strongly on how well institutions address the practical, social, and infrastructural demands of technical and vocational learning (Jusoh et al., 2025). Studies across TVET, STEM, engineering, and procedural training consistently reveal that online formats can widen access, support flexibility, and improve some forms of knowledge and skill development. It can also expose persistent weaknesses in hands-on training, connectivity, digital readiness, and learner engagement (Cai & Aquino, 2023; Mesuwini, 2024). The literature on effectiveness presents a more differentiated picture than either strong optimism or strong skepticism would suggest. A major meta-analysis identified that students in online conditions performed modestly better than those in face-to-face instruction on average, but this advantage was driven mainly by blended learning rather than purely online formats (Means et al., 2013).

A later systematic review of school-based evidence similarly discovered that digital technology outperformed regular instruction in most studies and again concluded that blended learning was considerably better than online learning alone, while also noting that self-efficacy was strongly linked to better outcomes (Topping et al., 2022). In technical disciplines specifically, a case study from a Chinese technical university reported that hybrid learning produced statistically significant gains across five engineering subjects and demonstrated stronger

learning effects than either fully online or fully face-to-face delivery (Guo et al., 2026). At the course level, online delivery has also exhibited effectiveness for selected technical subjects. An online technical writing and communication course for engineering and information technology students yielded high scores in satisfaction, self-efficacy, perceived competence, and course learning outcomes, suggesting that some communication-oriented technical courses can be taught fully online without harming performance (Yasin et al., 2022). In professional technical education, a systematic review of e-learning for practicing surgeons and proceduralists revealed high satisfaction and gains in declarative knowledge, procedural knowledge, and procedural competence in educational settings. However, no included study demonstrated improvements in workplace performance or patient outcomes (Williams et al., 2023). Taken together, the evidence suggests that online learning can support technical education effectively, but its strongest results appear in blended, carefully designed, and outcome-aligned implementations rather than in fully digital substitution alone.

A central theme in the literature is that pedagogical design matters more than platform adoption alone. Online collaboration in STEM education has been associated with knowledge co-construction, higher-order thinking, and stronger performance, with one study reporting a moderate positive relationship between social presence, cognitive presence, and successful performance (Nungu et al., 2023; Raffi et al., 2025). Broader survey evidence from online STEM higher education revealed that active learning designs, especially individual work,

group work, long-term work, and synchronous work, explained variation in students' perceived development of communication, collaboration, domain-general, and STEM-specific skills. These designs were also associated with greater course satisfaction (Ram et al., 2025). Framework-based work in engineering education similarly identified that combining active learning strategies, synchronous and asynchronous teaching, educational technologies, and a learning management system improved student–student interaction, student–instructor interaction, social presence, and perceived depth of understanding (Ahshan, 2021).

Interactive resources are especially important in technical learning because they can approximate practice-rich environments. Virtual laboratories, simulations, gamified assignments, and mobile-compatible tools have been reported to improve motivation, personalization, conceptual understanding, and preparation for later hands-on work (Uhomiohi et al., 2019). Additional evidence from STEM reviews and intervention studies indicates that multimedia tools, virtual simulations, and problem-based STEM e-learning can raise engagement, science process skills, and critical thinking while also supporting self-paced, student-centered learning (Dwiningsih et al., 2024; Maričić & Lavicza, 2024). In conclusion, the literature indicates that online learning for technical education is most effective when treated as a blended, interactive, and institutionally supported model that complements rather than replaces practical training. The strongest evidence supports combining digital access, active pedagogy, virtual practice tools, and sustained instructor and student support so that online learning can expand technical education without weakening its applied and skill-based character.

1.1 Research Questions

Accordingly, this study addresses the following research questions:

RQ1. What are the publication trends and growth patterns of research on online learning for technical education?

RQ3. Which countries are the most productive and influential contributors to the online learning for technical education literature?

RQ4. How are international research collaborations structured within the online learning for technical education domain?

RQ5. What thematic clusters and emerging research directions can be identified through keyword co-occurrence analysis in online learning for technical education research?

2. Methodology

The data collection process for this bibliometric study followed a systematic, rigorous approach designed to map the global literature on online learning for technical education (Donthu et al., 2021; Passas, 2024). Scopus was selected as the primary bibliographical database due to its extensive coverage of peer-reviewed, high-impact literature and its robust citation-tracking capabilities across multidisciplinary fields (Burnham, 2006). To isolate highly targeted records, a comprehensive search query was executed using string operators combining online learning modalities with various technical and vocational education terms, alongside explicit outcome indicators. The search parameters were strictly limited to English-language publications indexed under specific subject domains, including Social Sciences, Computer Science, Engineering, Mathematics, and Decision Sciences. Spanning a wide temporal scope from 1999 to 2026, the advanced title query initially identified a total of 354 records, establishing a comprehensive baseline for subsequent filtering.

Following the initial extraction, a transparent screening and exclusion phase was implemented to guarantee the thematic integrity of the corpus. The raw dataset of 354 identified records underwent a meticulous validation check to filter out erroneous entries, structural anomalies, or documents falling outside the strict conceptual boundaries of digital technical pedagogy. Through this process, 46 records were systematically excluded due to incomplete metadata, irrelevance to applied technical training, or duplicate indexing. This rigorous

filtering process yielded a final analytical dataset of 308 pristine documents. This refined corpus serves as the empirical foundation for all subsequent evaluation metrics, ensuring that the

study's conclusions are derived exclusively from a highly valid and representative collection of specialized academic literature (Figure 1).

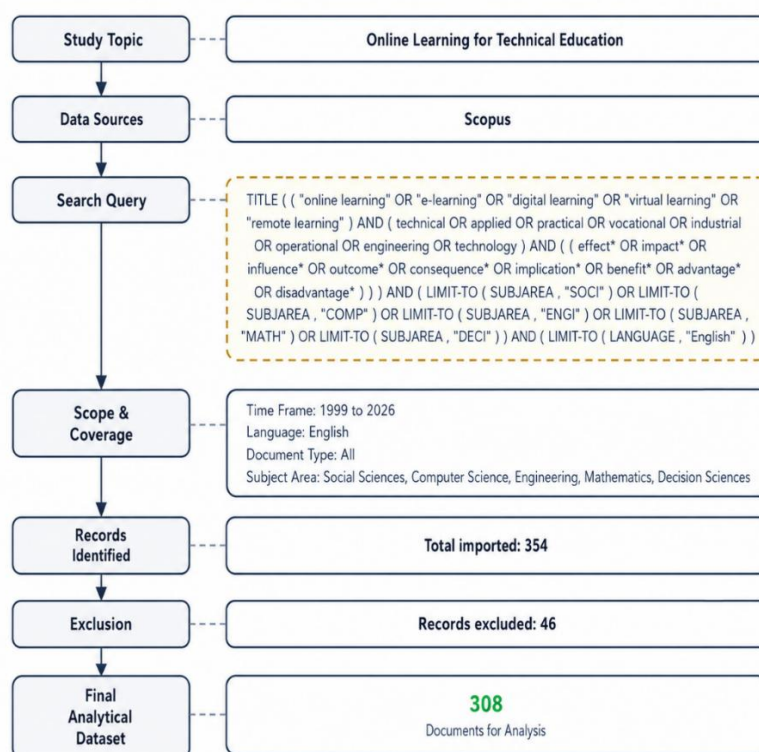


Figure 1. Bibliometric Study Flow Diagram

3. Results

This paper used BiblioSpy® (Ahmi, 2026) to conduct a comprehensive bibliometric analysis of the dataset. Specifically, the application was used to compile an overall bibliometric profile and dataset summary, analyse annual publication output, citation trends, and yearly bibliometric statistics, identify highly cited publications, and map the keyword co-occurrence networks. To ensure absolute data integrity before analytical execution, OpenRefine was deployed as the primary data-cleaning engine. Raw bibliometric exports from commercial databases frequently contain metadata inconsistencies, such as variant spellings of author names, disparate institutional indexing formats, and overlapping keyword synonyms (Bortruex, 2022; Miller & Vielfaure, 2022). OpenRefine's advanced text-clustering algorithms were utilized to merge identical entities, harmonize country and institutional affiliations, and standardize conflicting keyword

listings into uniform categories. This pre-processing phase eliminated structural noise and minimized data inflation, establishing a reliable, clean matrix. By resolving these discrepancies, OpenRefine significantly enhanced the precision of subsequent statistical evaluations, ensuring that performance metrics accurately reflect true scientific contributions (Ahmi, 2023; Sterner, 2019).

Once the dataset was thoroughly cleaned, VOSviewer was utilized as the primary computational tool to execute distance-based network visualizations and bibliometric mapping (Arruda et al., 2022; Wong, 2018). VOSviewer parsed the refined data to construct multi-dimensional networks, focusing on co-authorship maps to visually trace international research collaborations and institutional networks across global boundaries. Furthermore, keyword co-occurrence maps were generated to uncover dominant thematic clusters, emerging

research fronts, and shifting paradigms within online technical education over the 27-year timeframe. By integrating these visual clusters with proximity-based mapping, the VOSviewer analysis successfully translates complex bibliographic relational data into interpretable, high-density diagrams, revealing both the

structural backbone and the conceptual evolution of the field (CWTS, 2022).

RQ1. What are the publication trends and growth patterns of research on Online Learning for Technical Education?

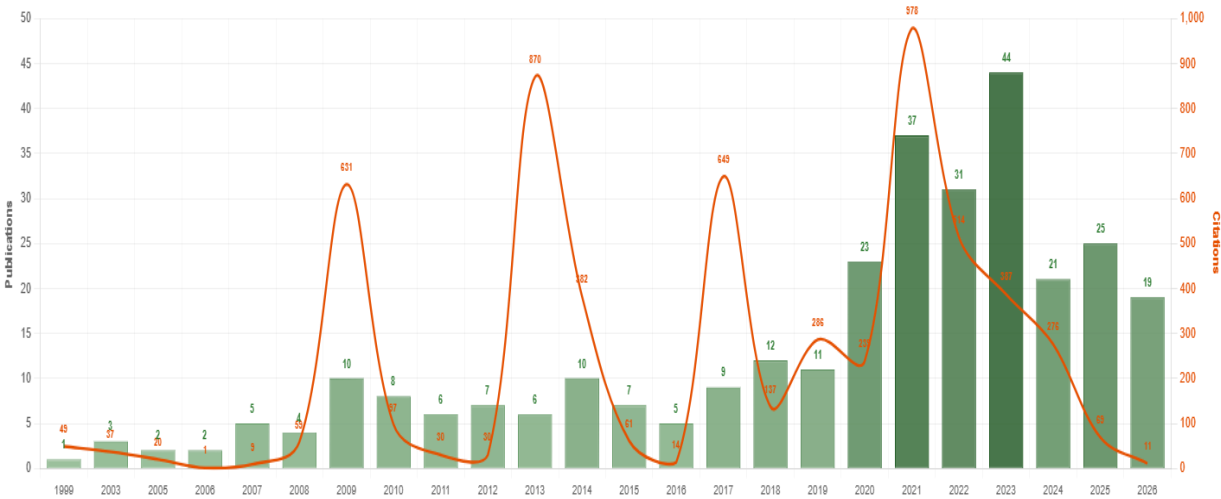


Figure 2. Annual Publications & Citations

Table 1. Details of Citation Impact

Year	TP	NCA	NCP	TC	C/P	C/CP	h	g	m	e
2026	19	67	3	11	0.58	3.67	2	3	0.071	2.45
2025	25	100	18	69	2.76	3.83	5	7	0.185	5
2024	21	71	16	276	13.14	17.25	4	16	0.154	15.23
2023	44	162	35	387	8.8	11.06	11	18	0.44	12.69
2022	31	81	29	514	16.58	17.72	11	22	0.458	18.11
2021	37	117	32	978	26.43	30.56	13	31	0.565	27.15
2020	23	62	20	239	10.39	11.95	9	15	0.409	10.63
2019	11	37	11	286	26	26	7	11	0.333	15.17
2018	12	36	12	137	11.42	11.42	6	11	0.3	9.11
2017	9	26	8	649	72.11	81.12	7	9	0.368	24.47
2016	5	11	2	14	2.8	7	2	3	0.111	3.16
2015	7	16	4	61	8.71	15.25	3	7	0.176	7.14

2014	10	32	9	382	38.2	42.44	5	10	0.312	18.63
2013	6	15	5	870	145	174	4	6	0.267	29.21
2012	7	13	2	30	4.29	15	2	5	0.143	5.1
2011	6	13	5	30	5	6	3	5	0.231	4.24
2010	8	15	7	97	12.12	13.86	4	8	0.333	8.54
2009	10	29	8	631	63.1	78.88	5	10	0.455	24.45
2008	4	7	3	59	14.75	19.67	2	4	0.2	7.35
2007	5	14	4	9	1.8	2.25	2	2	0.222	1.73
2006	2	3	1	1	0.5	1	1	1	0.125	0
2005	2	5	1	20	10	20	1	2	0.143	4.36
2003	3	9	2	37	12.33	18.5	2	3	0.4	5.74
1999	1	2	1	49	49	49	1	1	1	6.93

Note: TP = Total Publications; NCA = Number of Contributing Authors; NCP = Number of Cited Publications; TC = Total Citations; C/P = Citations per Publication; C/CP = Citations per Cited Publication; h = h -index; g = g -index; m = m -Quotient; e = e -index

The chronological progression of the dataset reveals a clear trajectory of academic expansion, transitioning from a nascent baseline to a highly active domain. Between 1999 and 2018, the field experienced a protracted period of low productivity, with Total Publications (TP) remaining in single or low double digits, peaking at only 12 papers in 2018. However, a sharp upward trajectory commenced in 2020 (TP = 23) and culminated in an explosive output peak in 2023 with 44 publications, accounting for over 14% of the total 308 publications recorded across the entire timeframe. This surge in volume directly parallels a substantial influx of research talent; the Number of Contributing Authors (NCA) rose from a mere 36 in 2018 to an all-time high of 162 in 2023. Although a downward shift in output is observed from 2024 to 2026 (19 publications), this is primarily attributable to incomplete data tracking for the current calendar year rather than a decline in thematic relevance (Figure 2).

In terms of academic citation impact, the field demonstrates strong visibility, accumulating a Total of 5,836 Citations (TC) (Table 1). The pinnacle of research influence occurred in 2021, which garnered the highest volume of citations (TC = 978) alongside the maximum recorded h -index of 13 and g -index of 31, signaling a dense collection of highly influential papers. From a quality standpoint, older publications exhibit remarkable enduring value; for instance, 2013 achieved the highest average citation rate with 145 Citations per Publication (C/P), driven by prolonged exposure over time. Conversely, the sharp drop in citation metrics for recent years, such as 2026 with a C/P of 0.58, does not indicate low-quality research. Rather, it illustrates the standard bibliometric citation lag, as newly published works require a multi-year window to be integrated, read, and cited by peer researchers.

RQ3. Which countries are the most productive and influential contributors to the

Online Learning for Technical Education literature?

The geographical distribution of research output in online learning for technical education reveals a clear divide between high-volume productivity and high-impact influence, led primarily by the United States and China. The United States stands out as the dominant force in this academic domain, with the highest total publications (TP = 42) and the largest community of researchers with 125 contributing authors (NCA) (Figure 3). Beyond volume, the US exhibits strong academic authority, with the highest Total Citations (TC = 2,096), a commanding h-index of 13, and a g-index of 42. This underscores a robust research infrastructure that consistently yields foundational, widely referenced literature. China follows closely as the second most productive nation with 30 publications and 92 contributing authors, demonstrating massive institutional investment and systemic focus on modernizing technical curricula through digital means. Meanwhile, Indonesia captures the third spot in volume (TP = 26, NCA = 99), reflecting a major regional push toward digital learning adoption, driven by geographical imperatives and educational equity initiatives. However, despite their high productivity, both China and Indonesia exhibit comparatively modest citation rates, with Indonesia recording a low average of 4.5 C/P and China logging a C/P of 11.57. This contrast between output volume and citation frequency suggests that while Asian nations are rapidly expanding their scientific footprint, their research may be heavily contextualized around localized implementations or still early in its citation-accumulation cycle compared to long-standing Western paradigms.

When shifting the analytical lens from sheer productivity to systemic influence and research

efficiency, the United Kingdom and Taiwan emerge as the primary global benchmarks. The United Kingdom, despite a modest output of 17 publications, demonstrates extraordinary qualitative influence, achieving the highest efficiency metric with 63.06 Citations per Publication (C/P) and an exceptional 97.45 Citations per Cited Publication (C/CP) (Table 2). This indicates that when UK research is published, it becomes highly integrated into global scientific dialogues, generating 1,072 total citations from a fraction of the output generated by the US or China. Similarly, Taiwan presents phenomenal research impact, matching India with 15 publications but outperforming most peers with a staggering 882 total citations and a high C/P of 58.8. Taiwan's academic efficiency is further highlighted by its h-index of 9 and an m-quotient of 0.562, indicating a sustained rate of high-impact research relative to the lifespan of its publications. Emerging contributors such as Saudi Arabia also exhibit distinct, specialized impact; while matching a lower volume threshold (TP = 12), the nation boasts the highest m-quotient in the entire dataset at 0.857, signaling an aggressive, rapidly accelerating trajectory of high-quality contemporary research. Conversely, nations like Germany (TP = 10, TC = 36) and Russia (TP = 8, TC = 37) mark the lower tier of this distribution, suggesting their contributions are either highly specialized, limited in global reach, or constrained by language and institutional dissemination channels. Ultimately, these bibliometric dynamics illustrate that while the US successfully bridges massive scale with deep academic influence, smaller text-dense research hubs like the UK and Taiwan command an outsized share of global authority per publication, effectively shaping the international trajectory of technical e-learning methodologies.

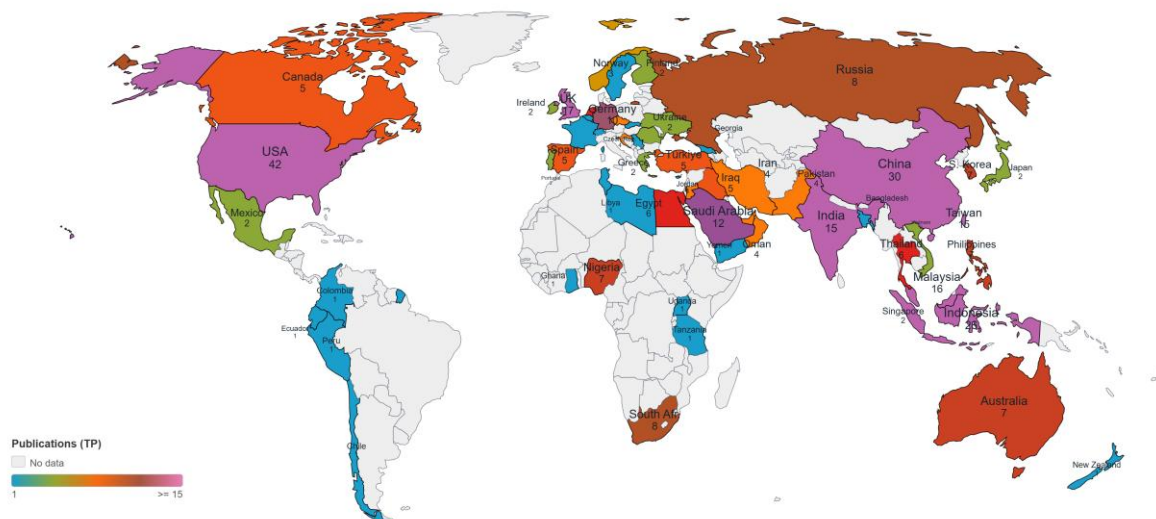


Figure 3. Global Distribution of Publications by Country

Table 2. Publication and Citation Metrics by Country

Country	TP	NCA	NCP	TC	C/P	C/CP	h	g	m	e
United States	42	125	35	2096	49.9	59.89	13	42	0.542	42.87
China	30	92	24	347	11.57	14.46	8	18	0.286	14.83
Indonesia	26	99	20	117	4.5	5.85	6	9	0.5	6.16
United Kingdom	17	43	11	1072	63.06	97.45	8	17	0.381	31.58
Malaysia	16	66	13	211	13.19	16.23	8	14	0.533	11.62
India	15	24	12	153	10.2	12.75	6	12	0.353	10.05
Taiwan	15	36	13	882	58.8	67.85	9	15	0.562	27.98
Saudi Arabia	12	45	12	242	20.17	20.17	6	12	0.857	13.75
Germany	10	30	7	36	3.6	5.14	3	5	0.176	4.47
Russia	8	29	5	37	4.62	7.4	5	6	0.556	3.46

Note: TP = Total Publications; NCA = Number of Contributing Authors; NCP = Number of Cited Publications; TC = Total Citations; C/P = Citations per Publication; C/CP = Citations per Cited Publication; h = h-index; g = g-index; m = m-Quotient; e = e-index

RQ4. How are international research collaborations structured within the Online Learning for Technical Education domain?

The country collaboration analysis revealed that research on online learning in technical

education is geographically diverse, with contributions from both developed and developing nations. The United States emerged as the most productive country with 40 publications, followed by China (30 documents), Indonesia (28 documents), Malaysia (17

documents), and India (16 documents) (Figure 4). In terms of collaboration strength, Malaysia demonstrated the highest level of international connectivity, recording six collaboration links and a Total Link Strength (TLS) of 9, followed by China (TLS = 7) and Jordan and the United Arab Emirates (TLS = 5 each) (Table 3). The network visualization identified several collaboration clusters, indicating that international research partnerships are primarily formed within regional and thematic groups rather than through a single globally integrated network. However, several countries, including India, Germany, South Africa, Russia, the Philippines, Canada, Spain, and Türkiye, exhibited no international collaboration links, suggesting that a substantial proportion of research output in this field is still conducted within national boundaries.

From an impact perspective, countries with earlier engagement in the field generally recorded higher citation performance. The United

Kingdom (62.38 citations per document), Taiwan (58.80 citations), Australia (57.33 citations), and the United States (49.90 citations) achieved the highest average citation rates, reflecting their influential contributions to developing online learning in technical education. Australia also recorded the highest average normalized citation score (3.48), indicating that its publications received citation impacts substantially above the global average for their publication years. In contrast, emerging contributors such as Indonesia, South Africa, Russia, and the Philippines demonstrated more recent average publication years (2022–2025) but relatively lower citation rates. This finding suggests that their research contributions are still in the early stages of accumulating scholarly influence. Overall, the findings indicate growing internationalization in this domain, with Asia playing an increasingly prominent role, while established research nations continue to exert strong influence through highly cited publications and collaborative networks.

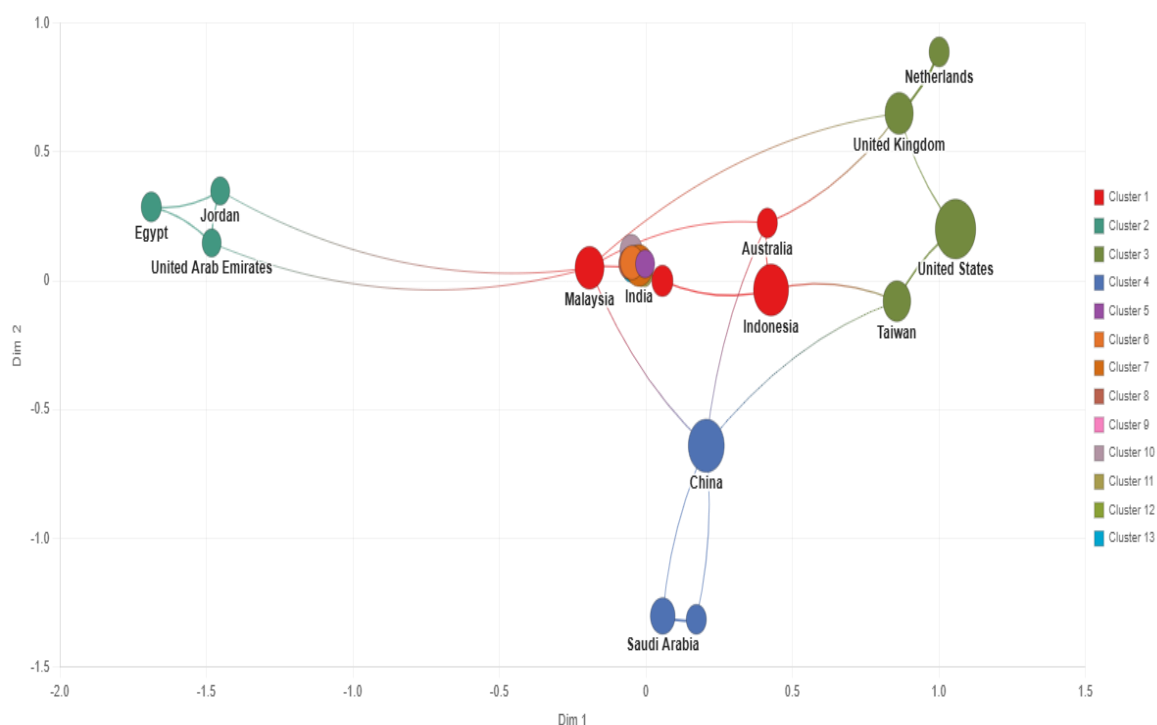


Figure 4. Network Map of Countries

Table 3. Top 10 Most Influential Countries (of 23 total)

No	Country	Cluster	Documents	Links	Total Link Strength	Relevance	Avg. Pub. Year	Avg. Citations	Avg. Norm. Citations
1	United States	3	40	2	3.00	40.000	2017.5	49.90	1.32
2	China	4	30	5	7.00	30.000	2021.3	11.57	1.68
3	Indonesia	1	28	3	3.00	28.000	2022.0	4.39	0.52
4	Malaysia	1	17	6	9.00	17.000	2020.4	13.18	1.35
5	India	7	16	0	0.00	16.000	2018.8	14.75	0.73
6	United Kingdom	3	16	4	4.00	16.000	2015.9	62.38	1.42
7	Taiwan	3	15	3	4.00	15.000	2014.3	58.80	2.10
8	Saudi Arabia	4	11	2	3.00	11.000	2022.6	20.00	1.23
9	Germany	6	9	0	0.00	9.000	2019.2	2.89	0.17
10	South Africa	10	8	0	0.00	8.000	2022.6	5.25	0.51

RQ5. What thematic clusters and emerging research directions can be identified through keyword co-occurrence analysis in Online Learning for Technical Education research?

The keyword co-occurrence analysis identified three major thematic clusters that characterize research on online learning in technical education. Cluster 1 represents the technological adoption and acceptance dimension, centred on highly frequent keywords such as *e-learning* (87 occurrences), *higher education* (15 occurrences), *SEM* (14 occurrences), *TAM* (11 occurrences), *technology acceptance* (7 occurrences), and *learning management system* (6 occurrences) (Figure 5). This cluster highlights researchers' emphasis on understanding factors influencing the adoption, acceptance, and implementation of online learning technologies. The prominence of Technology Acceptance Model (TAM) related terms and the high average citation impact of *technology acceptance* (70.43 citations) indicate that studies examining users' behavioural intentions

and perceptions of educational technologies have formed a significant foundation of the field. Cluster 2 focuses on online learning implementation and effectiveness, encompassing keywords such as *online learning* (44 occurrences), *COVID-19* (19 occurrences), *learning outcomes* (9 occurrences), *effectiveness* (7 occurrences), *vocational education* (5 occurrences), and *blended learning* (5 occurrences). The strong presence of pandemic-related terms reflects the substantial influence of COVID-19 in accelerating the adoption of online learning across technical and vocational education settings.

Cluster 3 represents learner-centred and emerging research themes, including *engineering education* (12 occurrences), *student engagement* (8 occurrences), *self-efficacy* (6 occurrences), *digital learning* (6 occurrences), and *learning effectiveness* (5

occurrences). Several keywords in this cluster have the most recent average publication years, particularly *SEM* (2023.9), *student engagement* (2023.9), *digital learning* (2024.0), and *self-efficacy* (2023.3), suggesting growing scholarly interest in understanding learner experiences and behavioural factors in online technical education environments. Moreover, *self-efficacy* recorded the highest average normalized citation score (4.91), indicating substantial research impact relative to publication year. These findings suggest that the

field has evolved from a primary focus on technology adoption and system implementation to more learner-centred perspectives that emphasize engagement, motivation, self-efficacy, and digital learning experiences. Consequently, future research is likely to continue exploring how technological innovations can enhance student engagement and learning outcomes within increasingly digitalized technical and vocational education contexts (Table 4).

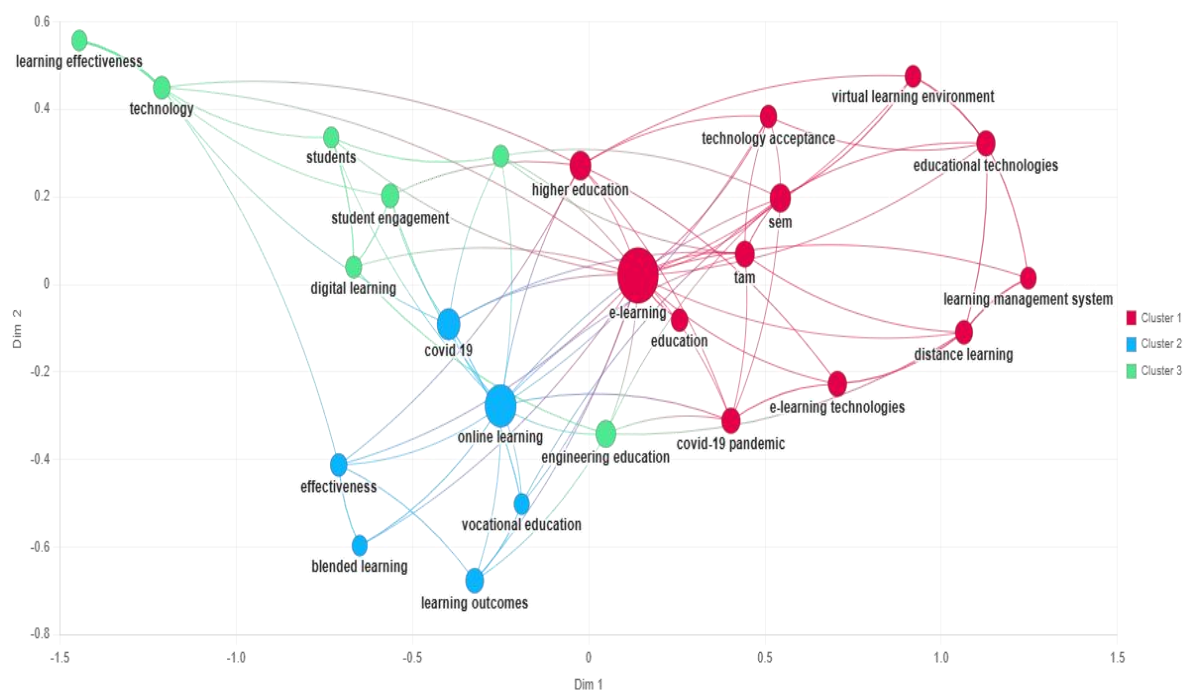


Figure 5. Network Visualisation of Author Keywords

Table 4. Top 10 most frequently occurring keywords (of 25 total, across six clusters) in online learning research identified through co-occurrence analysis

No	Term	Cluster	Occurrences	Links	Total Link Strength	Relevance	Avg. Pub. Year	Avg. Citations	Avg. Norm. Citations
1	e-learning	1	87	21	61.00	87.000	2018.4	15.06	0.83
2	online learning	2	44	14	42.00	44.000	2021.5	24.32	1.63
3	covid 19	2	19	7	15.00	19.000	2021.8	30.95	1.49

4	higher education	1	15	9	18.00	15.000	2020.9	21.67	2.25
5	sem	1	14	10	21.00	14.000	2023.9	39.50	1.83
6	engineering education	3	12	7	13.00	12.000	2020.5	19.25	1.01
7	tam	1	11	8	16.00	11.000	2021.5	52.82	2.42
8	covid-19 pandemic	1	10	7	11.00	10.000	2021.8	28.40	1.40
9	e-learning technologies	1	10	4	6.00	10.000	2019.7	14.10	1.31
10	educational technologies	1	10	6	12.00	10.000	2020.1	8.10	0.52

4. Discussion

The findings demonstrate that research on online learning for technical education has undergone substantial growth, particularly following the COVID-19 pandemic. The sharp increase in publication output between 2020 and 2023 reflects the urgent need for educational institutions to transition from conventional face-to-face delivery to online and hybrid learning environments. This trend aligns with previous studies highlighting how the pandemic accelerated digital transformation across technical and vocational education systems worldwide, exposing both opportunities and challenges associated with online delivery. Research from China, Malaysia, South Africa, and other countries consistently reported that while online learning ensured educational continuity, significant concerns remained regarding practical skill acquisition, technological infrastructure, instructor preparedness, and student readiness. The surge in scholarly attention therefore reflects a response to an emergency educational context and a broader recognition that online learning has become a

permanent component of technical and vocational education. The citation analysis further reveals that the intellectual foundation of the field is strongly rooted in technology acceptance, self-regulated learning, and student outcomes. Highly cited studies by Wang et al. (2013), Liu et al. (2009), and Tarhini et al. (2017) emphasized the importance of learners' technological self-efficacy, perceptions of technology usefulness, and behavioral intentions toward e-learning adoption. The prominence of keywords such as technology acceptance, TAM, and e-learning in the co-occurrence network further reinforces the centrality of these theoretical perspectives within the field. These findings are consistent with the broader educational technology literature, which suggests that successful implementation of online learning depends on technological availability and on learners' confidence, motivation, and willingness to engage with digital platforms. Consequently, TAM remain an important explanatory framework for understanding online learning adoption in technical education settings.

The geographical analysis highlights a noteworthy distinction between research productivity and research influence. However, the United States and China dominate publication output. Countries such as the United Kingdom and Taiwan exhibit substantially higher citation impact per publication. This pattern suggests that research quality, theoretical contribution, and international visibility may be more important determinants of scholarly influence than publication volume alone. Furthermore, the increasing contribution of countries such as Indonesia, Malaysia, Saudi Arabia, and other Asian nations reflects the growing globalisation of online learning research. Nevertheless, the collaboration network indicates that international partnerships remain fragmented, with many countries demonstrating limited or no collaboration links. The relatively strong collaborative positions of Malaysia and China suggest that regional and cross-border partnerships may play a crucial role in knowledge exchange and capacity building. Strengthening international collaboration could therefore accelerate the development of innovative pedagogical practices and enhance the global relevance of research findings. The keyword co-occurrence analysis reveals a clear evolution in research priorities over time. Earlier studies focused primarily on technological adoption, learning management systems, virtual learning environments, and e-learning technologies, reflecting the initial challenge of establishing digital learning infrastructure. More recent studies, however, have shifted towards learner-centred themes such as student engagement, self-efficacy, digital learning experiences, and learning effectiveness. The emergence of self-efficacy as one of the highest-impact keywords is particularly significant because it supports previous evidence demonstrating that students' confidence in their digital capabilities strongly influences engagement and academic achievement in online environments. Similarly, the growing prominence of student engagement and digital learning suggests that researchers are increasingly concerned with understanding how online learning experiences can be designed to sustain motivation, interaction, and meaningful

participation among technical education students.

Collectively, these findings indicate that the field is transitioning from a technology-centred paradigm toward a more holistic educational perspective that integrates pedagogical design, learner psychology, and digital innovation. This shift aligns with previous studies emphasizing the effectiveness of blended learning, active learning strategies, collaborative learning environments, virtual simulations, and interactive digital tools in supporting technical and vocational education. As technical education increasingly incorporates digital and hybrid delivery models, future research should focus on optimizing student engagement and developing authentic virtual practical experiences. It should also investigate how emerging technologies such as artificial intelligence, immersive simulations, and adaptive learning systems can support both theoretical understanding and practical skill development. Such efforts will be essential to ensure that online learning complements rather than compromises the applied and competency-based nature of technical education.

5. Conclusion

This bibliometric study offers a comprehensive picture of the development, intellectual structure, and emerging directions of research on online learning in technical education. Based on 308 Scopus-indexed publications from 1999 to 2026, the analysis presents a clear and sustained growth in scholarly attention, with a marked acceleration after the COVID-19 pandemic. The field has evolved from a relatively limited area of inquiry into a rapidly expanding research domain. Citation analysis also identified several influential studies that have shaped the literature, particularly those related to technology acceptance, self-regulated learning, learner characteristics, and instructional effectiveness. The study further highlights important geographical and collaborative patterns. The United States and China are the most productive countries, while the United Kingdom and Taiwan exhibit particularly strong citation impact, reflecting strong scholarly influence.

Although international collaboration is increasing, research partnerships remain uneven across countries. Keyword analysis revealed three major thematic clusters, consisting of technology adoption and acceptance, online learning implementation and effectiveness, and learner-centred issues such as engagement, self-efficacy, and digital learning experiences. Recent trends suggest a gradual shift from focusing on technology itself toward a stronger emphasis on how online learning environments support student participation, motivation, and achievement. Overall, the findings indicate that online learning in technical education is becoming a strategic and sustainable component of technical and vocational training rather than a temporary response to disruption. Future research should prioritize stronger international collaboration, more rigorous evaluation of pedagogical approaches, and deeper investigation of learner outcomes in online and blended technical education settings. In addition, emerging technologies such as artificial intelligence, virtual laboratories, immersive

simulations, and adaptive learning systems should be explored for their potential to improve competency-based learning. Researchers should also examine access, equity, teacher readiness, and institutional support to ensure online learning is both effective and inclusive. These directions can help strengthen the quality, relevance, and long-term impact of online learning in technical education.

Conflict of Interest

The authors declare no conflicts of interest.

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