SRSTI 14.35 DOI 10.53355/ZHU.2026.119.2.004

STREAM PEDAGOGY RESEARCH: BIBLIOMETRIC ANALYSIS OF SCOPUS (2005-2025)

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Abstract. This article presents a comprehensive bibliometric analysis of the evolution and current state of STREAM education within pedagogical research. It draws on data from the Scopus database from 2005 to 2025. The primary objective is to reveal key developmental trends and dominant themes in STREAM education, an interdisciplinary approach integrating science, technology, reading/writing, engineering, arts, and mathematics, within the context of modern pedagogy. Using the keywords 'pedagogy' and 'STREAM', the study examines 254 scientific documents after refining the initial search results. The analysis uses the Bibliometrix package in R Studio to generate insights through annual publication dynamics, keyword co-occurrence networks, thematic maps and country/affiliation distributions. The key findings reveal a significant increase in publications over the past decade, reflecting the growing global interest in STREAM as an extension of the STEM and STEAM models. Core research clusters highlight pedagogy, engineering education, digital and online learning, and the increasing importance of artificial intelligence. Geographic analysis indicates a concentration in leading academic nations, alongside limited but emerging international collaboration. The results provide a panoramic overview of the field's scientific landscape, emphasising its interdisciplinary nature and the potential for the further integration of digital tools. This study offers valuable guidance on future research directions, curriculum development and educational policy in STREAM pedagogy.

Keywords: *STREAM, pedagogy, bibliometric analysis, bibliometrix, education, review.*

Introduction

Over the past two decades, interdisciplinary, technology-driven and student-centred approaches have gained prominence in education, including STREAM education. This model integrates science, technology, reading/writing, engineering, arts and mathematics, and is increasingly discussed in pedagogical research amid digitalisation, artificial intelligence, online learning and evolving labour market demands. STREAM pedagogy serves as a key tool for modernising educational content and enhancing training quality. However, the specific dynamics and structure of scientific literature on STREAM pedagogy remain underexplored.

Pedagogical science now emphasises advanced interdisciplinary integration. The widely recognised STEM model (Science, Technology, Engineering, Mathematics) evolved into STEAM (adding Arts) and later STREAM. The 'R' component most commonly denotes reading and writing skills, though some studies interpret it as research or religious education [1]. While STEM and STEAM have numerous bibliometric reviews, STREAM – especially its pedagogical aspects and the role of 'R' – lacks comprehensive bibliometric synthesis. This creates a gap in understanding its thematic evolution, global footprint and intersections with AI and digital literacy.

This study conducts a bibliometric analysis of Scopus publications (2005-2025) using the keywords "STREAM" and "pedagogy" to identify development trends, dominant themes and the scientific structure of STREAM education in pedagogy. Based on 254 relevant documents, it provides one of the first dedicated bibliometric overviews of STREAM pedagogy, highlighting the growing importance of literacy in STEM/STEAM extensions and its potential for curriculum reform in developed and developing countries. Bibliometric methods allow quantitative analysis of publication dynamics, citations and author networks [2].

The STREAM educational paradigm: evolution and theoretical foundations.

The development of STREAM education reflects the process of integrating a humanitarian dimension into natural and technical sciences. Although the original STEM model emerged in the early 2000s to boost economic competitiveness, it was subsequently recognised that technical skills alone were inadequate [3]. The STEAM model was introduced to integrate creative thinking and design, and the subsequent development of STREAM highlighted the importance of functional literacy and communication [4]. In pedagogical research, the STREAM concept relies on Seymour Papert's constructionism approach and Jean Piaget's theory of cognitive development [5]. Constructionism defines education as 'learning through the creation of real products', enabling the creation of a STREAM environment spanning astronomical education for preschoolers to engineering projects for high school students (Table 1).

Table 1 – The Evolution and Key Components of Integrated Educational Models

Education Model	Components	Main Focus
STEM	Science, Technology, Engineering, Mathematics	Logical thinking, technical skills, economic progress (Zhumabay et al., 2024)
STEAM	STEM + Arts	Creativity, aesthetic awareness, innovative design (Associazione Jump, n.d.)
STREAM	STEAM + Reading/Writing	Literacy development, communication, critical analysis (KidSTREAM Children's Museum, n.d.)
STREAMS	STREAM + Social Studies	Global citizenship, social responsibility (AlAli et al., 2023)
Source: Compiled by the author		

The role of the 'R' component in STREAM education is a topic of particular debate among researchers. On the one hand, reading is considered the 'heart' and 'gateway' to all learning, developing critical thinking skills and vocabulary [6]. Conversely, some authors propose considering this component as research skills, teaching students how to determine the reliability of information sources and analyse data [7]. This integration enables students to not only master 'technical tools', but also to form informed judgements about when and how they should be used [1]. In the current AI-driven era, this component is of particular strategic importance in developing the ability to verify AI-generated texts, use generative tools ethically, and critically analyse sources – competencies that are becoming essential for 21(st)-century graduates [2].

Analysis of the Scopus and Web of Science (WoS) databases shows that the number of publications in the STEM/STEAM/STREAM educational field has increased sharply in recent years. For instance, a steady growth trajectory in STEM research was observed from 2002 to 2022, with the highest rate recorded in 2020 (180 articles) [8]. STEAM educational mapping between 2016 and 2025 revealed that the most active period of scientific output was between 2019 and 2024 [9]. Geographically, most of the research originates from the United States, followed by China, Spain, and the United Kingdom [2]. A bibliometric analysis of STEM/STEAM teacher training in Colombia revealed that 64 articles were published in Scopus and 31 in WoS between 2014 and 2024, demonstrating increasing interest in this field in developing countries [10]. Bibliometric mapping tools, such as VOSviewer, provide a visual representation of how research topics cluster together. The main keywords in the analysed literature are centred around 'interdisciplinary learning', 'project-based learning', 'critical thinking' and 'engineering design process'. Additionally, there has been a tenfold increase in publications on the integration of digital tools and artificial intelligence (AI) platforms over the past three years (2021–2024) [11].

The pedagogical and cognitive foundations of the 'Reading' component.

The 'Reading' component is the core of the STREAM model. It is not just a humanities subject; it is also studied as a foundation for cognitive development. Bibliometric analyses have been conducted within the context of the 'science of reading' [12]. These skills are crucial for mastering the natural sciences, as a high level of linguistic competence is required to decode and comprehend scientific texts. Neurobiological studies prove that reading skills are associated with the structural maturation of the brain and activity in the frontal and parietal regions of the left hemisphere [13]. Students can strengthen their cognitive architecture by reading scientific articles or technical diagrams, which can help them to solve mathematical and engineering problems more easily [4].

The main methodologies for integrating learning are as follows:

- CLIL (Content and Language Integrated Learning): the simultaneous acquisition of content and language through the teaching of non-language subjects (e.g. biology or technology) in a foreign language [14].

Digital Storytelling: presenting scientific research in the form of a story using technological tools [15].

- Synthetic Tree-Learning Model (STREAM): a six-level hierarchy of learning skills used to interpret evolutionary trees in biology [16].

These approaches increase students' "technical literacy" and encourage a culture of working with information. Research shows that STREAM curricula can increase students' motivation and interest in science.

A bibliometric review of STEM and STEAM education in Kazakhstan reveals a substantial surge in scientific activity within the country since 2019, with Nazarbayev University emerging as a leading research institution in this field. A project conducted by Katie Malone and her colleagues examined the state of STEM/STEAM education at elementary school level, including the perceptions of teachers and students [17]. Notable issues include the gender disparity (in 2016, only 37% of engineering students were female), language barriers when learning STEM terminology, and disparities in access to resources between rural and urban schools [3, 17]. Based on focus group interviews and analysis of school teaching materials, researchers at Nazarbayev University have proposed new teacher training strategies to modernise Kazakhstan's education system in line with international standards [17].

STREAM in preschool and primary education

As preschool children are natural researchers, introducing STREAM components at an early age positively impacts their cognitive development. A bibliometric analysis shows that STEAM in preschool institutions influences children's psyche, career perception and the speed at which they receive feedback.

The main challenges for educators in preschool STREAM education include:

- Shifting from traditional teaching methods to interdisciplinary integration.
- Developing simultaneous perception – the ability to perceive all parts of a phenomenon as a whole at once.
- Organising the learning environment through creative movement, role-playing games and drama.

Research indicates that STREAM programmes in preschool settings enhance environmental awareness and promote sustainable development literacy. At this stage, the 'R' component is implemented through fairy tales, popular science books and illustrated diagrams to ensure the balanced development of linguistic and scientific competencies [4].

Materials and methods

Bibliometric methods and digital tools

Bibliometric methods provide an overview of the research field (see Table 2). The key approaches include:

1. Citation analysis: assessing the impact of publications, authors or journals.
2. Co-word analysis: defining thematic structure and development trends.
3. bibliographic coupling, which identifies clusters of articles based on shared references.

Table 2 – Key Bibliometric Analysis Tools and Their Distinctive Features

Tool	Function	Advantage
VOSviewer	Visualization and mapping	Provides complex authorship and thematic networks (Koo, 2025)
ScientoPy	Data integration and cleaning	Can process Scopus and Web of Science data simultaneously (Sugiarni et al., 2024)
Bibliometrix (R package)	Comprehensive statistical analysis	Offers a wide range of graphical and numerical indicators (Koo, 2025)
Biblioshiny	Interactive web interface	Enables analysis without requiring programming skills (Nurazmi et al., 2025)
Source: Compiled by the author		

An important consideration in bibliometric research is the limitations of databases. For instance, Web of Science may not comprehensively cover publications from developing countries, so it is recommended that it is supplemented with Scopus or Google Scholar [2].

Since 2023, artificial intelligence, particularly ChatGPT, has become a dominant topic in bibliometric analyses, with 3,231 Web of Science (WoS) articles published between January 2023 and June 2024. This technology can automate and personalise the 'R' (reading/writing) component of STREAM education by providing rapid feedback on written work, analysing text and code, and encouraging interdisciplinary collaboration [2]. However, it also raises ethical and psychological questions regarding cognitive autonomy in learning [2]. Bibliometric maps show that AI is closely linked to clusters of 'innovation in education', 'ethics', and 'technological development' [2]. This suggests that STREAM education will increasingly integrate digital intelligence in the future.

A bibliometric analysis of STREAM education confirms its growing interdisciplinary nature, with reading and writing literacy becoming integral to scientific and technical education. Key insights from the literature include:

- The STREAM model is a logical extension of STEM and STEAM that enriches education from moral and communicative perspectives. The 'R' component helps students to become analysts and disseminators of scientific knowledge, not just consumers [4].

While the USA and China dominate global research, local STREAM models are emerging in countries such as Colombia, Romania and Kazakhstan, taking into account regional characteristics [3]. In Kazakhstan, for example, most studies focus on improving integration and language literacy in preschool and primary education [17].

- Advances in bibliometric tools (e.g. VOSviewer and Bibliometrix) enable the mapping of scientific spaces and the identification of hidden connections, thereby enhancing the quality of research and interdisciplinary collaboration [11].

Future research should focus on:

- longitudinal studies evaluating the long-term impact of STREAM education;
- Effective methodologies for integrating generative AI tools into STREAM lessons [2].
- Practical models for implementing the Sustainable Development Goals and environmental literacy through STREAM education[9].
- Expanded international cooperation networks to support STREAM education in developing countries [11].

STREAM education is therefore not merely an acronym, but a comprehensive pedagogical strategy aimed at fostering critical thinking and creativity in individuals who are capable of addressing 21(st)-century challenges. A bibliometric analysis clearly demonstrates that this strategy is scientifically sound and is strengthening its position within the global educational landscape.

Methods

This study used a bibliometric review methodology to map the evolution and structure of STREAM education within the field of pedagogical research. Data were retrieved from Scopus, one of the largest peer-reviewed abstract and citation databases, to ensure coverage of high-quality international literature.

The search query used was: TITLE-ABS-KEY ('STREAM' AND 'pedagogy') AND PUBYEAR > 2004 AND PUBYEAR < 2026. No restrictions were applied to the language or type of document at the initial stage. The search yielded 267 documents. To refine the scope and ensure relevance to pedagogical contexts, the following filters were applied:

- Publication years: 2005-2025 (inclusive);
- Document types: articles, conference papers, book chapters and reviews (excluding notes, editorials and letters unless they are pedagogically relevant).

Following manual screening for relevance, during which off-topic or duplicate entries were excluded, the final dataset comprised 254 documents.

All the data were exported from Scopus in BibTeX format and imported into R Studio (version 4.3.2 or later) using the Bibliometrix package (version 4.2.0 or later) [18]. The following steps were performed in the Bibliometrix/BiblioShiny environment:

- Data loading and initial inspection (via the biblioAnalysis() function).
- Duplicate removal and metadata cleaning, including author name unification (mergeAuthors()), correction of institutional affiliations and standardisation of keywords.
- Time coverage verification and re-filtering to 2005-2025.

The analysis included:

- descriptive statistics (annual production, sources, authors, affiliations, countries and document types), using the biblioAnalysis() and summary() functions;
- Keyword analysis: frequency (treemap), trend topics (trendTopics()), and co-occurrence network (conceptualStructure() with Louvain clustering).
- Thematic mapping: strategic diagram (thematicMap()), factorial map (conceptualStructure() with MCA).
- Collaboration analysis: country collaboration matrix (countryCollaboration()).

All visualisations (figures and tables) were generated directly in Bibliometrix/BiblioShiny. The analysis was conducted in December 2025.

The applied bibliometric methods thus enabled a systematic, quantitative, and structural analysis of the scientific literature on STREAM education and pedagogy. This revealed publication dynamics, key thematic clusters, and development trends in the field.

Results and discussion

This bibliometric review is based on 254 documents retrieved from Scopus using the keywords 'STREAM' and 'pedagogy' (2005-2025). The dataset covers a 20-year period, with an average document age of 6.82 years, suggesting that the majority of publications were released within the last decade. The documents were published across 177 different sources, reflecting broad dissemination rather than concentration in a few outlets. The average annual growth rate is 7.18%, confirming a steady increase in research output.

The authorship structure comprises 628 authors, with an average of 2.51 authors per document, and includes 102 single-authored papers. International co-authorship accounts for 13.78% of publications. On average, documents are cited 12.74 times; however, cited references data were not retrieved, precluding co-citation or bibliographic coupling analyses. There are a total of 1,009 author keywords (DE) and 803 Keywords Plus (ID). The document types are dominated by journal articles (144), followed by conference papers (44), book chapters (37) and review articles (18).

Figure 1 (Annual Scientific Production) shows low publication levels from 2005 to 2010 (1–8 articles per year). From 2011 to 2018, output stabilised at nine to 15 articles per year. A marked surge occurred after 2019, with 22 articles published in 2021, 21 in 2022, 18 in 2023, 21 in 2024 and a peak of 32 in 2025. This growth trajectory highlights the accelerating global interest in STREAM pedagogy, particularly in recent years, which coincides with the rise of digital tools, online learning and AI integration in education.

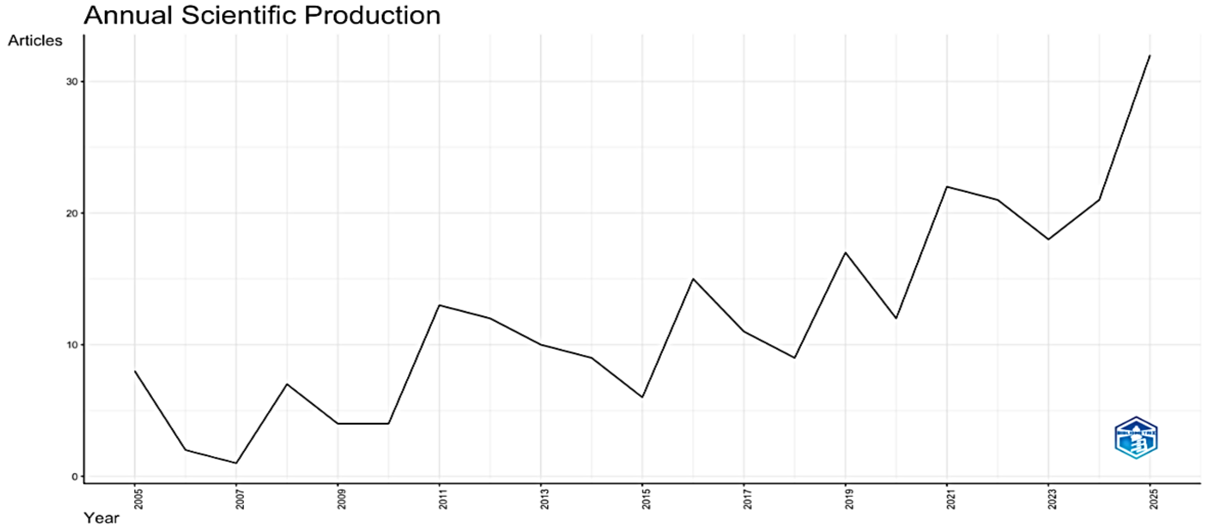

Figure 1 – Annual scientific production

Figure 2 (Most Relevant Sources) shows that publications are spread across a wide range of outlets, with no single source dominating. The top contributor is the *Journal of Engineering Education Transformations*, with four articles, followed by the *ACM International Conference Proceedings Series*, with three articles. Eight other sources each published two articles: *ASEE Annual Conference and Exposition Conference Proceedings; CEUR Workshop Proceedings; Cogent Education; Communications in Computer and Information Science; International Journal of Educational Management; Journal of Curriculum Studies; Journal of Digital Landscape Architecture; and Lecture Notes in Computer Science.*

The distribution across engineering education journals, computer science proceedings and general education titles highlights the interdisciplinary nature of STREAM pedagogy research, which bridges technical and engineering fields with broader pedagogical and curriculum studies.

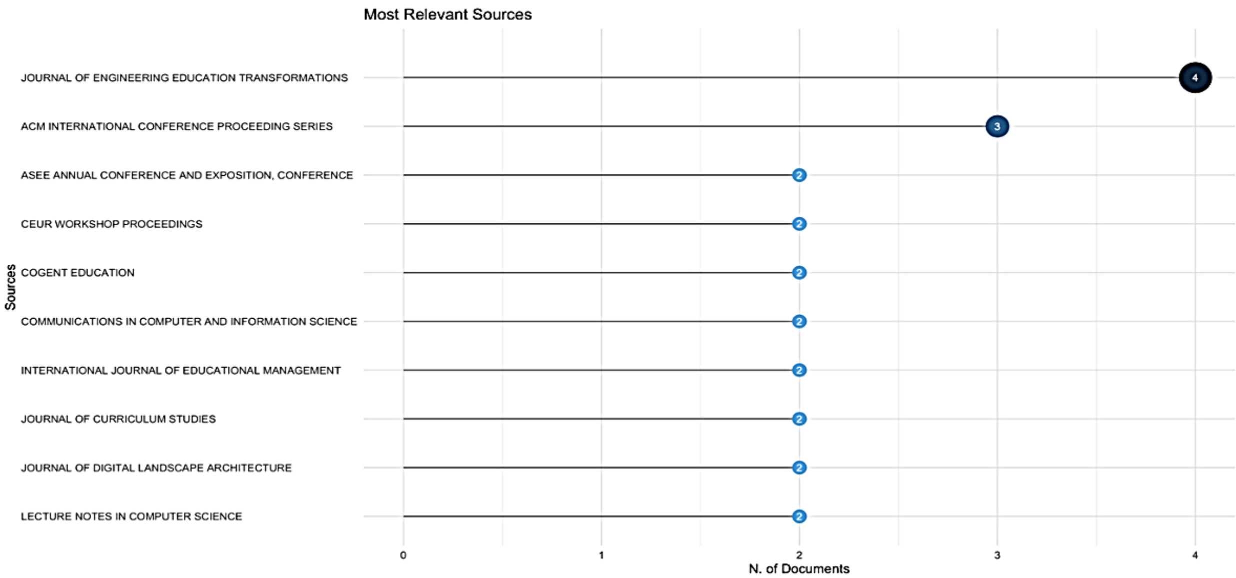

Figure 2 – Top-10 most relevant sources

Figure 3 (Authors' Production Over Time) illustrates the publication activity of leading authors throughout the study period. Red horizontal lines represent each author’s active publication period, and bubbles indicate years of publication. Bubble size reflects the number of articles published in a given year (N.Articles), and colour saturation shows the number of annual citations (TC/year).

The graph reveals varied productivity patterns: some authors published in only one or two years, while others were active for longer periods. Early contributors were active from 2005 to 2012, whereas recent authors have emerged more prominently from 2021 to 2024. While recent publications (2021 and 2024) exhibit relatively high annual citation rates, 2024 publications naturally have low or zero citations due to their recent publication date.

This distribution highlights the evolving landscape of authorship in the field: a combination of established researchers and a growing influx of new contributors since 2019, reflecting the growing popularity of STREAM pedagogy research in recent years.

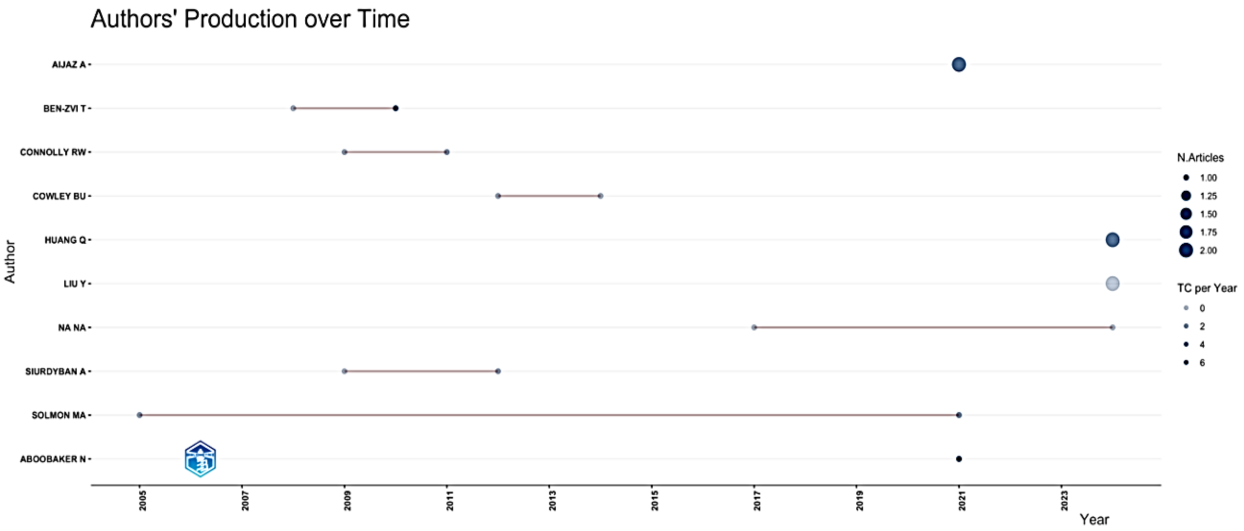

Figure 3 – Top-10 authors' production over time

Figure 4 (Affiliations' Scientific Production) reveals a decentralised institutional landscape for STREAM pedagogy research. The top contributors each published four articles: Covenant University; Michigan State University; Sabaragamuwa University, Sri Lanka; and the University of British Columbia. Six institutions each contributed three articles: The Herbert Wertheim College of Engineering, the Kalasalingam Academy of Research and Education, King's College London, the Manipal College of Health Professions, Northeastern University and Stanford University.

The broad distribution of contributions across diverse universities (from North America, Asia, Africa and Europe) rather than concentration in a few elite centres highlights the emerging, globally diffused nature of STREAM pedagogy scholarship. This involves both established, research-intensive institutions and newer contributors from developing regions.

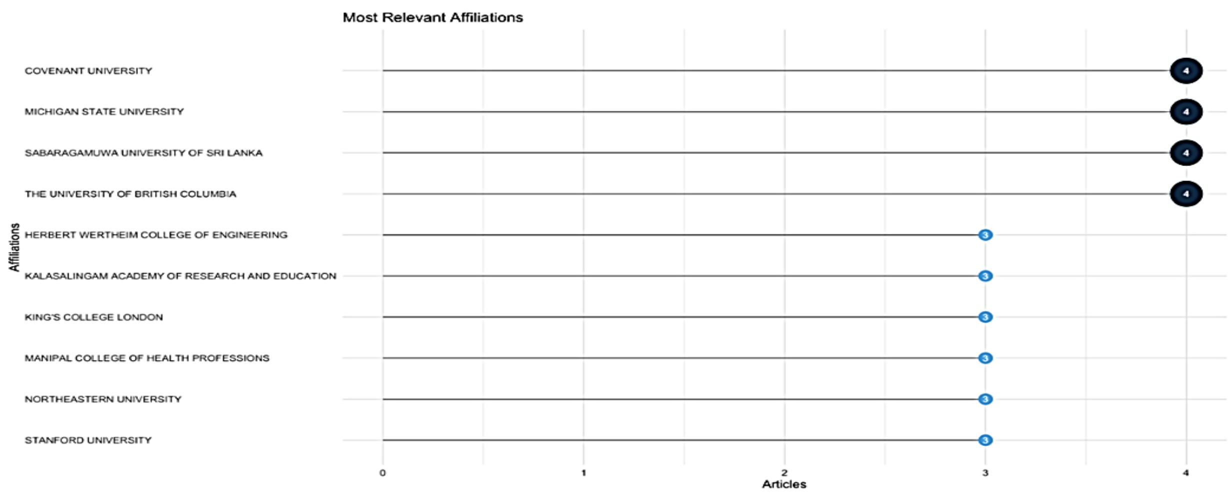

Figure 4 – Top-10 most relevant affiliations

Figure 5 (Corresponding Author Country Collaboration) shows the geographical distribution of publications by country of the corresponding author and the extent of international collaboration. The United States tops the list with 44 articles, followed by India (15), Canada (11) and Australia and China (nine each). Most publications in these top countries are single-country (SCP), indicating predominantly domestic authorship.

Overall, international co-authorship (MCP) remains low at 13.78% across the dataset. However, higher MCP shares are evident in China, the United Kingdom and Sweden. Countries with fewer total publications (e.g. Korea, Nepal and New Zealand) demonstrate relatively high levels of international collaboration. This pattern suggests that STREAM pedagogy research is dominated by leading academic nations with strong internal research capacity, while international cooperation is emerging but remains limited. The higher MCP in certain countries indicates growing global networks that could be utilised to support the implementation of STREAM in developing regions through collaborative teacher training and curriculum development.

A bibliometric review of STEM and STEAM education in Kazakhstan reveals a substantial surge in scientific activity within the country since 2019, with Nazarbayev University emerging as a leading research institution in this field. Notable issues include the gender disparity (in 2016, only 37% of engineering students were female), language barriers when learning STEM terminology, and disparities in access to resources between rural and urban schools [3, 17]. To address these challenges, Kazakhstan has implemented several reforms, including the 2023 "Concept of STEM Education" by the Ministry of Education, which emphasizes integration of STEAM into the national curriculum as elective subjects or extracurricular activities, aiming for full coverage by 2028 [19]. This aligns with global trends but adapts to local needs, such as promoting digital literacy and AI tools in primary education.

Implementation examples include pilot STEAM projects in schools of Astana and Almaty, such as engineering camps organized by American Corners, which empowered rural students through makerspace activities, and AI-enhanced learning pilots in 2025, integrating artificial intelligence into computer science classes. In universities, initiatives like the UniSat nanosatellite program at Al-Farabi Kazakh National University (in collaboration with UNICEF) focus on girls' involvement in aerospace technologies, with a dedicated educational hub in Turkestan promoting STEM among schoolgirls since 2022. UNICEF's STEAM programs in Turkestan, including gamification and Level Up initiatives (2023-2024), have targeted gender barriers by providing hands-on training in game development and nanosatellites, contributing to the Game Changers Coalition. Despite progress, barriers persist: stereotypes that STEM is "not for girls," lack of gender-responsive pedagogy in teacher training, and societal pressures prioritizing household duties over careers [20]. These efforts highlight Kazakhstan's emerging role in STREAM pedagogy, with potential for broader integration into the state educational standards (GOSO) to overcome urban-rural divides and foster inclusive innovation.

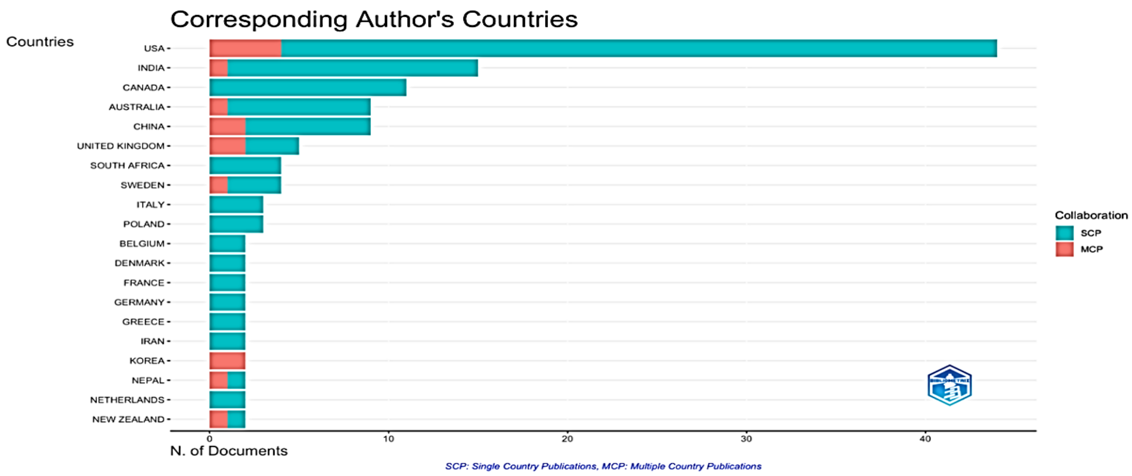

Figure 5 – Top corresponding author’s countries

Figure 6 (Most Cited Countries) shows the citation impact of countries based on total citations (TC) and average citations per article. The United States dominates, achieving 1,022 total citations with an average of 23.20 per article. Sweden ranks second in terms of total citations (514), but leads in terms of average impact (128.50), indicating a high level of influence from a smaller number of highly cited works. Canada (202 TC; average 18.40) and India (161 TC; average 10.70) follow, alongside other notable contributors: Australia (118 TC; average 13.10), Greece (72 TC; average 36.00), the United Kingdom (68 TC; average 13.60) and Belgium (58 TC; average 29.00). China (39 citations; average 4.30 per article) and South Korea (36 citations; average 18.00 per article) show lower totals, but still have a visible presence in the citation landscape.

These citation patterns highlight the concentration of high-impact STREAM pedagogy research in North America and Europe, with Sweden and Greece demonstrating exceptional per-article influence. The relatively lower impact of high-output countries such as China and India suggests opportunities to strengthen international visibility and collaboration, thereby elevating the quality and dissemination of research in developing regions.

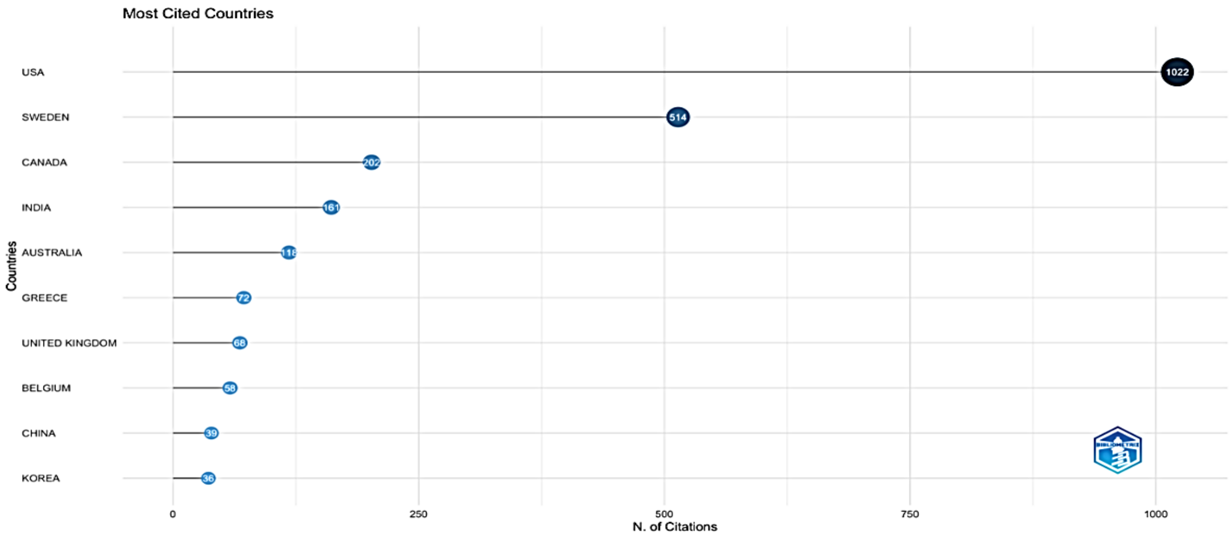

Figure 6 – Top-10 most cited countries

Table 3 (Most Globally Cited Documents) lists the top 15 publications by total citations (TC), annual citation rate (TC per year) and normalised TC. The most highly cited publications are Leander and Boldt (2012), which has received 469 citations (an average of 36.08 per year), and Lotz-Sisitka et al. (2015), which has received 436 citations (an average of 39.64 per year). Both publications demonstrate sustained high impact.

Earlier publications, such as those by Fenwick (2005), Roth (2014) and D'Isanto (2016), demonstrate stable long-term citation performance and strong normalised values. Among more recent works, Sitaridis and Kitsios (2024) stand out with their notably high annual citation rate and normalised TC, reflecting their rapid influence. Other notable recent contributions include those by Gabrielsson et al. (2020), Stevens & Vermeersch (2010), Cochrane et al. (2014) and Asamoah et al. (2017).

This citation profile indicates that foundational theoretical and empirical works from the 2010s continue to have a significant impact, while selected recent studies (especially those from 2020–2024) are gaining traction quickly. The significant influence of these papers highlights key pedagogical themes (e.g. embodied learning, transformative education and technology integration) that remain central to STREAM pedagogy research. Future studies should therefore build on these influential foundations while addressing the intersections of emerging AI and digital literacy to sustain and expand the field's impact.

Table 3 – Top 15 most cited documents

Paper	DOI	Total Citations	TC per Year	Normalized TC
(Leander & Boldt, 2012)	https://doi.org/10.1177/1086296X12468587	469	36,08	8,77
(Lotz-Sisitka et al., 2015)	https://doi.org/10.1016/j.cosust.2015.07.018	436	39,64	5,64
(Fenwick, 2005)	https://doi.org/10.1080/13678860500100541	121	5,76	5,94
(Roth, 2014)	NA	107	8,92	3,95
(D'Isanto, 2016)	NA	94	9,40	5,80
(Ben-Zvi, 2010)	https://doi.org/10.1016/j.dss.2010.01.002	77	4,81	1,71
(Sitaridis & Kitsios, 2024)	https://doi.org/10.1108/IJEBR-01-2023-0053	72	36,00	14,13
(Gabrielsson et al., 2020)	https://doi.org/10.1108/ET-11-2019-0265	65	10,83	6,05
(Stevens & Vermeersch, 2010)	https://doi.org/10.1080/03054981003629862	58	3,63	1,29
(Cochrane et al., 2014)	https://doi.org/10.3402/rlt.v22.24637	50	4,17	1,84
(Asamoah et al., 2017)	https://doi.org/10.1111/dsji.12125	48	5,33	3,20
(Yates & Millar, 2016)	https://doi.org/10.1080/09585176.2016.1174141	48	4,80	2,96
(Beal & Astakhova, 2017)	https://doi.org/10.1007/s10551-015-2762-6	40	4,44	2,67
Chen, Lasecki & Dong, (2021)	https://doi.org/10.1145/3434168	38	7,60	3,77
(Weiss et al., 2023)	https://doi.org/10.1177/10564926231181555	37	12,33	6,28
Source: Generated by the author through bibliometrix software				

Figure 7 (Treemap of Term Frequency) shows how the key terms are distributed in the dataset. The most frequent term is 'pedagogy' (46 occurrences), followed by 'teaching' and 'na' (33 each). Other high-frequency terms include "students" (24) and "education" (21). Subject-specific terms, such as 'engineering education' (18) and 'curriculum' (15), also appear frequently. Technology-related terms appear with moderate frequency: 'computer-assisted instruction' and 'e-learning' (12 each), as well as 'education computing', 'educational technology', and 'online learning'. Other moderately frequent terms include 'learning', 'human/humans', 'higher education', 'critical pedagogy', and 'teaching and learning'. Lower-frequency terms include "artificial intelligence", "Bloom's taxonomy", "course design", "design" and "engineering research".

This distribution of term frequencies confirms that STREAM pedagogy research remains firmly rooted in core educational concepts such as "pedagogy", "teaching", "students" and "curriculum", while technology integration and engineering education form significant secondary clusters. The relatively low frequency of 'artificial intelligence' suggests that, despite the recent growth in AI-related publications, its explicit integration into STREAM discourse is still in its infancy. These patterns indicate opportunities for future research to strengthen the link between traditional pedagogy and generative AI tools, particularly with regard to enhancing the 'R' (reading/writing/research) component for critical digital literacy.

Figure 7 – Treemap of terms frequency

Figure 8 (Trend Topics) illustrates the evolution of keywords from 2008 to 2024, based on the merged Scopus keywords (KW_Merged). The analysis highlights the three most frequent terms per year, with the size of the bubbles representing median frequency, and the horizontal lines showing the distribution range over time.

Core terms such as 'pedagogy', 'teaching', 'learning' and 'education' have remained consistently dominant throughout the period, reflecting the enduring pedagogical foundation of STREAM research. 'Students' peaked in frequency during the mid-2010s. From 2016 to 2019, 'e-learning', 'computer-aided instruction', and 'curriculum' gained prominence. Since 2020, 'higher education' has emerged as a leading term, accompanied by an increasing number of mentions of 'online learning' and 'education computing'. 'Artificial intelligence' appears sporadically with low to moderate frequency throughout the timeline.

These temporal shifts demonstrate a transition from general pedagogical and student-centred concepts towards technology-enhanced, higher education-focused themes, which has been particularly accelerated since 2020. The delayed and limited integration of 'artificial intelligence' despite recent global AI advancements suggests that explicit AI-STREAM connections are still in their infancy in the literature. These trends highlight the importance of future STREAM pedagogy research deliberately incorporating generative AI tools to enhance the 'R' (reading, writing and research) element, thereby promoting critical digital literacy and personalised learning in higher education settings.

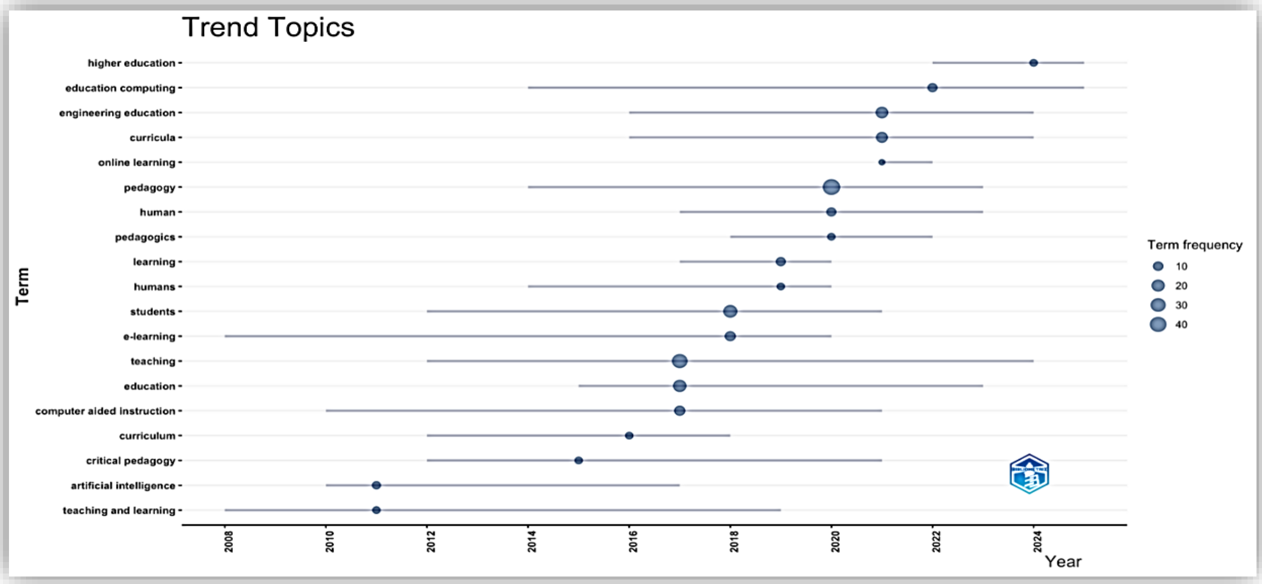

Figure 8 – Trend topics

Figure 9 (All Keywords Co-occurrence Network) illustrates the relationships between keywords using the Louvain clustering algorithm. Node size reflects keyword frequency and edges indicate co-occurrence within documents.

Three main clusters emerge:

Cluster 1 (central): 'pedagogy', 'teaching', 'student', 'curriculum', 'engineering education' – representing core pedagogical theories, curriculum design and subject-specific (especially engineering) education.

Cluster 2 focuses on human-centred, applied, and domain-specific (e.g. adult, health, and physical) education, with keywords including "education", "human/humans", "learning", "adult", "nursing", and "physical education".

Cluster 3: 'e-learning', 'computer-aided instruction' – centred on technology-mediated learning systems.

'Education' and 'student' act as bridging nodes, connecting the clusters.

This network structure reveals that pedagogy and teaching practices form the core of the field, with technology-related research (Cluster 3) developing somewhat independently, yet still linked to the pedagogical centre. Human-oriented and applied domains (Cluster 2) form a distinct yet interconnected area. Overall, the literature on STREAM pedagogy demonstrates interrelated yet thematically differentiated layers: foundational pedagogy, domain-specific applications and technological tools. This configuration highlights the interdisciplinary potential of STREAM, but also indicates the need for stronger integration between technology clusters and core pedagogical and student-centred approaches, particularly with regard to embedding generative AI and digital literacy tools more deeply into the curriculum and engineering education practices to enhance critical thinking and the 'R' component.

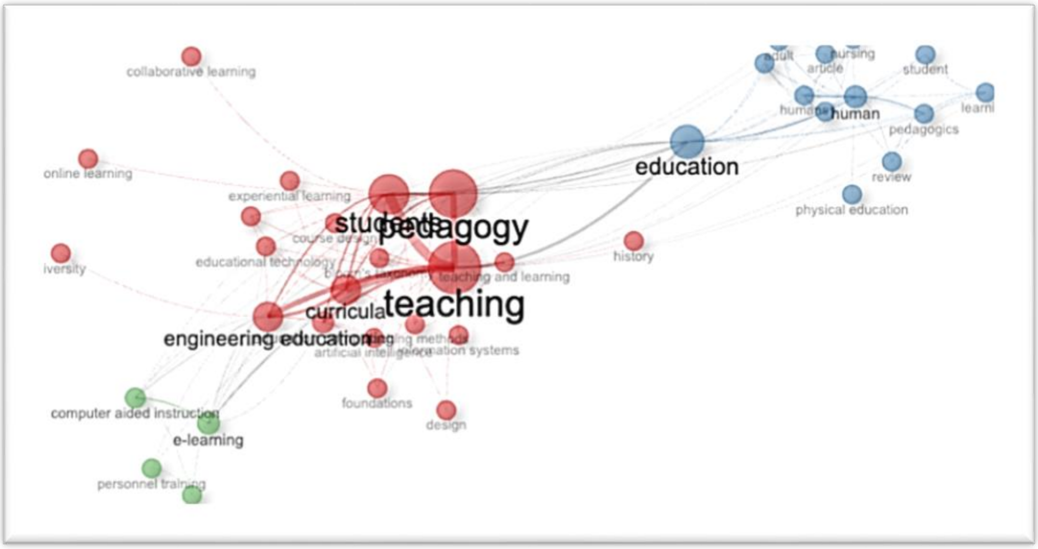

Figure 9 – Keywords co-occurrence network

Figure 10 (Thematic Strategic Map) illustrates how research topics are mapped based on KW_Merged keywords from Scopus, which are clustered using the Louvain algorithm. Topics are positioned in one of four quadrants according to their centrality (i.e. their relevance to the field) and their density (i.e. their internal development).

Motor themes (high centrality and density):

"Pedagogy – Students – Artificial Intelligence" and "Teaching – Engineering Education – Curriculum" are well developed and central. They encompass technology/AI integration in pedagogical approaches, student-centred learning and engineering education.

"Education – Human – Learning" reflects the broad interdisciplinary nature of education and learning concepts.

Basic themes (high centrality, low density):

‘Computer-aided instruction – e-learning – personnel training’ – widely connected but internally underdeveloped, representing frequently used concepts without a tightly focused direction.

Niche themes (low centrality, high density):

‘Higher education – online learning – agency’ – internally coherent, but with limited links to the broader field, indicating a specialised focus on higher education and online learning dynamics.

Emerging or declining themes (low centrality, low density):

“Critical pedagogy – philosophy of education – critical thinking” – primarily theoretical.

‘Downstream – entrepreneurship education – educational theory’ is an emerging direction, not yet fully formed, as seen in recent publications.

Overall, the map places pedagogy, teaching and technology-based education, especially in the fields of AI and engineering, at the heart of STREAM pedagogy research. Theoretical and emerging interdisciplinary areas remain peripheral or nascent. This structure highlights the field's strong pedagogical and technological foundations, but also reveals gaps in the consolidation of basic themes and the integration of niche and emerging topics. To advance STREAM pedagogy, future work should prioritise integrating AI-motor themes with fundamental e-learning principles and developing emerging areas (e.g. critical thinking and entrepreneurship education) into curricula and teacher training programmes to reinforce the 'R' element and promote interdisciplinary coherence.

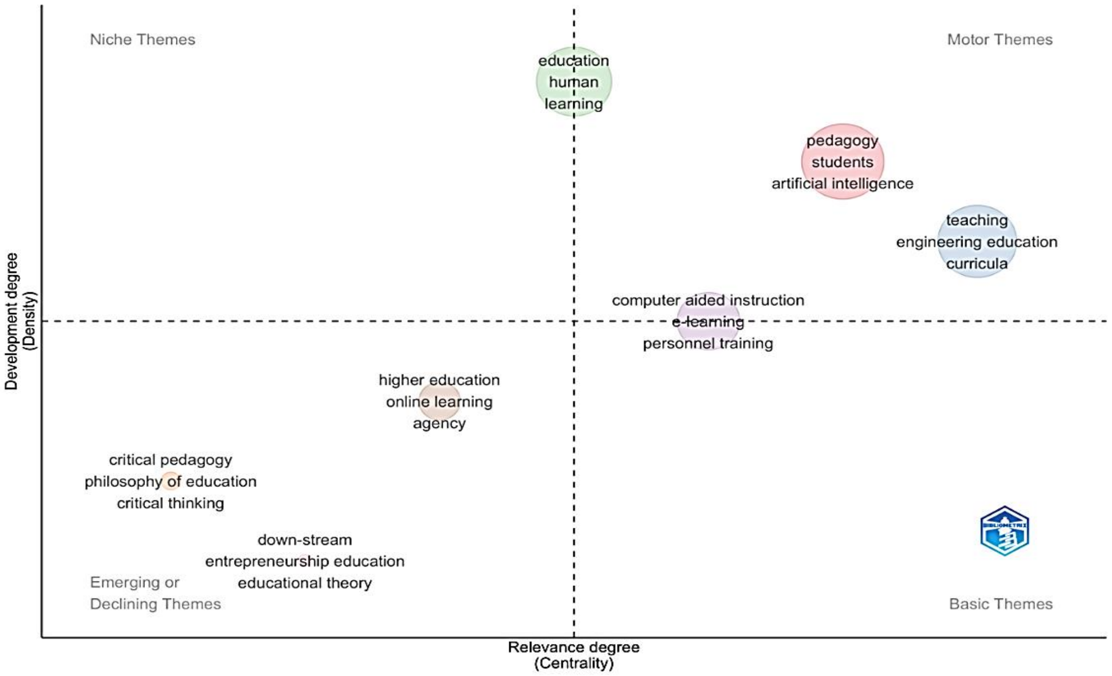

Figure 10 – Thematic strategic map

Figure 11 (Factorial Map – Multiple Correspondence Analysis, MCA) illustrates the conceptual structure of the keywords, as determined by the KW_Merged field in the Scopus dataset. MCA identifies two main dimensions: Dim 1 (explaining 44.92% of the variance) and Dim 2 (explaining 23.46% of the variance). Together, these dimensions explain 68.38% of the total variance, which confirms the representativeness of the map.

Key thematic groups emerge:

- Left side: 'teaching', 'curriculum', 'course design', 'learning systems', 'Bloom's taxonomy', 'teaching tools' – focused on curriculum design, methodological foundations, and structured learning approaches.
- Upper-left quadrant: 'Problem-based learning', 'higher education', 'mobile learning' – highlighting modern, innovative, and technology-enhanced methods.
- Right side: 'education', 'learning', 'student', 'pedagogics', 'physical education', and 'India' – representing general educational contexts, student-centred research, and some subject-specific or regional emphases.
- Right edge of Dim 1: 'human', 'humans', 'adult' – forming a distinct group around adult education and human-centred approaches.

Dimension 1 separates pedagogical/methodological design (left) from human/adult-learner focus (right). Dimension 2 differentiates traditional structural elements from modern, technology-integrated approaches.

This MCA structure reveals two parallel, yet conceptually distinct, streams within the STREAM pedagogy literature: one rooted in traditional curriculum and teaching design and the other in human-centred and adult education. Modern innovations (e.g. problem-based, mobile and online learning) cluster around higher education and technology, while research focused on adults/humans remains somewhat isolated. These findings suggest ways in which innovative, technology-driven methods could be better integrated with human-centred approaches, particularly by embedding AI tools and digital literacy into curriculum design and adult/teacher training programmes. Such integration could reinforce the 'R' component (reading, writing and research skills) and encourage more cohesive, student- and adult-centred STREAM implementations in various educational settings.

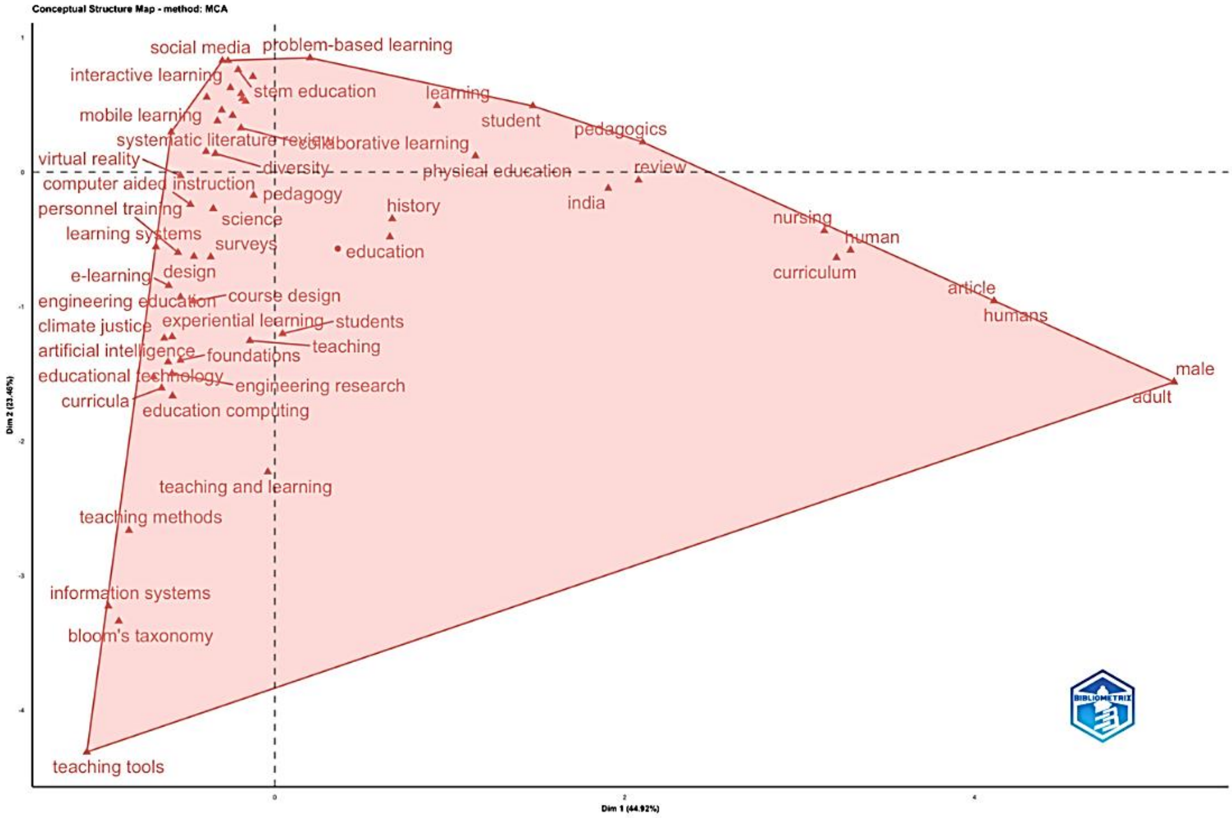

Figure 11 – Factorial Map (Multiple Correspondence Analysis, MCA)

Table 4 (Top Six Countries' Collaboration) summarises the most frequent international co-authorship pairs in STREAM pedagogy research.

- United States – United Kingdom: 5 joint articles (highest frequency);
- United States – Australia: Four articles
- United States – Canada: United States – Canada: 4 articles
- Australia – New Zealand: 2 articles (an example of regional cooperation)
- Canada – United Kingdom: 2 articles
- United Kingdom – Austria: 2 articles

These collaborations emphasise the strength of the transatlantic relationship (between the USA and the UK, and the USA and Canada), as well as the development of new connections with Oceania (between the USA and Australia, and Australia and New Zealand) and Europe (between the UK and Austria). The United States' dominance as a central hub reflects its leading role in high-impact STREAM research, while its partnerships with the UK, Canada and Australia indicate well-established academic networks in English-speaking countries.

This pattern of limited but focused international cooperation underscores the fact that STREAM pedagogy research remains concentrated among a few developed nations with robust research infrastructures. The relatively low overall MCP (13.78%) suggests opportunities to expand global networks, particularly by fostering collaborations with emerging contributors, such as India, China and Kazakhstan, to share best practices in curriculum integration, teacher training and AI-enhanced STREAM implementation in diverse cultural and resource contexts. Strengthening such partnerships could accelerate the adoption of STREAM models in developing countries, enhancing the field's inclusivity and global relevance.

Table 4 – Top 6 Countries' collaboration world map

From	To	Frequency
USA	UNITED KINGDOM	5
USA	AUSTRALIA	4
USA	CANADA	4
AUSTRALIA	NEW ZEALAND	2
CANADA	UNITED KINGDOM	2
UNITED KINGDOM	AUSTRIA	2
Source: Generated by the author through bibliometrix software		

Conclusion

This bibliometric review, based on 254 Scopus documents from 2005 to 2025, provides a comprehensive overview of STREAM education in pedagogical research. The findings reveal an evident increase in publication output over the past decade, with a significant rise after 2019 and a peak in 2025. Key thematic clusters reveal the deep integration of STREAM pedagogy with core educational concepts such as pedagogy, teaching and curriculum design, as well as with engineering education, digital and online learning, and emerging artificial intelligence applications. Bibliometric maps confirm that pedagogical theories and curriculum design remain central, while e-learning, computer-assisted instruction and AI-enhanced learning have gained significant momentum in recent years. Post-2020 trends further emphasise higher education, online learning, and student agency.

Geographically, research is concentrated in developed academic systems (the USA, Canada, Australia and the UK), with limited but growing international collaboration (e.g. the USA–UK and USA–Canada/Australia pairs). Institutional output is decentralised, involving both established universities and contributors from diverse regions.

Overall, the analysis highlights the interdisciplinary nature of STREAM as a logical extension of STEM/STEAM, with the 'R' (reading, writing and research) component playing an increasingly strategic role in the AI era with regard to critical digital literacy, source evaluation and the dissemination of knowledge in an ethical manner.

The results provide a robust methodological basis for future empirical studies, the modernisation of curricula, and evidence-based educational policy. Key recommendations for advancing STREAM pedagogy include:

- Longitudinal studies to assess the long-term impact on student outcomes, critical thinking, and career readiness.
- Development of practical methodologies for integrating generative AI tools into STREAM lessons, emphasising ethical use and enhancement of the 'R' component.
- Models linking STREAM to Sustainable Development Goals and environmental literacy.
- Expanded international networks to support STREAM adoption in developing countries, addressing local challenges such as gender gaps, language barriers and urban-rural disparities in Kazakhstan.

As a practical example of STREAM implementation in school settings, project-based lessons integrating all components are recommended (e.g., creating a model of a sustainable city using AI for source analysis, scale calculations, and report writing). Such approaches enhance critical thinking and student motivation, particularly in the context of Kazakhstan with its gender and regional specifics.

By addressing these issues, STREAM can evolve into a more inclusive, AI-enhanced teaching strategy that can prepare individuals to think critically and creatively in the 21(st) century.

Author Contributions

Omarkhanova A. – Conceptualization, methodology, data collection from Scopus, software implementation (Bibliometrix/R Studio), formal analysis, visualization (figures and tables), writing – original draft (Introduction, Methods, Results and discussion), writing – review and editing.

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STREAM-ПЕДАГОГИКА ЗЕРТТЕУЛЕРІ: SCOPUS БИБЛИОМЕТРИЯЛЫҚ ТАЛДАУЫ 2005-2025

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Аңдатпа. Осы мақала Scopus дерекқорының 2005 жылдан 2025 жылға дейінгі мәліметтері негізінде педагогикалық зерттеулердегі STREAM-білім берудің эволюциясы мен қазіргі жағдайын жан-жақты библиометриялық талдауды ұсынады. Негізгі мақсат – ғылымды, технологияны, оқу/жазуды, инженерлікті, өнерді және математиканы біріктіретін межпәндік тәсіл ретіндегі STREAM-білім берудің даму үрдістерін, басым тақырыптарын және жалпы ғылыми құрылымын заманауи педагогика контекстінде анықтау. "Педагогика" және "STREAM" кілт сөздері арқылы алынған бастапқы нәтижелерді нақтылағаннан кейін 254 ғылыми құжат талданды. Талдау R Studio ортасындағы Bibliometrix пакеті көмегімен жүргізілді, оған жылдық жарияланымдар динамикасы, кілт сөздердің бірлесіп кездесу желілері, тақырыптық карталар, сондай-ақ елдер мен аффилиациялар бойынша бөлініс кіреді. Негізгі нәтижелер соңғы он жылдықта жарияланымдардың айтарлықтай өсуін көрсетеді, бұл STREAM-ға STEM және STEAM модельдерінің жалғасы ретіндегі жаһандық қызығушылықтың артуын куәландырады. Зерттеудің негізгі кластерлері педагогика, инженерлік білім беру, цифрлық және онлайн оқыту, сондай-ақ жасанды интеллектің өсіп келе жатқан рөлін атап өтеді. Географиялық талдау ғылыми белсенділіктің жетекші елдерде шоғырланғанын және халықаралық ынтымақтастықтың шектеулі, бірақ дамып келе жатқанын көрсетеді. Алынған деректер саладағы ғылыми құрылымның панорамалық көрінісін береді, оның межпәндік сипатын және цифрлық құралдарды одан әрі интеграциялау әлеуетін атап өтеді. Нәтижелер болашақ зерттеулер, оқу бағдарламаларын әзірлеу және STREAM-педагогика саласындағы білім беру саясаты үшін бағдар бола алады.

Кілт сөздер: *STREAM, педагогика, библиометриялық талдау, библиометрикс, білім беру, шолу.*

ИССЛЕДОВАНИЯ STREAM-ПЕДАГОГИКИ: БИБЛИОМЕТРИЧЕСКИЙ АНАЛИЗ SCOPUS 2005-2025

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Аннотация. Настоящая статья представляет всесторонний библиометрический анализ эволюции и современного состояния STREAM-образования в педагогических исследованиях на основе данных базы Scopus за период с 2005 по 2025 год. Основная цель – выявить ключевые тенденции развития, доминирующие темы и общую научную структуру STREAM-образования как междисциплинарного подхода, объединяющего науку, технологии, чтение/письмо, инженерию, искусство и математику, в контексте современной педагогики. С использованием ключевых слов "педагогика" и "STREAM" проанализировано 254 научных документа после уточнения исходного поиска. Анализ выполнен с помощью пакета Bibliometrix в среде R Studio, включая динамику ежегодных публикаций, сети совместного появления ключевых слов, тематические карты, а также распределение по странам и аффилиациям. Ключевые результаты демонстрируют значительный рост числа публикаций за последнее десятилетие, что свидетельствует о возрастающем глобальном интересе к STREAM как продолжению моделей STEM и STEAM. Основные кластеры исследований подчеркивают роль педагогики, инженерного образования, цифрового и онлайн-обучения, а также растущую значимость искусственного интеллекта. Географический анализ показывает концентрацию научной активности в ведущих странах с ограниченным, но развивающимся международным сотрудничеством.

Полученные данные дают панорамный обзор научной архитектуры области, подчеркивая её междисциплинарный характер и потенциал дальнейшей интеграции цифровых инструментов. Результаты могут служить ориентиром для будущих исследований, разработки учебных программ и образовательной политики в сфере STREAM-педагогики.

Ключевые слова: *STREAM, педагогика, библиометрический анализ, библиометрикс, образование, обзор.*

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