Available online at: https://jurnal-fkip.ut.ac.id/index.php/ijrse/issue/archive
International Journal of Research in STEM Education (IJRSE)
ISSN 2721-2904 (online)
Volume 8 Number 1-1 (2026): Special Issue (August): 91 - 114

Technology-Enhanced Design Learning in STEM/STEAM Education: A Bibliometric Analysis

[1]O, Norashiken, [2]Norhafizah Mohamad Dasuki, [3]Normah Kassim, [4]Zainon Nooraizedfiza

[1,3,4]Faculty of Mechanical Engineering & Technology, Universiti Malaysia Perlis, Pauh Putra Campus, 02600 Arau, Perlis, Malaysia.
[1,2,3,4]Fakulti Pengurusan Teknologi dan Teknousahawanan, Centre of Technopreneurship Development, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Malaysia.
norashiken@unimap.edu.my

Abstract

This study aims to examine the development, intellectual structure, and thematic configuration of research on technology-enhanced design learning, with particular attention to the intersection of technology education, engineering education, design learning, and STEM/STEAM education. A bibliometric and science-mapping approach was employed using Scopus-indexed journal articles published between 2016 and 2026. The search was conducted within the title, abstract, and keyword fields and was limited to English-language journal articles. After screening and eligibility assessment, 470 documents were retained for analysis. Bibliometric performance indicators were generated using biblioMagika, while Biblioshiny was used to examine author keyword co-occurrence networks and thematic structures. Data cleaning and keyword harmonisation were conducted before analysis to improve consistency and reliability. The findings show that technology design education has developed into an active interdisciplinary research area with visible publication growth, citation reception, and collaborative authorship. The field is strongly anchored in technology education, engineering education, students, curricula, teaching, and design processes. However, STEM/STEAM education, educational technology, e-learning, artificial intelligence, and computational thinking remain only partially integrated into the field's central structure. The thematic analysis indicates a developed pedagogical core but weaker interdisciplinary integration. The study is limited to Scopus-indexed English-language journal articles; therefore, relevant studies from other databases, languages, and non-journal sources may be excluded. Future research should expand database coverage and examine classroom-level implementation of technology-enhanced design learning. This study contributes by mapping the knowledge structure of technology-enhanced design learning and clarifying its dominant, emerging, and underdeveloped themes.

Keywords: *Bibliometric analysis; Engineering design education; Technology-enhanced design learning; Technology education; STEM/STEAM education;*

INTRODUCTION

Digital technologies are now deeply embedded in STEM education, but the educational meaning of "technology-enhanced learning" remains less settled than its policy popularity suggests. Evidence from meta-analytic research shows that digital tools can improve secondary mathematics and science learning (Hillmayr et al., 2020), and broader evidence across four decades of educational technology research indicates positive, though variable, effects on achievement (Tamim et al., 2011). Yet these findings do not resolve a more specific problem in engineering design education: a digitally supported classroom may improve access, visualization, or engagement without necessarily developing students' capacity to frame problems, generate design alternatives,

Corresponding author:
O, Norashiken, norashiken@unimap.edu.my,
DOI: https://doi.org/10.33830/ijrse.v8i1-1.15193

evaluate constraints, prototype solutions, and justify design decisions. The unresolved issue is therefore not whether technology can support learning, but how technology becomes educationally meaningful when learning is organized around engineering design.

This distinction matters because engineering design occupies a distinctive position in STEM/STEAM education. It is not merely a classroom activity or a final project; it is a mode of thinking that requires learners to coordinate scientific ideas, mathematical reasoning, technological knowledge, material constraints, user needs, and iterative decision making. Integrated STEM frameworks emphasize that meaningful STEM learning requires purposeful connections among disciplines rather than superficial aggregation (English, 2016; Kelley & Knowles, 2016). Yata et al. (2020) similarly argued that stronger STEM practice requires clearer relationships among science, technology, mathematics, and engineering activity. Within this logic, engineering design functions as a possible integrative mechanism. However, its integrative role cannot be assumed. Design may support STEM learning when it is pedagogically structured, but it may also become a loosely defined activity if the conceptual connection between design processes, disciplinary knowledge, and learning outcomes is left underdeveloped.

Empirical studies illustrate both the promise and the complexity of this field. Fan and Yu (2017) showed that an integrative STEM curriculum can benefit high school students' engineering design practices. In the Malaysian context, Mohd Shahali et al. (2017) found that middle secondary students' interest in STEM subjects and careers improved after participation in an integrated STEM programme using a five-phase engineering design process. These findings are important because they indicate that engineering design can increase the educational and motivational relevance of STEM learning. However, literature also cautions against treating design-rich learning as automatically transformative. Bevan (2017) argued that making in science education should be scrutinized critically, rather than accepted as inherently productive. Sung and Kelley (2019) further showed that learners' design thinking can be examined through process patterns, implying that design learning requires attention to sequence, iteration, and cognitive activity rather than artefact production alone.

A related complication appears in the distinction between STEM and STEAM. STEAM is often positioned as a way to enrich STEM through creativity, aesthetics, communication, and human-centred design. However, Perignat and Katz-Buonincontro (2019) found that STEAM research remains conceptually diffuse, with varied definitions and purposes across studies. This matters for engineering design-enhanced technology education because the field frequently draws on concepts such as creativity, design thinking, innovation, and technological literacy, yet these constructs are not always operationalized consistently. Li et al. (2019) argued that design and design thinking are central to STEM education, while Li and Zhan (2022) showed that K–12 design thinking integrated learning requires stronger empirical consolidation. The field therefore faces a double challenge: engineering design is increasingly invoked as a powerful STEM/STEAM pedagogy, but the research base connecting design, technology, STEM integration, and learning remains conceptually dispersed.

Technology-enhanced education adds another layer to this problem. Lai and Bower (2019) found that evaluation of educational technology spans multiple dimensions, including learning outcomes, affective elements, behaviour, design, pedagogy, technology features, presence, and institutional environment. This multidimensionality is valuable, but it also reveals why technology-enhanced engineering design education is difficult to define. Technology may function as a learning tool, a design medium, a simulation environment, a fabrication platform, an assessment mechanism, or an object of critical inquiry. If these functions are not distinguished, the field risks conflating educational technology with technology education. The former often concerns the use of digital tools for instruction, whereas the latter concerns learners' understanding of technological systems, design processes, and technological decision making. This distinction is theoretically important because engineering design-enhanced technology education is concerned not only with using technology to teach, but also with helping learners think, act, and decide through technology-rich design processes.

The expansion of STEM education research further strengthens the need for field-level synthesis. Li et al. (2020) reviewed 798 STEM education journal articles and demonstrated that STEM education scholarship has grown into a diverse international research domain. Growth, however, does not necessarily produce conceptual coherence. In emerging interdisciplinary fields, scholarship may expand across journals, methods, and contexts while leaving key constructs weakly connected. This is precisely the issue addressed in the present study. Engineering design-enhanced technology education sits at the intersection of educational technology, technology education, engineering education, design learning, STEM/STEAM pedagogy, and curriculum innovation. Existing studies explain important parts of this intersection, but they do not show how the field is intellectually organized.

Bibliometric and science-mapping methods are appropriate for this problem because they allow the structure of a research field to be examined systematically. Bibliometric analysis can reveal publication development, influential sources, citation concentration, and research frontiers (Donthu et al., 2021), while science mapping can expose intellectual and conceptual relationships among documents, authors, journals, and keywords (Zupic & Čater, 2015). Tools such as Bibliometrix and VOSviewer support the analysis and visualization of large bibliographic datasets (Aria & Cuccurullo, 2017; van Eck & Waltman, 2010). For the present study, these methods are not used merely to count publications. They are used to examine whether engineering design-enhanced technology education has developed a coherent knowledge structure or remains a set of partially connected conversations.

This study contributes to literature in three ways. First, it provides a bibliometric profile of engineering design-enhanced technology education by examining publication trends, citation patterns, source titles, and highly cited documents. Second, it maps the conceptual structure of the field through author keyword co-occurrence and thematic analysis, clarifying how technology education, engineering education, STEM/STEAM education, educational technology, and design learning are connected. Third, it identifies areas where the field appears consolidated and areas where conceptual integration remains weak. The contribution is non-obvious because the study does not simply ask whether technology or design improves STEM learning. Instead, it asks how the scholarship itself has organized these ideas and what that organization reveals about the field's maturity, boundaries, and future research agenda.

The objective of this study is to examine the development, scholarly performance, intellectual structure, and thematic configuration of technology-enhanced design learning research at the intersection of technology education, engineering education, design learning, and STEM/STEAM education. Specifically, the study aims to (1) analyse publication and citation patterns; (2) identify the principal journals, documents, and citation indicators shaping the field; (3) map conceptual relationships using author-keyword co-occurrence and thematic analysis; and (4) determine the extent to which the field is consolidated, fragmented, or positioned for future development.

Accordingly, this study is guided by four research questions: (1) What publication and citation patterns characterize research on engineering design-enhanced technology education? (2) Which journals, documents, and citation indicators define the field's scholarly profile? (3) What conceptual relationships are visible through author keyword co-occurrence and thematic mapping? and (4) What do these bibliometric patterns reveal about the field's consolidation, fragmentation, and future research directions? The study applies bibliometric performance analysis and science mapping to Scopus-indexed journal articles published between 2016 and 2026. The remainder of the paper reviews relevant literature, explains the search strategy and bibliometric procedures, presents the findings, discusses their implications for STEM/STEAM design education, and concludes with limitations and future research directions. This study examines the development, scholarly performance, intellectual structure, and thematic configuration of technology-enhanced design learning within STEM/STEAM education.

LITERATURE REVIEW

Previous bibliometric studies have examined related areas of design education, but their scopes remain concentrated on specific subdomains. Küçükyağcı (2025) mapped basic design education in architecture, urban planning, and landscape architecture, highlighting publication patterns, dominant countries, keywords, and emerging technology-related terms. Budhyani et al. (2025) examined experiential and technology-integrated pedagogy in vocational design education, with attention to project-based learning, immersive technologies, digital assessment, and cultural responsiveness. Johann et al. (2020) focused on design thinking as a tool for entrepreneurship education, while Jia et al. (2025) analysed design thinking research in education and identified creativity, project-based learning, and competency-based innovation as important research directions. Collectively, these studies show that design education research is increasingly connected to technology, creativity, experiential learning, and student-centred pedagogy.

However, existing bibliometric studies have not specifically consolidated the literature on engineering design-enhanced technology education, particularly at the intersection of technology education, engineering education, design learning, STEM/STEAM education, and educational technology. Prior studies either focus on basic design, vocational design, entrepreneurship education, or design thinking in general education, leaving limited evidence on how technology-design education is intellectually structured as a research field. Therefore, the present study is important because it provides a focused bibliometric and science-mapping analysis of this interdisciplinary area using performance indicators, highly cited documents, source-title analysis, author keyword co-occurrence, and thematic mapping. This study contributes by clarifying the field's knowledge structure, identifying its dominant and underdeveloped themes, and offering a stronger evidence base for future research in technology-enhanced design learning.

Table 1. Summary of previous studies

Author	Domain & Search Query	Objective of the Study	Total Document, Data Source & Coverage	Attributes Examined	Main Findings
Küçükyağcı (2025)	Domain: Basic design education in architecture, planning, and landscape architecture. Search Query: ALL FIELDS "basic design education" OR "basic design course" OR "basic design studio" AND "architectural education" OR "architecture education" OR "landscape architecture education" OR "urban planning education"	Map academic studies on basic design education	2,171 publications from Web of Science (1970–2024)	-Author-Country-Keyword-Document type	Identified architecture as the leading field, Türkiye as the most productive country, and post-2020 trends including creative thinking, virtual reality, AI, augmented reality, and project-based learning.

Author	Domain & Search Query	Objective of the Study	Total Document, Data Source & Coverage	Attributes Examined	Main Findings
Budhyani et al. (2025)	Domain: Experiential and technology-integrated pedagogy in vocational design education. Search Query: ("design education" OR "creative arts education") AND ("experiential learning") AND ("technology integration") AND ("vocational education")	Examine the convergence of experiential learning, technology integration, and cultural responsiveness	241 open-access articles from Dimensions AI (2015–2025)	- Co-authorship patterns- Keyword co-occurrence- Bibliographic coupling	Found growing research on individual themes, but limited integrated studies combining experiential, technological, and culturally responsive strategies.
Johann et al. (2020)	Domain: Design thinking as a tool for entrepreneurship education. Search Query: "Design Thinking" AND "Entrepreneurial Education"	Analyze DT studies related to entrepreneurial mindset	146 publications from Web of Science (2009–2019)	- Intellectual productivity- Production concentration- Co-citation map- Keyword co-occurrence	Highlighted DT as a student-centered methodology supporting innovative education, entrepreneurial skills, and creative participation.
Jia et al. (2025)	Domain: Design thinking in education. Search Query: TI="design* think*" AND AB="design* think*" AND AK="design* think*"	Assess past and present DT research and guide future studies	276 documents from Web of Science (1997–2024)	- Publication trends- Leading contributors- Co-citation networks- Collaboration networks- Keyword trends	Found publication growth since 2021, with design thinking, creativity, and project-based learning as core and emerging areas.

RESEARCH METHOD

This study adopted a bibliometric and science-mapping approach to examine the development, structure, and thematic configuration of research on technology-enhanced design learning. The method was designed to identify publication patterns, citation performance, influential sources, highly cited documents, and conceptual relationships within the literature. Scopus was selected as the bibliographic database because it provides structured metadata suitable for bibliometric analysis, including titles, abstracts, author keywords, citations, affiliations, and source information. The study combined performance analysis with science mapping to provide both descriptive and relational insights into the field. Data screening, cleaning, and harmonisation were conducted before analysis to improve reliability and reproducibility. Bibliometric indicators were generated using biblioMagika, while Biblioshiny was used to visualize keyword co-occurrence networks and thematic structures.

Methodological design

This study employed a bibliometric and science-mapping design to examine the structure, development, and thematic configuration of research on technology-enhanced design learning. Bibliometric analysis is appropriate when a research area has accumulated a sufficiently large body of publications and the objective is to identify publication trends, influential sources, citation patterns, authorship structures, and conceptual relationships across the literature (Donthu et al., 2021; Zupic & Čater, 2015). In contrast to a traditional narrative review, which depends primarily on interpretive synthesis, bibliometric analysis enables the systematic examination of publication metadata and citation relationships at scale. This approach is particularly suitable for fields such as technology-enhanced education, design learning, and STEM/STEAM education, where research is dispersed across education, technology education, engineering education, design education, and digital learning outlets.

The study combined two complementary bibliometric procedures: performance analysis and science mapping. Performance analysis was used to evaluate productivity and impact indicators, including annual publication output, citation counts, active journals, prolific authors, contributing institutions, countries, and highly cited documents. Science mapping was used to examine the conceptual and relational structure of the field through keyword co-occurrence, clustering, overlay visualization, density visualization, and thematic mapping. This two-stage design follows established recommendations that bibliometric studies should not rely only on descriptive counts but should also examine the intellectual, social, and conceptual structures of a research field (Donthu et al., 2021; Mukherjee et al., 2022; Zupic & Čater, 2015).

Database selection and justification

Bibliographic data were retrieved from Scopus. Scopus was selected because it provides broad interdisciplinary coverage, structured citation metadata, author and institutional information, source-title data, abstracts, author keywords, indexed keywords, and export formats compatible with bibliometric software. These characteristics are important for bibliometric and science-mapping studies because the reliability of the analysis depends on consistent metadata fields and sufficient coverage of the relevant scholarly domain.

The use of Scopus is also appropriate for a topic that crosses education, engineering, technology, design, and STEM/STEAM learning. Comparative studies have shown that Scopus and Web of Science are among the most widely used structured databases for bibliometric research, although their coverage differs by discipline, language, source type, and region (Falagas et al., 2008; Harzing & Alakangas, 2016; Mongeon & Paul-Hus, 2016). Scopus was therefore used as a single-source database to avoid duplicate records and metadata-integration errors that can arise when combining multiple bibliographic databases. This choice improves internal consistency and reproducibility, but it also means that publications indexed only in Web of Science, ERIC, Google Scholar, Dimensions, or non-indexed local sources were outside the scope of the analysis. The limitation is acknowledged because database selection can influence bibliometric findings (Mongeon & Paul-Hus, 2016).

Search strategy and scope

The search was conducted in Scopus on 4 June 2026. The search covered the period 2016–2026 and focused on journal articles written in English. The search was conducted within the title, abstract, and keyword fields because these fields capture the main conceptual content of each document while maintaining stronger topical precision than full-text searching. In bibliometric research, field-restricted searching is commonly used to balance recall and precision: searching too broadly may retrieve weakly related documents, while searching too narrowly may omit relevant studies (Donthu et al., 2021; Gusenbauer & Haddaway, 2020). The title-abstract-keyword strategy was therefore selected to retrieve documents in which technology education and design were central to the publication rather than incidental terms.

The search string was developed around two core concepts: technology education and design. The final Scopus search string was:

(TITLE-ABS-KEY("technology education") AND TITLE-ABS-KEY(design))
AND (LIMIT-TO(DOCTYPE, "ar"))
AND (LIMIT-TO(LANGUAGE, "English"))
AND (LIMIT-TO(SRCTYPE, "j"))
AND PUBYEAR > 2016 AND PUBYEAR < 2026

The search was limited to journal articles because journal publications normally undergo peer-review processes and provide more stable citation metadata than editorials, conference abstracts, book chapters, notes, or trade publications. The English language restriction was applied to ensure consistency in keyword processing, text-based mapping, and interpretation of title, abstract, and keyword data. Although this criterion improves linguistic consistency, it may underrepresent relevant studies published in Malay, Indonesian, or other languages. The time span of 2016–2026 was selected to capture the recent decade in which technology-enhanced learning, design learning, and STEM/STEAM-oriented educational innovation became increasingly visible in school and higher education research.

Screening and eligibility process

The document selection process followed a transparent flow-based procedure adapted from established systematic reporting conventions (Moher et al., 2009; Page et al., 2021). Although the study is bibliometric rather than a systematic review of evidence effectiveness, a flow diagram was used to document the identification, screening, and inclusion stages. The selection process is summarized in Figure 1. At the identification stage, the Scopus search retrieved 492 records. The records were exported with full bibliographic information, including authors, title, abstract, author keywords, indexed keywords, source title, publication year, affiliations, country information, citation count, references, and DOI where available. At the screening stage, records were checked for duplication, incomplete metadata, and topical relevance. Twenty-two records were removed because they were duplicates or were not sufficiently aligned with the topic of technology education and design learning. The final dataset consisted of 470 journal articles retained for bibliometric and science-mapping analysis.

The inclusion criteria were: (a) Scopus-indexed journal articles; (b) publications within the 2016–2026 time span; (c) English-language documents; (d) articles containing the core concepts of technology education and design in the title, abstract, or keywords; and (e) publications relevant to technology-enhanced education, design learning, design education, STEM/STEAM education, engineering education, or related pedagogical contexts. The exclusion criteria were: (a) non-journal sources; (b) non-article document types; (c) non-English publications; (d) duplicate records; (e) records with insufficient bibliographic metadata for analysis; and (f) publications in which the terms “technology” and “design” were used in unrelated technical, industrial, medical, or non-educational contexts.

Data extraction and preparation

The final dataset was exported from Scopus in formats compatible with the selected bibliometric tools. The exported records were retained as the primary dataset and preserved separately from the cleaned dataset to maintain an audit trail. Data preparation involved checking document titles, author names, institutional names, source titles, publication years, citation counts, author keywords, indexed keywords, abstracts, and DOI fields. This step was necessary because bibliometric analysis is sensitive to inconsistencies in metadata, especially when constructing author, institution, country, and keyword networks. Data preparation followed the principle that bibliometric results should be reproducible from clearly documented search strings, database filters, screening criteria, and cleaning procedures (Donthu et al., 2021; Lim et al., 2024). The raw Scopus export, cleaned dataset, search date, search string, exclusion decisions, thesaurus file, and software outputs were retained as part of the study documentation.

Data cleaning and harmonization

Data cleaning and harmonization were conducted before the final bibliometric and network analyses. OpenRefine was used to clean and harmonize author keywords because keyword variants can fragment co-occurrence networks and distort thematic clusters. For example, synonymous or near-synonymous terms were standardized where appropriate, such as "STEM," "STEM education," "STEAM," "STEAM education," "technology education," "design education," "engineering design," "design thinking," "e-learning," and "technology-enhanced learning." Spelling variants, singular/plural differences, capitalization differences, and hyphenation inconsistencies were reviewed. OpenRefine was selected because it supports clustering, faceting, transformation, and systematic cleaning of bibliographic data (Ahmi, 2023). Institutional names were standardized using biblioMagika and manually checked where required. Institutional harmonization was important because universities and research organizations may appear in multiple variants, including abbreviations, translated names, campus-level names, and inconsistent punctuation. Standardizing these variants reduces artificial fragmentation in institutional productivity analysis and collaboration mapping. Cleaning decisions were documented in a thesaurus or replacement file so that the transformation process could be reviewed and replicated.

The cleaning process was conducted conservatively. Terms were merged only when they represented the same concept or an obvious spelling/formatting variant. Conceptually distinct terms were retained separately to avoid imposing artificial similarity on the data. This conservative strategy is important because excessive merging can reduce the interpretive validity of science maps, while insufficient merging can produce fragmented and unstable keyword clusters.

Bibliometric performance analysis

Bibliometric performance analysis was conducted using biblioMagika and cross-checked with the cleaned Scopus dataset. The analysis included annual publication output, total citations, citations per publication, cited publications, contributing authors, authors per paper, active source titles, prolific authors, active institutions, active countries, highly cited documents, h-index, g-index, and related citation indicators. Performance analysis provides an overview of the volume, productivity, and influence of the literature and serves as a necessary precursor to science mapping because it identifies the main contributors and publication channels before relational structures are interpreted (Donthu et al., 2021; Zupic & Čater, 2015). Citation-based indicators were interpreted cautiously. Citation counts can reflect scholarly influence, but they may also be affected by publication age, field size, database coverage, self-citation, document accessibility, and disciplinary citation norms. Therefore, citation indicators were used descriptively rather than as definitive measures of research quality. This approach is consistent with bibliometric guidance that emphasizes responsible interpretation of performance metrics and the need to connect bibliometric outputs to substantive field-level interpretation (Mukherjee et al., 2022).

Science mapping and visualization

Biblioshiny, the web interface of the bibliometrix R package, was used to complement the VOSviewer analysis. Bibliometrix was developed for comprehensive science mapping and supports descriptive bibliometric analysis, conceptual structure analysis, thematic mapping, collaboration analysis, and trend-topic analysis (Aria & Cuccurullo, 2017). In this study, Biblioshiny was used to generate thematic maps and conceptual structure outputs based on cleaned author keywords. Thematic mapping was used to classify themes according to centrality and density. Centrality indicates the degree of connection between a theme and other themes in the field, while density indicates the internal development of a theme. This allows themes to be interpreted as motor themes, basic themes, niche themes, or emerging/declining themes. Thematic maps therefore complement VOSviewer network visualizations by providing a strategic interpretation of how themes are positioned in the field rather than only showing their network proximity (Aria & Cuccurullo, 2017; Cobo et al., 2011).

The use of both VOSviewer and Biblioshiny was intentional. VOSviewer provided detailed visual inspection of keyword co-occurrence relationships, clustering, overlay patterns, and density structures, while Biblioshiny provided broader thematic classification and conceptual structure analysis. Using both tools strengthened methodological triangulation because the interpretation did not depend on a single visualization environment (Lim et al., 2024).

Transparency, reliability, and reproducibility

To ensure transparency and reproducibility, all major methodological decisions were documented, including the database used, date of search, search string, search fields, time span, document-type filter, language filter, source-type filter, screening criteria, exclusion reasons, final dataset size, data cleaning procedures, and software tools. The raw Scopus export was preserved separately from the cleaned dataset. Cleaning decisions were documented through keyword and institutional-name harmonization files. VOSviewer and Biblioshiny parameters, including counting method, keyword threshold, normalization method, and data fields used, were recorded to enable replication.

The methodological workflow aligns with established recommendations for bibliometric research, which emphasize transparent search procedures, justified database selection, careful data cleaning, appropriate performance indicators, and theoretically meaningful interpretation of science maps (Donthu et al., 2021; Lim et al., 2024; Mukherjee et al., 2022; Zupic & Čater, 2015). The method does not claim to capture all possible literature on technology-enhanced design learning. Rather, it provides a transparent and reproducible Scopus-based map of journal articles that meet the stated search and eligibility criteria.

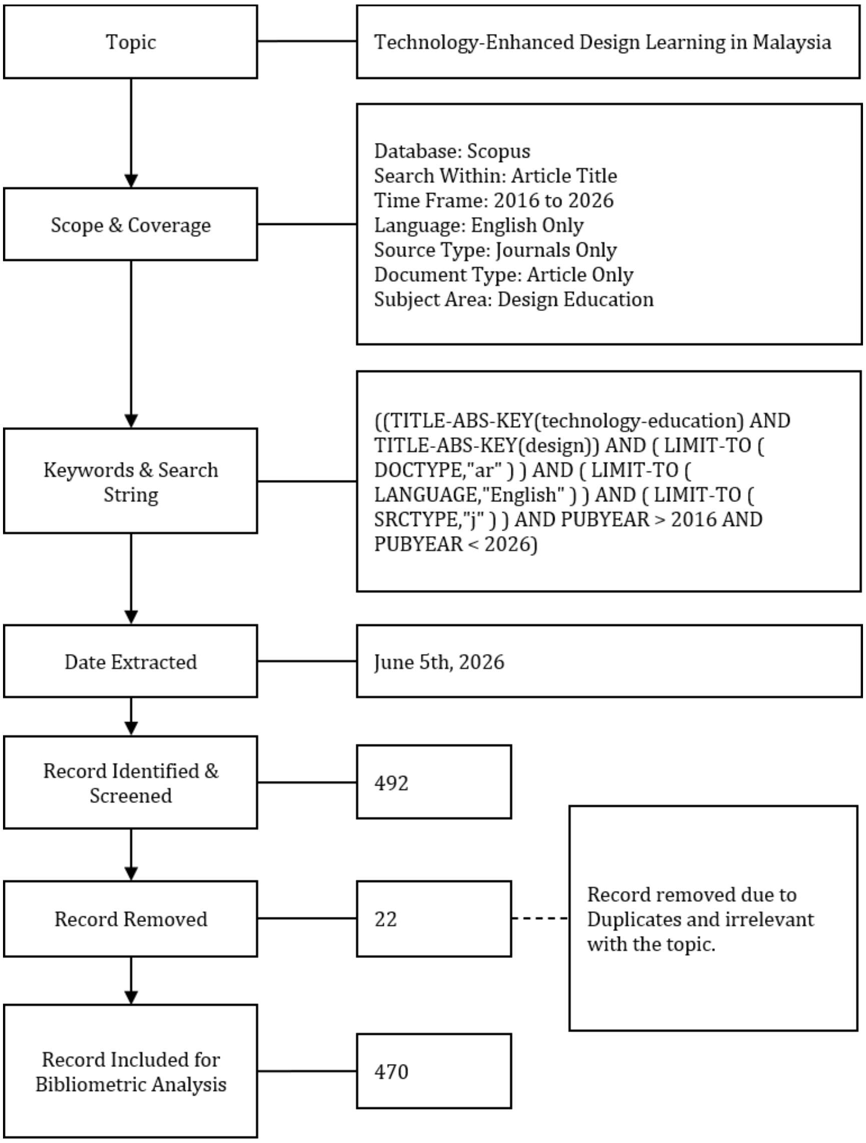

Figure 1. Flow diagram of the search strategy.
Source: Ahmi et al. (2025), Moher et al. (2009)

FINDING AND DISCUSSION

Documents Profiles

This chapter presents the bibliometric and science-mapping results on technology-design education from 470 Scopus-indexed journal articles published between 2016 and 2026. The findings are organized according to document profiles, publication trends, source titles, highly cited documents, author keyword co-occurrence, and thematic analysis. The results first describe the overall publication and citation structure of the field, followed by an examination of its leading journals and influential studies. The chapter then maps the conceptual relationships among key research terms to identify dominant, emerging, and weakly integrated themes within technology-enhanced design learning.

The document profile reveals a field with sufficient scale, citation reception, collaborative breadth, and intellectual concentration to warrant deeper science-mapping analysis. Taken together, the publication, citation, authorship, and h-core indicators suggest that technology-design education has reached a stage where descriptive counting alone is insufficient. The field now requires interpretation of its intellectual architecture: which concepts dominate, which forms of pedagogy are central, which educational levels are represented, and which technological or design-oriented approaches remain peripheral. This is the main value of the document profile. It does not simply show that publications exist; it establishes that the field has accumulated enough scholarly substance to justify asking higher-order questions about structure, maturity, and future direction.

For scholars, the profile creates a rationale for moving from individual intervention studies toward integrative theorization. For institutions, it points to the importance of supporting interdisciplinary research teams capable of combining design, engineering, educational technology, and STEM/STEAM pedagogy. For policymakers and curriculum planners, the profile suggests that technology-design education is not an isolated curricular issue but an emerging knowledge domain relevant to digital education, design capability, and future-oriented learning.

Empirically, the profile changes the basis of discussion. Rather than asking whether technology and design are relevant to education, the more appropriate question becomes how this research domain is structured, where its intellectual centre lies, and which areas require stronger conceptual or methodological development. This provides the foundation for the subsequent analyses of publication trends, source titles, highly cited documents, and keyword co-occurrence networks.

Publication Trends

Table 2 shows the publications by year from 2016 to 2026. From this table, it show in the year 2024, the highest publication which is 69 publications. The gap between total publications and cited publications indicates that the field is expanding faster than all publications can be absorbed into the citation network.

Table 2 Publication by Year

Year	TP	NCA	NCP	TC	C/P	C/CP	*h*	*g*	*m*
2016	10	21	9	175	17.50	19.44	8	10	0.727
2017	25	68	25	793	31.72	31.72	13	25	1.300
2018	24	52	22	278	11.58	12.64	11	16	1.222
2019	44	138	39	932	21.18	23.90	19	30	2.375
2020	34	95	34	703	20.68	20.68	15	26	2.143
2021	34	115	32	521	15.32	16.28	15	22	2.500
2022	60	254	57	882	14.70	15.47	17	27	3.400
2023	62	188	53	489	7.89	9.23	13	18	3.250
2024	69	233	57	359	5.20	6.30	10	14	3.333
2025	59	187	35	129	2.19	3.69	6	9	3.000
2026	49	179	8	13	0.27	1.63	2	2	2.000
Total	**470**	**1530**	**371**	**5274**	**11.22**	**14.22**	**34**	**52**	**3.091**

Note: TP=total number of publications; NCA=Number of contributing authors; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index; m=m-index.
Source: Generated by the author(s) using biblioMagika® (Ahmi,2024)

A substantial proportion of publications have received citations, which indicates that the field has a functioning scholarly conversation. At the same time, the presence of uncited or minimally cited publications suggests that not all contributions have yet entered the field's visible knowledge structure. This is not necessarily a weakness. In a growing field, uncited publications often include recent studies, specialized case studies, context-specific curriculum work, or articles published in outlets with slower citation diffusion.

The more important issue is interpretive: citation reception should be treated as a signal of scholarly uptake, not as a direct measure of quality. Some recent or locally relevant studies may be empirically valuable even if they have limited citation counts. This is particularly relevant for technology-design education, where context-specific studies in schools, national curricula, teacher training, or local STEM/STEAM initiatives may have strong practical significance but slower international citation visibility.

Theoretically, the cited–uncited distinction reveals a tension between field growth and field consolidation. A consolidated field has shared references, recurring theories, and identifiable methodological standards. A rapidly expanding field may instead contain many useful but weakly connected studies. The present profile suggests that technology-design education is developing both conditions simultaneously: a visible citation core and a wider set of newer or less integrated publications.

Future research should therefore examine not only which studies are cited, but why they are cited. Highly cited papers may function as conceptual anchors, methodological references, or empirical exemplars. Less cited papers may represent emerging contexts, new technologies, or underdeveloped research directions. This distinction is important for building a balanced research agenda that does not equate citation visibility with conceptual importance.

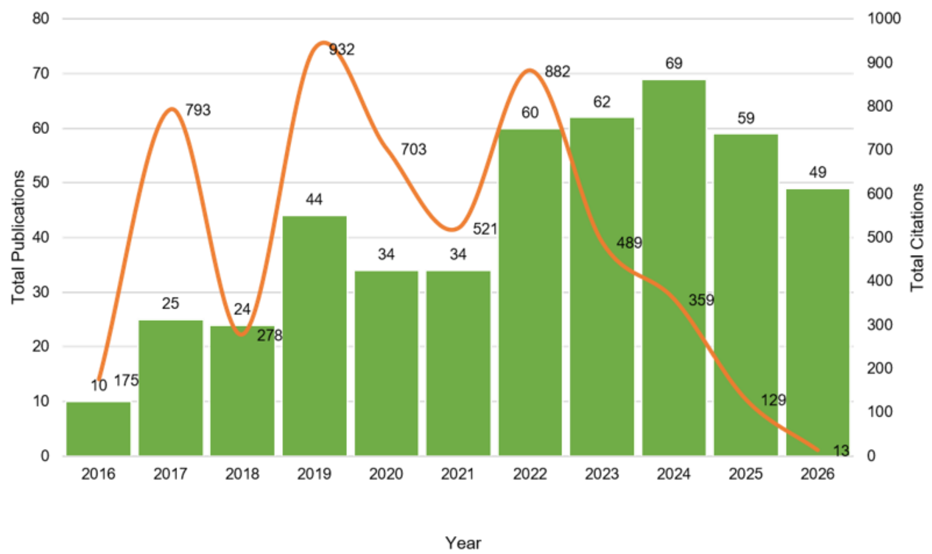

Figure 2. Total Publications and Citations by Year
Source: Generated by the author(s) using biblioMagika® (Ahmi,2024)

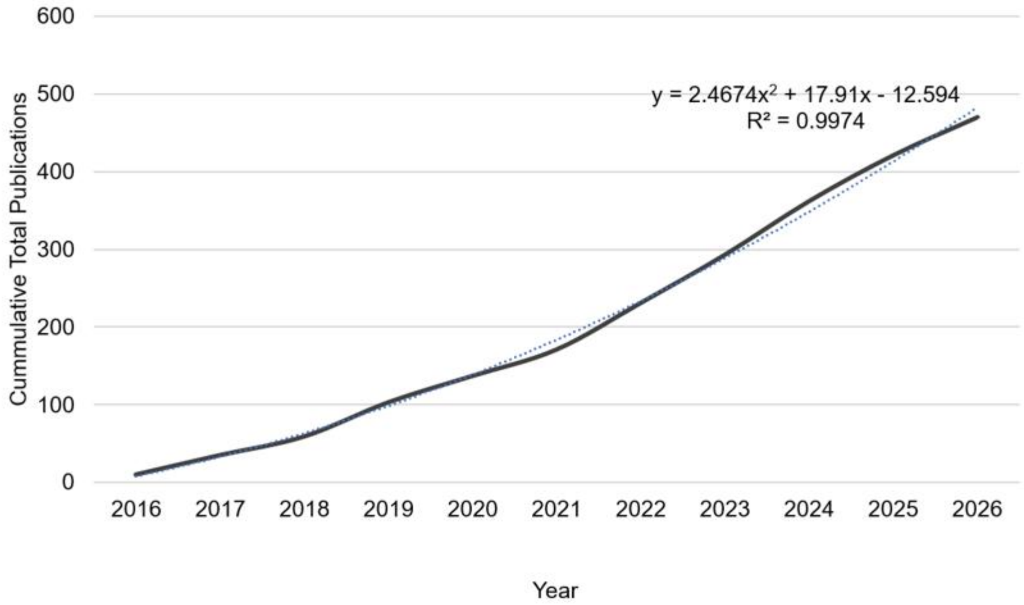

Figure 3. Publication Growth
Source: Generated by the author(s) using biblioMagika® (Ahmi,2024)

The annual profile positions technology-design education as a field in active consolidation, where publication growth, collaborative expansion, and citation concentration are occurring simultaneously.

Taken together, the annual indicators suggest that the field is neither immature nor fully settled. It has accumulated enough publications, citations, authors, and influential documents to justify systematic interpretation, but its recent growth suggests that conceptual boundaries are still being negotiated. This is precisely why the present bibliometric study is timely. The field now requires more than descriptive documentation; it requires clarification of its intellectual structure, core themes, methodological preferences, and underdeveloped areas.

The main contribution of this profile is that it reframes technology-design education as a research domain undergoing consolidation. The evidence does not merely show that more papers are being published. It suggests that scholars are increasingly treating technology-design education as a meaningful intersection of design pedagogy, technological literacy, digital learning, engineering design, and STEM/STEAM education. At the same time, the variation in citation uptake indicates that this intersection is not yet fully stabilized.

For scholars, the profile provides justification for deeper science mapping. For institutions, it indicates a growing need for interdisciplinary research capacity. For policymakers and curriculum planners, it suggests that technology-design education is becoming an evidence-supported area for curriculum innovation, teacher professional development, and STEM/STEAM implementation. For future research, the key task is to move from growth measurement to conceptual differentiation: identifying which forms of technology-design learning are empirically robust, pedagogically coherent, and contextually relevant.

Publications by Source Titles

For scholars, the profile provides justification for deeper science mapping. For institutions, it indicates a growing need for interdisciplinary research capacity. For policymakers and curriculum planners, it suggests that technology-design education is becoming an evidence-supported area for curriculum innovation, teacher professional development, and STEM/STEAM implementation. For future research, the key task is to move from

growth measurement to conceptual differentiation: identifying which forms of technology-design learning are empirically robust, pedagogically coherent, and contextually relevant.

Table 3 Most active source titles that published 20 or more documents.

Source Title	TP	NCA	NCP	TC	C/P	C/CP	*h*	*g*	*m*
International Journal of Technology and Design Education	102	319	102	1482	14.53	14.53	21	31	1.909
Design and Technology Education	15	47	15	5	0.33	0.33	1	1	0.200
Education and Information Technologies	9	19	9	127	14.11	14.11	7	9	1.000
Research in Science and Technological Education	7	18	7	26	3.71	3.71	3	5	0.750
Journal of Technology Education	7	11	7	35	5.00	5.00	4	5	0.400
International Journal of Engineering Education	7	23	0	14	2.00	2.00	2	3	0.200
Eurasia Journal of Mathematics, Science and Technology Education	7	13	7	91	13.00	13.00	4	7	0.364
Sustainability (Switzerland)	7	41	7	195	27.86	27.86	6	7	0.750
International Journal of Child-Computer Interaction	7	39	7	151	21.57	21.57	5	7	0.833
Education and Training	6	17	6	61	10.17	10.17	4	6	0.400
International Journal of Evaluation and Research in Education	5	18	5	40	8.00	8.00	2	5	0.250
Journal of Engineering Technology	5	14	2	17	3.40	8.50	2	4	0.222
African Journal of Research in Mathematics, Science and Technology Education	5	8	5	31	6.20	6.20	3	5	0.300
Discover Education	4	7	4	6	1.50	1.50	1	2	0.500
Computer Applications in Engineering Education	4	12	4	28	7.00	7.00	2	4	0.250
Education Sciences	4	16	4	10	2.50	2.50	2	3	0.500
Frontiers in Education	3	12	3	16	5.33	5.33	3	3	0.600
Canadian Journal of Science, Mathematics and Technology Education	3	9	3	22	7.33	7.33	3	3	0.600
Sensors	3	11	3	23	7.67	7.67	2	3	0.400

Note: TP=total number of publications; NCA=Number of contributing authors; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index; m=m-index.
Source: Generated by the author(s) using biblioMagika® (Ahmi,2024)

The source-title findings position technology-design education as a field with a strong specialist core, selective high-impact interdisciplinary outlets, and an expanding but potentially fragmented publication ecology. The field's intellectual centre is clearly associated with technology and design education, but its wider development depends on interactions with educational technology, STEM/STEAM education, engineering education, sustainability, and human–computer interaction. This dual structure is important. It means that technology-design education has sufficient disciplinary grounding to avoid being a vague educational trend, yet it also has enough interdisciplinary reach to contribute to broader debates about digital learning, design capability, and future-oriented education.

Empirically, the findings change the way the field should be interpreted. The question is not simply which journals publish the most articles. The more important question is how different journals perform different functions in the knowledge system. Some sources consolidate the field, some connect it to adjacent disciplines, some increase citation visibility, and some may support professional or practice-oriented discourse. Recognizing these different roles prevents a simplistic interpretation of productivity and citation indicators.

For future research, the source-title profile provides a roadmap for deeper inquiry. Highly productive specialist journals should be examined to identify the field's dominant concepts and pedagogical assumptions. High-citation interdisciplinary journals should be examined to identify emerging directions that broaden the field's relevance. Lower-citation but field-specific outlets should be assessed for their contribution to professional practice and curriculum implementation. This layered interpretation allows the source-title analysis to contribute to theory building rather than remain a descriptive ranking of journals.

Highly Cited Documents

For scholars, the profile provides justification for deeper science mapping. For institutions, it indicates a growing need for interdisciplinary research capacity. For policymakers and curriculum planners, it suggests that technology-design education is becoming an evidence-supported area for curriculum innovation, teacher professional development, and STEM/STEAM implementation. For future research, the key task is to move from growth measurement to conceptual differentiation: identifying which forms of technology-design learning are empirically robust, pedagogically coherent, and contextually relevant.

Table 4 Top 20 highly cited articles

No.	Authors	Title	Source Title	Cites	Cites per Year
1	Bevan B. (2017)	The promise and the promises of Making in science education	Studies in Science Education	200	20.00
2	Suen H.-Y.; Chen M.Y.-C.; Lu S.-H. (2019)	Does the use of synchrony and artificial intelligence in video interviews affect interview ratings and applicant attitudes?	Computers in Human Behavior	183	22.88
3	Fan S.-C.; Yu K.-C. (2017)	How an integrative STEM curriculum can benefit students in engineering design practices	International Journal of Technology and Design Education	156	15.60
4	Code J.; Ralph R.; Forde K. (2020)	Pandemic designs for the future: perspectives of technology education teachers during COVID-19	Information and Learning Science	110	15.71
5	Magulod G.C., Jr. (2019)	Learning styles, study habits and academic performance of Filipino university students in applied science courses: Implications for instruction	Journal of Technology and Science Education	92	11.50
6	Otterborn A.; Schanborn K.; Hultan M. (2019)	Surveying preschool teachersâ€™ use of digital tablets: general and	International Journal of Technology	83	10.38

No.	Authors	Title	Source Title	Cites	Cites per Year
		technology education related findings	and Design Education		
7	Mancha R.; Shankaranarayanan G. (2021)	Making a digital innovator: antecedents of innovativeness with digital technologies	Information Technology and People	80	13.33
8	Seskir Z.C.; MigdaÅ‚ P.; and Weidner C. et al (2022)	Quantum games and interactive tools for quantum technologies outreach and education	Optical Engineering	70	14.00
9	HallstrÃ¶m J. (2022)	Embodying the past, designing the future: technological determinism reconsidered in technology education	International Journal of Technology and Design Education	67	13.40
10	Lin X.-F.; Chen L.; and Chan K.K. et al (2022)	Teachersâ€™ Perceptions of Teaching Sustainable Artificial Intelligence: A Design Frame Perspective	Sustainability (Switzerland)	64	12.80
11	Yata C.; Ohtani T.; Isobe M. (2020)	Conceptual framework of STEM based on Japanese subject principles	International Journal of STEM Education	60	8.57
12	Akkuay Atakar N.; Gass A.; Foster A.; Lee F.J. (2017)	Development of a game-design workshop to promote young girls' interest towards computing through identity exploration	Computers and Education	60	6.00
13	Atwood-Blaine D.; Huffman D. (2017)	Mobile Gaming and Student Interactions in a Science Center: the Future of Gaming in Science Education	International Journal of Science and Mathematics Education	59	5.90
14	Bhattacharyya S.S.; Nair S. (2019)	Explicating the future of work: perspectives from India	Journal of Management Development	58	7.25
15	Schaper M.-M.; Smith R.C. and Tamashiro M.A.; et al (2022)	Computational empowerment in practice: Scaffolding teenagersâ€™ learning about emerging technologies and their ethical and societal impact	International Journal of Child-Computer Interaction	57	11.40
16	Ogbuanya T.C.; Chukwuedo S.O. (2017)	Career-training mentorship intervention via the Dreyfus model: Implication for career behaviors and practical skills acquisition in vocational electronic technology	Journal of Vocational Behavior	57	5.70
17	Hsieh Y.-Z.; Lin S.-S. and Luo Y.-C et al (2020)	ARCS-assisted teaching robots based on anticipatory computing and emotional Big Data for improving	Sustainability (Switzerland)	53	7.57

No.	Authors	Title	Source Title	Cites	Cites per Year
		sustainable learning efficiency and motivation			
18	Chien Y.-H. (2017)	Developing a pre-engineering curriculum for 3D printing skills for high school technology education	Eurasia Journal of Mathematics, Science and Technology Education	49	4.90
19	Smith R.C.; Schaper M.-M. and Tamashiro M.A.; et al (2023)	A research agenda for computational empowerment for emerging technology education	International Journal of Child-Computer Interaction	49	12.25
20	Sung E.; Kelley T.R. (2019)	Identifying design process patterns: a sequential analysis study of design thinking	International Journal of Technology and Design Education	48	6.00

Source: Generated by the author(s) using biblioMagika® (Ahmi,2024)

The highly cited documents reveal a field whose influence is organized around design rich STEM learning, technology education, digital transformation, and emerging technology participation, but whose boundaries remain conceptually porous.

Taken together, the highly cited documents indicate that technology-design education is shaped by four overlapping intellectual currents: making and design-based STEM learning, technology education and engineering design, AI and emerging digital technologies, and career-oriented technical competence. This configuration matters because it positions the field as both pedagogical and sociotechnical. The most influential work does not simply ask whether technology improves learning; it asks how learners engage with technology through design, participation, creativity, ethical reflection, and future-oriented capability development.

The theoretical contribution of this analysis is that it reframes the citation core as a map of tensions rather than a list of best papers. The field's most visible documents do not point to a single settled paradigm. Instead, they reveal competing emphases: material making versus digital innovation, engineering design versus computational empowerment, STEM curriculum versus career preparation, and classroom pedagogy versus societal technology participation. This is precisely why bibliometric study is timely. The field has accumulated enough influential work to justify synthesis, but its conceptual boundaries are still being negotiated.

For future research, the priority is to clarify how these influential streams relate to one another. Scholars should examine whether design learning functions as the integrating construct across making, STEM/STEAM, AI education, and digital innovation, or whether these areas remain loosely connected through shared terminology. Curriculum developers and teacher educators should care because the answer determines how technology-design education should be implemented: as tool use, design thinking, engineering design, maker pedagogy, AI literacy, or interdisciplinary STEM/STEAM practice.

Co-occurrence Analysis

The author keyword co-occurrence network indicates that technology-design education is organized around a strong pedagogical core, while its connections with STEM/STEAM education, educational technology, artificial intelligence, and computational thinking remain only partially integrated. As shown in Figure 4, the most central area of the network is concentrated around "technology education," "engineering education," "students," "curricula," "teaching," "design thinking," "product design," and "design and technology." This pattern suggests that the field is not mainly concerned with technology as a neutral instructional tool. Rather, its intellectual centre is pedagogical, focusing on how students learn through design, how teachers organize design-oriented curricula, and how technology or engineering education supports applied problem solving.

The red cluster represents the most consolidated part of the network. It is associated with curriculum, teaching, students, technological literacy, engineering education, design processes, and design thinking. This indicates that the field has developed around recurring questions of design pedagogy: how design tasks are structured, how learners engage with technological problems, and how learning outcomes are linked to engineering or technology education. Therefore, technology-design education should be understood as a structured educational process, not merely as informal creativity or simple technology adoption. The green cluster is associated with STEM/STEAM education, science education, mathematics education, engineering technology education, and design-based learning. Its position near, but not fully within, the central pedagogical core suggests that STEM/STEAM is related to technology-design education but not yet fully integrated into its theoretical structure. This is important because design learning is often assumed to act as a natural bridge across STEM/STEAM disciplines. However, the network suggests that this relationship still requires clearer explanation. Future studies should examine whether design learning genuinely integrates science, technology, engineering, arts, and mathematics, or whether it is used mainly as a practical activity attached to STEM instruction.

The blue cluster includes educational technology, computational thinking, information technology education, artificial intelligence, COVID-19, higher education, and related digital-learning terms. Its separation from the central cluster shows that educational technology is connected to the field but remains partly peripheral. This distinction is significant because "technology education" and "educational technology" are not the same. Technology education focuses on learners' technological understanding, design capability, and problem-solving processes, whereas educational technology often emphasizes digital tools and instructional delivery. Overall, the co-occurrence network positions technology-design education as a field in active consolidation. Its strongest core is centered on technology education, engineering education, students, curricula, and design processes. However, adjacent areas such as STEM/STEAM education, AI, computational thinking, and digital learning still require stronger conceptual integration. The main implication is that future research should move beyond broad claims about technology-enhanced learning and explain more precisely how digital tools, engineering design, and STEM/STEAM pedagogy contribute to students' de-sign capability.

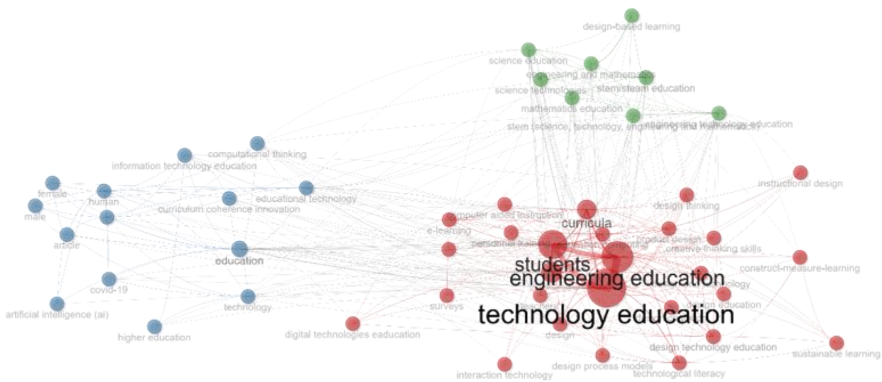

Figure 4. Network visualization of the co-occurrence analysis of the author keywords
Source: Generated by the author(s) using Biblioshiny (Aria & Cuccurullo, 2017)

Thematic Analysis

The thematic analysis indicates that technology-design education has a relatively developed pedagogical core, but its connections with STEM/STEAM education, educational technology, e-learning, and design-based learning remain less consolidated. The strongest theme is formed around "technology education," "engineering education," and "students," which appears in the motor theme quadrant. This suggests that the most central and internally developed research conversation in the dataset focuses on student learning within technology and engineering education contexts. Therefore, the field should not be understood merely as the use of digital tools in education. Rather, it is more strongly concerned with how students develop technological understanding, engineering reasoning, and design capability through structured pedagogical and curriculum-oriented activities.

This finding is important because it clarifies the intellectual centre of the field. Technology-design education is currently anchored in learning about and through technological systems, design processes, and engineering-oriented problem solving. For teacher educators, this implies that professional preparation should not focus only on digital competence, but also on design pedagogy, technological literacy, engineering inquiry, and student-centred learning. For curriculum planners, the finding suggests that technology-design education has suffi-cient conceptual maturity to support curriculum development and STEM/STEAM implementation, provided that design learning is clearly structured and aligned with learning out-comes.

However, the thematic map also shows that "STEM/STEAM education," "engineering technology education," and "science education" are positioned as emerging or weakly consolidated themes. This does not mean that STEM/STEAM education is unimportant. Instead, it suggests that, within this dataset, STEM/STEAM has not yet become the dominant organizing logic of technology-design education. This is theoretically significant because design learning is often assumed to function naturally as a bridge across science, technology, engineering, arts, and mathematics. The results suggest that this relationship still requires clearer conceptual and empirical explanation. Future studies should therefore examine whether design learning truly integrates STEM/STEAM disciplines or whether it is used only as a practical classroom activity.

Similarly, "educational technology," "education computing," and "e-learning" appear as peripheral or transitional themes. This indicates that digital learning tools are present in the literature but are not yet fully integrated into the field's central pedagogical structure. The finding highlights the need to distinguish between technology education and educational technology. Technology education emphasizes technological capability, design reasoning, and problem solving, whereas educational technology often emphasizes digital tools, platforms, and delivery systems.

Overall, the thematic analysis shows that the field has a strong specialist core but weaker interdisciplinary integration. Future research should move beyond broad claims about technology-enhanced learning and develop clearer frameworks linking technology education, engineering design, STEM/STEAM pedagogy, and educational technology. Such integration is necessary to build a more coherent theory of technology-enhanced design learning.

Figure 5. Thematic Analysis.
Source: Generated by the author(s) using Biblioshiny (Aria & Cuccurullo, 2017)

DISCUSSION

This study shows that engineering design-enhanced technology education has developed into an active interdisciplinary research area, but its intellectual structure remains only partially consolidated. The document profile, citation indicators, source-title distribution, highly cited documents, co-occurrence network, and thematic map collectively suggest that the field is no longer a small or isolated topic. Instead, it has accumulated a visible body of scholarship across technology education, engineering education, design learning, STEM/STEAM education, and educational technology. However, the findings also indicate that growth in publications does not necessarily mean conceptual coherence. This supports the view that bibliometric analysis is useful not only for measuring output, but also for clarifying the structure and boundaries of an emerging field (Donthu et al., 2021; Zupic & Čater, 2015).

The strongest finding is that the field is organized around a pedagogical core consisting of technology education, engineering education, students, curricula, teaching, and design processes. This suggests that the main concern of literature is not merely the use of digital tools, but the development of students' design capability through technological and engineering-oriented learning. This finding aligns with integrated STEM scholarship, which argues that meaningful STEM learning requires purposeful disciplinary connections rather than simple subject combination (English, 2016; Kelley & Knowles, 2016). It also supports studies showing that engineering design can strengthen students' STEM learning and engagement (Fan & Yu, 2017; Mohd Shahali et al., 2017).

Nevertheless, the network and thematic findings reveal that STEM/STEAM education, educational technology, e-learning, AI, and computational thinking remain less fully integrated into the field's central structure. This is theoretically important because technology-enhanced design learning is often assumed to naturally connect technology, design, and STEM/STEAM. The present findings suggest a more cautious interpretation: these areas are related, but their conceptual relationships still require clearer explanation. This supports previous concerns that design thinking and STEAM education remain conceptually diffuse and require stronger empirical consolidation (Li et al., 2019; Li & Zhan, 2022; Perignat & Katz-Buonincontro, 2019).

For practice, the findings imply that educators should not treat technology-enhanced design learning as simple digital tool use. Teaching should instead emphasize problem framing, ideation, modelling, prototyping, testing, iteration, and reflection. For future research, scholars should develop clearer conceptual models linking technology education, engineering design, STEM/STEAM pedagogy, and educational technology. More empirical studies are also needed to examine how these concepts operate in real classroom contexts, especially in secondary education and Malaysian STEM/STEAM settings.

LIMITATION & FURTHER RESEARCH

This study has several limitations. First, the analysis was limited to Scopus-indexed English-language journal articles published between 2016 and 2026. Therefore, relevant studies from other databases such as Web of Science, ERIC, Dimensions, Google Scholar, and regional repositories may have been excluded. Second, the study focused only on journal articles; conference papers, book chapters, policy documents, and curriculum reports were not included, although they may contain important insights on technology-enhanced design learning. Third, the search strategy was based on selected keywords related to technology education and design, which may not fully capture studies using alternative terms such as design-based learning, engineering design, maker education, digital fabrication, or STEAM pedagogy. Fourth, bibliometric analysis depends on citation and keyword metadata, which may be affected by database coverage, author keyword choices, and indexing inconsistencies.

Future research should expand the dataset by including multiple databases and broader document types to improve coverage. Further studies should also compare different educational levels, especially secondary school, vocational education, and higher education. In addition, qualitative systematic reviews or empirical classroom studies are recommended to examine how technology-enhanced design learning is implemented in practice, particularly in STEM/STEAM education contexts.

ACKNOWLEDGMENTS

The authors would like to acknowledge the support and guidance provided by their respective institutions throughout the completion of this study. The authors also appreciate the availability of bibliometric analysis tools and databases that supported the data collection, cleaning, mapping, and interpretation processes.

REFERENCES

Ahmi, A., Hassan, H., Abdullah, M., & Jamalurus, H. L. Concentrating Power: A Bibliometric Analysis of Ownership Structures.

Ahmi, A. (2023). OpenRefine: An approachable tool for cleaning and harmonizing bibliographical data. AIP Conference Proceedings, 2827, Article 030006. https://doi.org/10.1063/5.0164724

Ahmi, Aidi. "Bibliometric Analysis using biblioMagika®." *Academic Research Society of Malaysia* (2024).

Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. Journal of Informetrics, 11(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007

Bevan, B. (2017). The promise and the promises of Making in science education. Studies in Science Education, 53(1), 75–103. https://doi.org/10.1080/03057267.2016.1275380

Budhyani, I. D. A. M., Nitiasih, P. K., Sila, I. N., & Mahayanti, N. W. S. (2025). Bibliometric Analysis of Experiential and Technology-Integrated Pedagogy in Vocational Design Education. *Journal of Cultural Analysis and Social Change*, 2890-2897.

Cobo, M. J., López-Herrera, A. G., Herrera-Viedma, E., & Herrera, F. (2011). Science mapping software tools: Review, analysis, and cooperative study among tools. Journal of the American Society for Information Science and Technology, 62(7), 1382–1402. https://doi.org/10.1002/asi.21525

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research, 133, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research, 133, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

English, L. D. (2016). STEM education K–12: Perspectives on integration. International Journal of STEM Education, 3, Article 3. https://doi.org/10.1186/s40594-016-0036-1

Falagas, M. E., Pitsouni, E. I., Malietzis, G. A., & Pappas, G. (2008). Comparison of PubMed, Scopus, Web of Science, and Google Scholar: Strengths and weaknesses. The FASEB Journal, 22(2), 338–342. https://doi.org/10.1096/fj.07-9492LSF

Fan, S.-C., & Yu, K.-C. (2017). How an integrative STEM curriculum can benefit students in engineering design practices. International Journal of Technology and Design Education, 27(1), 107–129. https://doi.org/10.1007/s10798-015-9328-x

Gusenbauer, M., & Haddaway, N. R. (2020). Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources. Research Synthesis Methods, 11(2), 181–217. https://doi.org/10.1002/jrsm.1378

Harzing, A.-W., & Alakangas, S. (2016). Google Scholar, Scopus and the Web of Science: A longitudinal and cross-disciplinary comparison. Scientometrics, 106(2), 787–804. https://doi.org/10.1007/s11192-015-1798-9

Hillmayr, D., Ziernwald, L., Reinhold, F., Hofer, S. I., & Reiss, K. M. (2020). The potential of digital tools to enhance mathematics and science learning in secondary schools: A context-specific meta-analysis. Computers & Education, 153, Article 103897. https://doi.org/10.1016/j.compedu.2020.103897

Jia, H., Zhong, Y., Lin, C. L. S., Mandrinos, S., Woon, F. C., Cao, Z., & Gong, Y. (2026). Charting the blueprint: a bibliometric analysis reveals future strategies in lung cancer targeted therapy (2003–2025). *Journal of Thoracic Disease*, *18*(3), 195.

Johann, D. A., Nunes, A. D. F. P., Santos, G. B. D., Silva, D. J. C. D., Bresciani, S. A. T., & Lopes, L. F. D. (2020). Mapping of scientific production on design thinking as a tool for entrepreneurship education: a bibliometric study of a decade. *World Journal of Entrepreneurship, Management and Sustainable Development*, *16*(4), 271-285.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. International Journal of STEM Education, 3, Article 11. https://doi.org/10.1186/s40594-016-0046-z

Küçükyağcı, P. Ö. (2025). Bibliometric Analysis of Basic Design Education. *Online Journal of Art & Design*, *13*(3).

Lai, J. W. M., & Bower, M. (2019). How is the use of technology in education evaluated? A systematic review. Computers & Education, 133, 27–42. https://doi.org/10.1016/j.compedu.2019.01.010

Li, T., & Zhan, Z. (2022). A systematic review on design thinking integrated learning in K–12 education. Applied Sciences, 12(16), Article 8077. https://doi.org/10.3390/app12168077

Li, Y., Schoenfeld, A. H., diSessa, A. A., Graesser, A. C., Benson, L. C., English, L. D., & Duschl, R. A. (2019). Design and design thinking in STEM education. Journal for STEM Education Research, 2, 93–104. https://doi.org/10.1007/s41979-019-00020-z

Li, Y., Wang, K., Xiao, Y., & Froyd, J. E. (2020). Research and trends in STEM education: A systematic review of journal publications. International Journal of STEM Education, 7, Article 11. https://doi.org/10.1186/s40594-020-00207-6

Lim, W. M., Kumar, S., & Donthu, N. (2024). How to combine and clean bibliometric data and use bibliometric tools synergistically: Guidelines using metaverse research. Journal of Business Research, 182, Article 114760. https://doi.org/10.1016/j.jbusres.2024.114760

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. International Journal of STEM Education, 6, Article 2. https://doi.org/10.1186/s40594-018-0151-2

Mohd Shahali, E. H., Halim, L., Rasul, M. S., Osman, K., & Zulkifeli, M. A. (2017). STEM learning through engineering design: Impact on middle secondary students' interest towards STEM. Eurasia Journal of Mathematics, Science and Technology Education, 13(5), 1189–1211. https://doi.org/10.12973/eurasia.2017.00667a

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & the PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. BMJ, 339, Article b2535. https://doi.org/10.1136/bmj.b2535

Mongeon, P., & Paul-Hus, A. (2016). The journal coverage of Web of Science and Scopus: A comparative analysis. Scientometrics, 106(1), 213–228. https://doi.org/10.1007/s11192-015-1765-5

Mukherjee, D., Lim, W. M., Kumar, S., & Donthu, N. (2022). Guidelines for advancing theory and practice through bibliometric research. Journal of Business Research, 148, 101–115. https://doi.org/10.1016/j.jbusres.2022.04.042

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, Article n71. https://doi.org/10.1136/bmj.n71

Perianes-Rodriguez, A., Waltman, L., & van Eck, N. J. (2016). Constructing bibliometric networks: A comparison between full and fractional counting. Journal of Informetrics, 10(4), 1178–1195. https://doi.org/10.1016/j.joi.2016.10.006

Perignat, E., & Katz-Buonincontro, J. (2019). STEAM in practice and research: An integrative literature review. Thinking Skills and Creativity, 31, 31–43. https://doi.org/10.1016/j.tsc.2018.10.002

Sung, E., & Kelley, T. R. (2019). Identifying design process patterns: A sequential analysis study of design thinking. International Journal of Technology and Design Education, 29(2), 283–302. https://doi.org/10.1007/s10798-018-9448-1

Tamim, R. M., Bernard, R. M., Borokhovski, E., Abrami, P. C., & Schmid, R. F. (2011). What forty years of research says about the impact of technology on learning: A second-order meta-analysis and validation study. Review of Educational Research, 81(1), 4–28. https://doi.org/10.3102/0034654310393361

van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

Waltman, L., van Eck, N. J., & Noyons, E. C. M. (2010). A unified approach to mapping and clustering of bibliometric networks. Journal of Informetrics, 4(4), 629–635. https://doi.org/10.1016/j.joi.2010.07.002

Yata, C., Ohtani, T., & Isobe, M. (2020). Conceptual framework of STEM based on Japanese subject principles. International Journal of STEM Education, 7, Article 12. https://doi.org/10.1186/s40594-020-00205-8

Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. Organizational Research Methods, 18(3), 429–472. https://doi.org/10.1177/1094428114562629