

Exploring the research trends in STEAM education for preschoolers: a bibliometric analysis

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Doina Florica Tifrea ^a, Alina Felicia Roman ^{a*} 

^a Faculty of Educational Sciences, Psychology and Social Work, "Aurel Vlaicu" University of Arad, Arad, Romania

*Corresponding author: romanalinafelicia@yahoo.com

Abstract

This study offers an in-depth bibliometric analysis of current research on STEAM (Science, Technology, Engineering, Arts, and Mathematics) education in preschool settings, using a dataset of 42 publications from the Web of Science Core Collection. By applying VOSviewer for co-occurrence network analysis (full counting, minimum of 3 keyword occurrences), we identified four main thematic clusters: (1) Innovative teaching practices and teacher training, highlighting the importance of educator preparedness and curriculum development; (2) Child development through STEAM, focusing on improvements in creativity, collaboration, and cognitive skills; (3) Technology and engineering integration, examining the use of robotics, coding, and design thinking with young learners; and (4) Cultural and environmental contexts, emphasizing localized, inclusive, and outdoor learning approaches. The findings show increasing international attention to early STEAM education, along with a clear need for better assessment tools and stronger support for teacher training. This analysis helps clarify where the field stands and where it might go next, offering valuable insights for educators, researchers, and policymakers interested in early childhood education.

Keywords:

STEAM education, preschool, early childhood, teacher training, bibliometric analysis

1. Introduction

In the evolving landscape of education, the integration of STEAM — Science, Technology, Engineering, Arts, and Mathematics — has become a cornerstone of innovation, creativity, and holistic development. While STEM education has long been associated with preparing students for future careers in technical fields, the deliberate inclusion of the arts in STEAM frameworks emphasizes creativity, emotional expression, and interdisciplinary thinking (Başaran & Bay, 2023; Sabou-Baboş et al., 2020). This approach is not merely an educational trend; it is a paradigm shift aiming to equip learners with the ability to navigate complexity and uncertainty in a rapidly changing world.

Within this context, early childhood education has emerged as a critical space for implementing STEAM methodologies. Scholars argue that preschoolers are particularly receptive to STEAM learning, as it aligns naturally with their exploratory and creative tendencies (Chang, 2023; Şuteu et al., 2024). Research by Popa and Ciascai (2017) shows that even young learners demonstrate positive attitudes towards STEM and STEAM learning, fostering early cognitive, social, and emotional benefits. However, despite the recognized potential, there remains a notable gap in understanding the specific characteristics, thematic

trends, and research directions within STEAM education targeting preschool populations.

In general education research, numerous studies have already explored the implementation, challenges, and opportunities of integrating technology and STEAM-based pedagogies (Rad et al., 2022b; Rad et al., 2023a). For instance, investigations into the Technology Acceptance Model (TAM) and predictive neural network models (Rad et al., 2022a; Rad et al., 2022b) have shed light on how preschool teachers navigate technological innovations in their classrooms. Similarly, studies grounded in the Theory of Planned Behavior have emphasized the role of intentionality and organizational climate in shaping educational practices (Redeş et al., 2023; Rad et al., 2023c). Yet, while the integration of AI, smart learning environments, and digital pedagogy is expanding (Rad, 2025; Rad & Rad, 2025; Rad et al., 2024a), specific attention to STEAM-focused research within early childhood settings remains fragmented and underexplored.

Moreover, the role of teachers as facilitators of STEAM learning is increasingly acknowledged, but there is an urgent need to better understand their preparedness, professional confidence, and access to effective mentoring (Chang, 2023; Bocoş et al., 2024;



Rad & Bocoş, 2024). Research has demonstrated that while technological infrastructures may be available, the human factors — such as metacognitive skills, organizational support, and adaptive capacities — are equally, if not more, decisive for successful STEAM implementation (Rad et al., 2024; Rad et al., 2023; Bocoş et al., 2024).

Given these considerations, the present study aims to fill a critical research gap by conducting a bibliometric analysis of 42 peer-reviewed publications indexed in the Web of Science Core Collection, all focused on STEAM education for preschoolers. Using VOSviewer as a co-occurrence network analysis tool (applying full counting with a minimum threshold of 3 keyword occurrences), we systematically identify and map the key thematic clusters shaping this research domain. Our analysis not only visualizes the intellectual structure of the field but also offers insights into the strengths, limitations, and emergent areas of inquiry.

Specifically, this study addresses the following research questions:

- What are the main thematic areas in current STEAM preschool research?
- Which topics and concepts have received the most scholarly attention?
- Where do knowledge gaps remain, pointing toward future research priorities?

By answering these questions, we aim to provide educators, researchers, and policymakers with a clearer understanding of the global research landscape on STEAM education in preschool contexts. Our findings seek to support evidence-based decision-making, contribute to the professional development of early childhood educators, and inspire innovative, inclusive, and context-sensitive educational practices worldwide.

2. Methodology

2.1 Data Collection

The data for this bibliometric analysis were drawn from the Web of Science Core Collection (WoS), one of the most comprehensive and widely respected academic databases for multidisciplinary research. The search strategy was designed to capture the breadth of scholarship focusing on STEAM education in early childhood and preschool contexts, using the keywords “STEAM” AND “early childhood” and “STEAM” AND “preschool.” These terms were selected to ensure that the dataset would reflect both

general early learning environments and more specific institutional or curricular settings.

The search was conducted in early 2025, yielding a final dataset of 42 peer-reviewed publications. These records spanned journal articles, conference proceedings, and book chapters, reflecting the diversity of publication types in this emerging field. The relatively small yet focused sample size underscores the niche nature of this research area, where STEAM education in preschool settings is still carving out its academic and practical space compared to the broader, better-established STEM and STEAM research at primary, secondary, and tertiary levels.

This deliberate dataset restriction ensured that the bibliometric analysis remained highly relevant to early childhood education, avoiding dilution by unrelated or tangentially connected studies. While small samples can limit certain types of quantitative analysis, in bibliometric work they can nonetheless yield rich insights into thematic developments, conceptual patterns, and research gaps — especially when paired with robust analytical tools and careful interpretation.

2.2 Bibliometric Tools

To analyze the collected data, we employed VOSviewer, a specialized software tool designed for constructing and visualizing bibliometric networks. VOSviewer is well-regarded in scientometric research for its user-friendly interface and ability to generate sophisticated visual maps of co-authorship, co-citation, and, most relevant here, keyword co-occurrence networks.

The specific analysis type applied was co-occurrence analysis of all keywords provided in the Web of Science records. We used the full counting method, meaning that each co-occurrence between two keywords was counted with equal weight, regardless of how many times it appeared within a single document. This approach allowed us to map broad thematic linkages rather than prioritize disproportionately frequent pairings within a single source.

To ensure the clarity and interpretability of the network, we set a minimum threshold of 2 keyword occurrences across the dataset. This filtering reduced the total pool from an initial 216 keywords to a final set of 26 keywords that met the inclusion criterion. While more stringent thresholds can sometimes improve the focus of a map, we opted for this balanced cutoff to retain sufficient thematic diversity while still highlighting robust trends.

2.3 Analytical Procedure

The analytical procedure unfolded in several structured steps. First, the dataset was imported into VOSviewer, where we generated a co-occurrence network of the selected keywords. This network map visualizes keywords as nodes, with the size of each node reflecting its occurrence frequency and the thickness of connecting lines (edges) indicating the strength of co-occurrence relationships between pairs of terms.

To identify clusters, we applied VOSviewer's default clustering algorithm, which groups related keywords into color-coded thematic groups based on their proximity and interconnections in the co-occurrence network. Each cluster represents a distinct area of conceptual focus or methodological emphasis within the broader research landscape of preschool STEAM education.

In addition to the network visualization, we generated an overlay visualization, which allows temporal and impact-oriented dimensions to be superimposed onto the network map. This visualization includes indicators such as average publication year, average citation count, and normalized citation scores, helping us understand not only which topics are prominent but also how they have evolved over time and how influential they have been in shaping the field.

Finally, we extracted quantitative data from the VOSviewer analysis, including occurrence weights, total link strength, and citation metrics, which we organized into Table 1 for detailed reporting. This table provides a systematic overview of the clusters, offering both a macroscopic (network-level) and microscopic (keyword-level) view of the research trends.

Overall, this methodological framework ensures that our bibliometric analysis is not merely descriptive but offers a rigorous, replicable, and meaningful contribution to the understanding of how STEAM education is conceptualized, investigated, and advanced within the field of early childhood education research.

3. Results

The bibliometric analysis encompassed 42 publications drawn from the Web of Science Core Collection, covering the period from 2017 to 2025. This relatively recent time window reflects the growing academic and practical attention devoted to STEAM education in preschool and early childhood

settings. The majority of studies were published in highly regarded international journals such as *Early Childhood Education Journal*, *Education Sciences*, *Frontiers in Psychology*, *Sustainability*, *Research in Science & Technological Education*, and *Journal of Nutrition Education and Behavior* (Wu et al., 2025; Su et al., 2024; Johnston et al., 2022; Trina et al., 2024; Dixon et al., 2023). Additionally, key proceedings like the ICERI Conference (Zsoldos-Marchis & Ciascai, 2019) and the International Conference on Computers in Education (Chang, 2023) contributed to the dataset, highlighting the presence of both journal-based and conference-based research outputs.

Geographically, the dataset reflects a diverse international focus, with notable contributions from countries such as Vietnam (Bui et al., 2023; Duong et al., 2024), Spain (Ortiz-Revilla et al., 2023), China (Nong et al., 2022), Turkey (Hacıoğlu & Suiçmez, 2022; Ivanova, 2024), and Romania (Şuteu et al., 2024; Voicu & Matei, 2021), alongside regional syntheses of Asia-Pacific trends (Salas-Pilco, 2021) and broader cross-national comparisons. Prominent authors like Ciascai and colleagues have been instrumental in driving the dialogue on STEAM and STREAM education across multiple studies, demonstrating a consistent research commitment to exploring innovative and interdisciplinary pedagogies (Sabou-Baboş et al., 2020; Popa & Ciascai, 2017; Zsoldos-Marchis & Ciascai, 2019).

3.1 Cluster Analysis (Thematic Areas)

The VOSviewer co-occurrence analysis identified four main thematic clusters that structure the intellectual landscape of preschool STEAM research. Each cluster represents a distinct yet interconnected area of investigation, highlighting the multidimensional nature of this evolving field.

Cluster 1: Innovative Teaching Practices and Teacher Training

This cluster includes keywords such as acceptance, design, education, engagement, model, science, self-efficacy, and technology, pointing to a strong emphasis on curriculum design, educator preparedness, and pedagogical innovations. Chang (2023) stresses the importance of professional confidence and preparedness among preschool teachers when integrating STEAM activities, aligning with broader investigations into the attitudes and conceptions of early educators in Spain (Ortiz-Revilla et al., 2023) and Romania (Şuteu et al., 2024).

Bui et al. (2023) provide empirical data on Vietnamese preschool teachers' readiness for STEAM implementation, revealing both enthusiasm and significant training needs. Meanwhile, Rad and colleagues have deeply explored technology acceptance models in early childhood education, using both neural network approaches and planned behavior frameworks to understand how teachers engage with educational technologies (Rad, Egerău et al., 2022; Rad, Magulod Jr. et al., 2022; Rad, Redeş et al., 2023). These works collectively point to the conclusion that innovative STEAM practices rely not only on resource availability but also on teachers' beliefs, professional identity, and institutional support (Bocoş et al., 2024; Rad & Bocoş, 2024).

Cluster 2: Child Development through STEAM

The second cluster, anchored by keywords like childhood, children, food-based learning, fruit, nutrition education, obesity, and preschool, focuses on how STEAM learning environments promote creativity, cognitive development, health, and social collaboration. Dixon et al. (2023) explore the integration of food-based learning with scientific concepts in preschool, highlighting opportunities to enhance nutrition education alongside cognitive skills. Similarly, Johnston et al. (2022) and Wu et al. (2025) emphasize the role of inquiry-based learning and child-centered engagement strategies in nurturing young learners' curiosity and problem-solving capacities.

The intersection of multiple intelligences and STREAM education, as examined by Sabou-Baboş et al. (2020), reinforces the idea that arts integration fosters diverse developmental outcomes, complementing scientific and technical skills. Early childhood settings become dynamic spaces where learning is multisensory, contextually meaningful, and deeply intertwined with children's health, emotions, and relational experiences.

Cluster 3: Technology and Engineering Integration

This cluster centers on keywords like arts, challenges, early childhood education, science education, STEAM education, and STEM education, drawing attention to the technological and engineering dimensions of preschool learning. Ivanova (2024) investigates game-based technologies for STEM and STEAM education in kindergartens, illustrating how playful, digital tools can scaffold foundational engineering and computational thinking skills.

Cross-national reviews, such as those by Kwan and Wong (2021) and Salas-Pilco (2021), reveal a growing global emphasis on integrating robotics, coding, and design thinking into early learning environments, though challenges remain in teacher training and curriculum alignment. Tomé and De Abreu (2022) examine the intersections between media literacy and STEAM, suggesting that interdisciplinary approaches can strengthen both cognitive and socio-emotional competencies. Notably, Rad (2025) and Rad & Rad (2025) expand this conversation by analyzing how AI and smart learning environments reshape pedagogical possibilities under the digital pedagogy paradigm.

Cluster 4: Cultural and Environmental Contexts

The final cluster, featuring keywords like child, early childhood, kindergarten, STEAM, and STEM, underscores the importance of local practices, outdoor learning, inclusivity, and cultural adaptation. Studies like Trina et al. (2025) and Trina et al. (2024) systematically review the role of outdoor environments in supporting preschoolers' STEAM learning, pointing to nature-based and culturally embedded practices as key factors in sustaining inquiry and engagement.

Duong et al. (2024) provide comparative insights into STEAM implementation across different national contexts, emphasizing how local educational cultures shape both opportunities and constraints. Hacıoğlu and Suiçmez (2022) offer a powerful example of inclusive, empathy-driven STEAM design, detailing a project where preschoolers collaboratively reimagine school spaces to accommodate visually impaired peers. This localized, child-centered lens is echoed in the work of Veziroglu-Celik et al. (2025), who explore how both children's and teachers' perspectives shape the meaning and impact of STEAM learning in diverse early childhood contexts.

Taken together, the bibliometric findings reveal a vibrant, multifaceted research landscape, where pedagogical innovation, child development, technological integration, and cultural responsiveness converge to define the future of STEAM education for preschoolers. The next section will explore these trends in depth, offering a critical interpretation of the results and outlining directions for research, practice, and policy.

3.2 Visualizations

To deepen the understanding of the thematic structures identified in the bibliometric analysis, we

employed two key visualizations generated with VOSviewer: the network visualization and the overlay visualization. Together, these figures provide both a static and dynamic perspective on how keywords connect across the 42 selected publications.

Figure 1

Network visualization

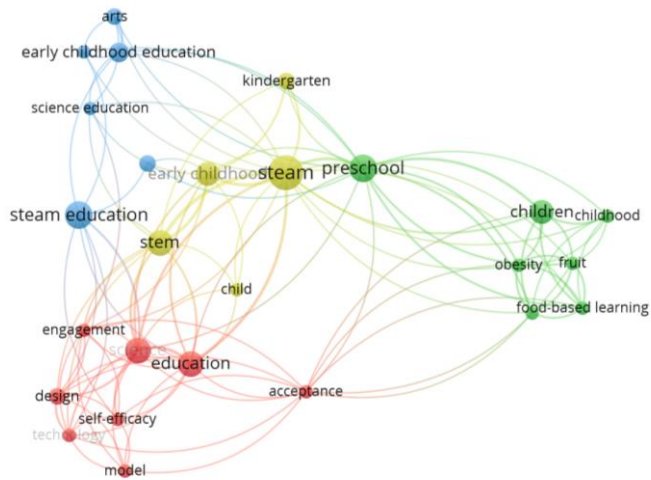


Figure 1 (Network Visualization) offers a clear graphical representation of the 26 keywords that met the inclusion threshold (minimum of two occurrences). In this map, each keyword is represented as a node (circle), with the size of the node proportional to its frequency of occurrence across the dataset. The lines (edges) connecting nodes indicate the strength of co-occurrence between keywords, and the thickness of these lines represents the intensity of the connection (VOSviewer total link strength).

Importantly, the keywords are organized into four distinct color-coded clusters, which visually reflect the thematic areas identified in the cluster analysis. For example, the red cluster (Cluster 1) centers on terms like “education,” “engagement,” “acceptance,” and “self-efficacy,” underscoring the focus on pedagogical strategies and teacher training (Chang, 2023; Bui et al., 2023; Ortiz-Revilla et al., 2023). The green cluster (Cluster 2) contains terms like “childhood,” “children,” “food-based learning,” and “nutrition education,” reflecting research on child development outcomes (Dixon et al., 2023; Wu et al., 2025). The blue cluster (Cluster 3) includes keywords like “arts,” “early childhood education,” and “science education,” highlighting technology and interdisciplinary integration (Ivanova, 2024; Kwan & Wong, 2021), while the yellow cluster (Cluster 4) groups terms such as “kindergarten,” “STEAM,” and “STEM,” pointing toward culturally responsive and environmental

approaches (Trina et al., 2024; Hacıoğlu & Suiçmez, 2022).

This visual map reveals the interconnected nature of the research landscape, where even thematically distinct clusters are linked through cross-cutting concepts like “STEAM education” and “preschool.” It becomes clear that while researchers may specialize in particular areas, there is considerable overlap in how ideas, methods, and goals circulate across the STEAM education field (Zsoldos-Marchis & Ciascai, 2019; Voicu & Matei, 2021).

Figure 2

Overlay visualization

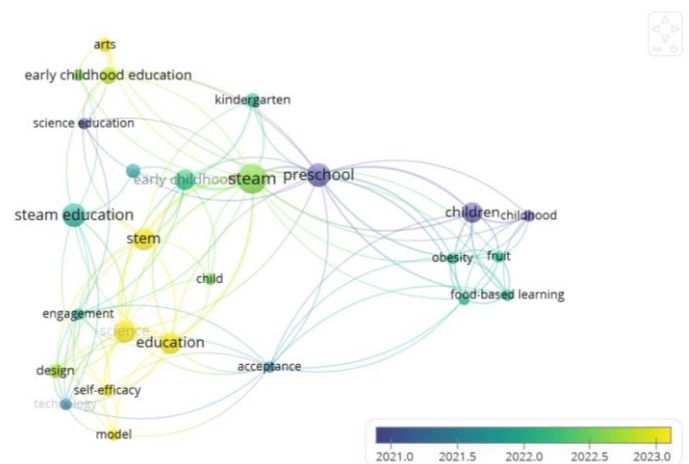


Figure 2 (Overlay Visualization) adds a temporal layer to the analysis by color-coding nodes according to their average publication year. This dynamic map helps us trace how the field has evolved over time, with older topics shaded in darker tones and newer topics shown in lighter, more vibrant colors.

The visualization reveals that early work in the dataset (pre-2021) tended to focus on foundational concepts such as “early childhood,” “education,” and “acceptance,” reflecting an initial stage where scholars were establishing theoretical frameworks and evaluating readiness for STEAM integration (Popa & Ciascai, 2017; Rad, Magulod Jr. et al., 2022). More recent publications (post-2022) highlight emerging topics like “arts,” “design,” “engagement,” and “technology,” signaling a shift toward innovative, practice-driven explorations (Su et al., 2024; Chen & Dong, 2024; Rad & Rad, 2025).

Additionally, the overlay map shows that areas such as food-based learning, nutrition education, and obesity have recently gained attention (Dixon et al., 2023), suggesting a growing interdisciplinary convergence between STEAM education and health sciences. This points to a maturation of the research field, where initial explorations are giving way to

nanced, context-specific applications that bridge disciplinary divides (Trina et al., 2025; Nong et al., 2022).

3.3 Quantitative Indicators

To gain a deeper and more precise understanding of the intellectual and thematic structure of preschool STEAM education research, we examined key quantitative indicators derived from the VOSviewer

Table 1

Thematic clusters

id	label	x	y	cluster	weight<Links>	weight<Total link strength>	weight<Occurrences>	score<Avg. pub. year>	score<Avg. citations>	score<Avg. norm. citations>
1	acceptance	0.1797	-0.4992	1	13	13	2	2021.5	11	1.0561
56	design	-0.6901	-0.5171	1	9	11	3	2022.667	4	0.745
68	education	-0.223	-0.403	1	13	21	7	2023	4.7143	0.8556
73	engagement	-0.5986	-0.2843	1	11	11	2	2022	9	1.2
121	model	-0.453	-0.777	1	7	7	2	2023	2	0.2667
173	science	-0.4088	-0.3558	1	13	25	7	2023.286	4.7143	1.0257
175	self-efficacy	-0.4788	-0.5965	1	8	9	2	2023	3	0.9725
205	technology	-0.649	-0.6522	1	9	11	2	2021.5	6	0.6175
29	childhood	1.2365	0.1158	2	7	8	2	2018.5	16	1.1
30	children	1.0072	0.1289	2	8	16	6	2016.5	15	1.1146
	food-based									
85	learning	1.1475	-0.2059	2	8	13	2	2022	11.5	1.3895
88	fruit	1.1135	-0.0494	2	8	13	2	2022	11.5	1.3895
	nutrition									
128	education	0.9732	-0.2244	2	8	13	2	2022	11.5	1.3895
130	obesity	0.9255	-0.0565	2	8	13	2	2022	11.5	1.3895
148	preschool	0.381	0.2815	2	16	25	8	2020.5	7.625	2.3376
15	arts	-0.4911	0.8128	3	5	6	3	2023	1.6667	1.8431
27	challenges	-0.597	0.6899	3	5	5	2	2022.5	4	1.8963
	early childhood									
63	education	-0.4745	0.6882	3	6	7	4	2022.75	2	1.3124
	science									
174	education	-0.5758	0.492	3	6	6	2	2021	7	1.4333
183	steam education	-0.6151	0.1188	3	9	10	8	2021.875	3.25	0.6408
190	stem education	-0.3733	0.2996	3	3	3	3	2021.667	2.3333	0.6444
28	child	-0.0625	-0.1414	4	5	5	2	2022.5	0	1
62	early childhood	-0.1628	0.2611	4	10	20	6	2022.167	24.8333	1.3486
108	kindergarten	0.1124	0.5874	4	4	6	3	2022	39.6667	2.939
179	steam	0.1088	0.2658	4	18	37	13	2022.539	14.1538	1.3156
189	stem	-0.332	0.0212	4	11	22	7	2023	6.7143	1.0774

Occurrence count refers to the frequency with which a keyword appears across the dataset, providing a measure of its prominence or centrality in the research field. The keywords with the highest occurrences are notably “steam” (13 occurrences), “preschool” (8 occurrences), “education” (7 occurrences), and “science” (7 occurrences). These high-frequency terms reflect the foundational pillars of the research landscape, showing how studies

analysis. Table 1 synthesizes the numerical data for the 26 most significant keywords, detailing their occurrence counts, total link strength, average publication year, average citation count, and normalized citation scores. Together, these indicators provide valuable insights into the temporal development, scholarly impact, and thematic centrality of each research topic.

consistently return to core issues of STEAM integration, preschool settings, and educational models.

Total link strength, on the other hand, indicates the sum of the co-occurrence links between a given keyword and all other keywords, thus capturing the degree of connectedness or interdisciplinarity. Here, “steam” stands out again with a total link strength of 37, followed closely by “preschool” (25), “science”

(25), and “education” (21). This suggests that these concepts are not only frequent but also well-integrated across thematic clusters, acting as conceptual bridges between otherwise distinct areas of research. For example, studies on science education (Rad, Egerău et al., 2022; Ortiz-Revilla et al., 2023) consistently link to technology, arts, and child development topics, demonstrating the cross-cutting nature of STEAM scholarship.

The average publication year provides insight into the temporal emergence of specific topics. Older-average keywords (before 2020) like “children” (2016.5) and “childhood” (2018.5) point to longstanding research traditions centered on developmental psychology and educational needs (Popa & Ciascai, 2017; Sabou-Baboş et al., 2020). In contrast, more recent keywords — such as “design” (2022.7), “engagement” (2022), “model” (2023), and “arts” (2023) — signal emerging research frontiers, reflecting the recent scholarly shift toward innovative pedagogical methods, inquiry-based learning, and creative approaches (Chen & Dong, 2024; Su et al., 2024; Rad, 2025).

Notably, “kindergarten” (2022) and “early childhood education” (2022.75) are positioned at the intersection of both established and emerging lines of inquiry, suggesting that while research attention to these educational contexts is not entirely new, their connections to modern STEAM initiatives are only recently being deeply explored (Ivanova, 2024; Veziroglu-Celik et al., 2025).

Average citation count reflects the raw impact of the publications associated with a given keyword, while the normalized citation score adjusts for differences in publication year and field, providing a fairer comparison of influence across topics.

In terms of average citations, keywords like “kindergarten” (39.7), “early childhood” (24.8), “food-based learning” (11.5), and “fruit” (11.5) stand out, suggesting that research exploring the intersection of STEAM education and health, nutrition, or specific learning environments has received substantial scholarly attention (Dixon et al., 2023; Wu et al., 2025). Interestingly, although the average citation numbers are high, some of these topics have relatively low normalized citation scores (e.g., “kindergarten” at 2.94), indicating that their impact is partly driven by a small number of highly cited papers rather than broad, field-wide influence.

Conversely, keywords like “arts” (1.84), “challenges” (1.90), and “preschool” (2.34) achieve

relatively strong normalized citation scores despite lower average citations, reflecting consistent and steady scholarly recognition across multiple papers, even if no single publication dominates the citation landscape (Trina et al., 2025; Johnston et al., 2022).

When combining these quantitative indicators, several key insights emerge:

- Foundational concepts like “steam,” “preschool,” and “education” act as central nodes in the field, frequently appearing and connecting widely across studies, underscoring their conceptual centrality (Rad & Rad, 2025; Rad, 2025).
- Emergent topics such as “design,” “engagement,” “self-efficacy,” and “model” point to cutting-edge explorations in pedagogical innovation, closely tied to teacher training and classroom strategies (Chang, 2023; Bocoş et al., 2024).
- Health-related intersections (e.g., “nutrition education,” “obesity,” “food-based learning”) are increasingly visible, reflecting a promising interdisciplinary trend where STEAM frameworks are applied to broader child well-being and developmental issues (Dixon et al., 2023; Hacıoğlu & Suiçmez, 2022).

Contextual factors like “early childhood,” “kindergarten,” and “cultural environment” are gaining both scholarly attention and citation traction, suggesting a growing recognition of how localized practices, inclusivity, and outdoor learning environments shape STEAM outcomes (Trina et al., 2024; Duong et al., 2024).

4. Discussion

The present bibliometric analysis reveals a rich, evolving, and multidimensional research landscape at the intersection of STEAM education and early childhood development. By systematically mapping the conceptual and thematic contours of this field, several dominant themes, emerging areas, and critical research gaps have been illuminated — offering both reflective insights and practical pathways forward.

At the heart of current research lies the persistent emphasis on pedagogical innovation, particularly in designing developmentally appropriate STEAM learning environments that foster creativity, critical thinking, and interdisciplinary exploration (Magnusson & Bäckman, 2023; Sullivan & Bers, 2018). Studies consistently highlight how integrating arts, music, and robotics — such as through dancing robots or digital music games — enhances young

learners' engagement and motivation (Raziūnaitė et al., 2018; Sullivan & Bers, 2018).

Another central theme is the role of teacher preparation and professional confidence. Chang (2023) and Bui et al. (2023) emphasize that without targeted training and institutional support, even the most promising STEAM initiatives may struggle to take root. Moreover, Rad, Egerău et al. (2023) and Bocoş et al. (2024) highlight the psychological dimensions of teacher readiness, exploring how constructs like self-efficacy, organizational climate, and technology acceptance shape the adoption of innovative pedagogies in preschool settings.

Simultaneously, research foregrounds child development outcomes — especially how STEAM learning environments can enhance social collaboration, problem-solving, and even health-related behaviors. Bayles et al. (2021), for instance, show how food-based STEAM activities can positively affect children's nutritional status, linking cognitive and physical well-being. This aligns with the findings of Dixon et al. (2023), who call attention to the integration of science and health topics within the early childhood classroom.

While established themes dominate, the analysis also points to emerging frontiers that are only beginning to receive scholarly attention. One such area is the intersection of artistic expression, emotional development, and therapeutic interventions — exemplified by di Carminati and Peiró (2017), who explore the role of art therapy in reducing aggressiveness in young children. Likewise, the inclusion of family and parental involvement, as reviewed by Salvatierra and Cabello (2022) and Novikova and Gallo-Fox (2024), signals an increasing awareness of the broader social ecology that supports (or hinders) STEAM learning.

Another underexplored yet promising area is the integration of AI and computational thinking into early learning environments. While there is growing research in primary and secondary settings (Aravantinos et al., 2024; Gunčaga & Záhorec, 2023), preschool-specific studies remain sparse — a gap that invites attention, particularly as young children increasingly encounter algorithmic logics through toys, games, and digital tools. Furthermore, Lai and Wong (2022) suggest that collaborative problem-solving in programming could be a fertile area of investigation for early childhood researchers interested in social cognition and group dynamics.

Finally, health-related topics such as taste sensitivity, dietary behaviors, and nutrition education — explored by Nor et al. (2021), Subba (2002), and Karagoz et al. (2024) — are gaining traction but remain marginal in the core STEAM discourse. This suggests an opportunity for deeper interdisciplinary exploration between educational sciences, psychology, nutrition, and public health.

The findings align strongly with global educational frameworks such as the UN Sustainable Development Goals (SDGs), particularly SDG 4: Quality Education, and SDG 3: Good Health and Well-Being. The emphasis on inclusive, equitable, and quality education is reflected in the diverse cultural and environmental contexts represented in the literature, from Vietnam (Duong et al., 2024) to Lithuania (Raziūnaitė et al., 2018) to Singapore (Sullivan & Bers, 2018). Moreover, the integration of health and nutrition topics resonates with early childhood development frameworks that advocate for holistic approaches combining cognitive, emotional, and physical well-being (Bayles et al., 2021; Dixon et al., 2023).

For educators, the results underscore the necessity of robust professional development programs that build confidence, metacognitive awareness, and pedagogical adaptability. As Rad & Bocoş (2024) argue, learning organizations must go beyond technical training to cultivate reflective, innovative practitioners capable of navigating complex classroom dynamics. Chang (2023) and Bui et al. (2023) similarly highlight the need for context-sensitive support systems that address not only knowledge gaps but also psychological barriers to innovation.

For policymakers, the analysis reveals an urgent need for better assessment tools and curriculum frameworks tailored to the unique demands of early childhood STEAM education. Many studies, including Ioannou et al. (2024) and Trina et al. (2024), call attention to the lack of standardized evaluation mechanisms capable of capturing the nuanced cognitive, social, and emotional outcomes associated with STEAM learning. Developing culturally responsive, evidence-based guidelines could help ensure that STEAM initiatives achieve both educational and developmental goals.

For researchers, several areas invite deeper empirical exploration. Longitudinal studies examining the long-term impacts of early STEAM education on later academic achievement, career aspirations, or social-emotional development are critically needed.

Additionally, equity issues — particularly concerning access to high-quality STEAM experiences across socioeconomic, cultural, and geographic divides — remain underexamined. Finally, expanding research on the integration of AI, machine learning, and smart technologies (Rad, 2025; Rad & Rad, 2025) could illuminate how emerging digital tools reshape both learning processes and teacher-student interactions.

In conclusion, the bibliometric findings reveal not only the vibrancy of preschool STEAM education research but also its untapped potential. By addressing the identified gaps and capitalizing on emerging trends, the field can move toward a more inclusive, innovative, and empirically grounded future — one that serves the diverse needs of children, families, educators, and societies alike.

6. Conclusions

This study set out to explore the evolving research landscape of STEAM education in preschool contexts through a rigorous bibliometric analysis of 42 publications from the Web of Science Core Collection. By applying co-occurrence network analysis and cluster identification via VOSviewer, we illuminated key thematic areas, emerging research frontiers, and conceptual linkages shaping this dynamic field.

Our results point to several dominant themes, particularly the central role of innovative teaching practices and teacher training (Chang, 2023; Bui et al., 2023; Rad et al., 2023a), the developmental benefits of child-centered STEAM approaches (Bayles et al., 2021; Sullivan & Bers, 2018), the rise of technology and engineering integration (Ivanova, 2024; Aravantinos et al., 2024), and the increasing attention to cultural and environmental contexts (Trina et al., 2024; Hacıoğlu & Suiçmez, 2022). These themes align with global educational priorities such as the Sustainable Development Goals, underscoring the relevance of STEAM frameworks not only for cognitive development but also for promoting equity, inclusivity, and well-being.

Yet, the analysis also revealed important gaps and under-researched areas. While promising work has emerged at the intersections of art, emotion, and therapy (di Carminati & Peiró, 2017), family engagement (Salvatierra & Cabello, 2022; Novikova & Gallo-Fox, 2024), and health and nutrition (Dixon et al., 2023; Karagoz et al., 2024), these strands remain relatively marginal and warrant further scholarly attention. Likewise, although advances in AI and computational thinking have been documented in primary and secondary education (Aravantinos et al.,

2024; Gunčaga & Záhorec, 2023), their integration into preschool STEAM remains an open frontier with enormous potential — particularly given the increasingly digital lives of today's young learners.

From a practical standpoint, the findings emphasize several key imperatives. For educators, professional development that addresses not only technical competencies but also self-efficacy and reflective practice is essential (Rad & Bocoş, 2024; Bocoş et al., 2024). For policymakers, there is a clear need to develop robust assessment tools, context-sensitive curricula, and supportive infrastructures that can sustain innovation in diverse educational settings (Ioannou et al., 2024; Duong et al., 2024). For researchers, future inquiries should prioritize longitudinal, cross-cultural, and interdisciplinary studies that deepen our understanding of how early STEAM experiences shape long-term outcomes and address persistent equity challenges.

In closing, this bibliometric exploration does not merely map where the field has been — it points toward where it must go. As global educational landscapes continue to shift under the pressures of technological change, climate challenges, and evolving social expectations, STEAM education for preschoolers will play a pivotal role in cultivating the creativity, resilience, and collaborative spirit needed to meet the future. By harnessing the insights revealed in this study, educators, researchers, and policymakers can collectively shape an evidence-based, inclusive, and visionary agenda for the next generation of learners.

Authors note:

Doina Florica Tifrea, Assistant Professor and PhD. student in Educational Sciences, is focused on researching STEAM-oriented behaviors in extracurricular activities among preschool children. She is particularly interested in understanding how early exposure to science, technology, engineering, arts, and mathematics (STEAM) can enhance cognitive and social development in young learners through structured yet exploratory activities.

Alina Felicia Roman, Dean of The Faculty of Educational Sciences, Psychology and Social Work, Aurel Vlaicu University Arad, PhD Supervisor at The Doctoral School: “Education, Reflection, Development” at Babeş Bolyai University from Cluj-Napoca since 2016; Fields of research: Evaluation in the educational process, Modern approaches to

education, The state of wellbeing in students, Integrated learning, Curricular design for early education, Teachers' early and continuous education, Outdoor education.

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