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DEVELOPING A KNOWLEDGE MAP FOR THE EARLY CHILDHOOD STEAM EDUCATION: A VISUAL ANALYSIS USING CITESPACE AND HISTCITE

Yumeng Li,
Corrienna Abdul Talib

Abstract. *This scientometric analysis explores the evolution and dynamics of Early Childhood STEAM education. Web of Science database is employed as a primary data source and visualization tools like CiteSpace and HistCite are used to systematically investigate 179 publications published between 2008 and 2023. It looks at research patterns to unearth notable shifts in focus and intensity influenced by the COVID-19 pandemic. Keyword analysis reveals the field's evolution, from foundational elements to broader dimensions encompassing technology, pedagogy, and gender disparities. A transition towards experiential learning, emotional identity, and professional development is evident, which reflects a pedagogical shift towards comprehensive and inclusive education. Temporal analysis using Citation Burst Analysis delineates phases of research, emphasizing shifts from fundamental exploration to pedagogical methods and experiences. Acknowledgement of influential scholars, collaborations, and global trends underscores events of interdisciplinary partnerships and international collaborations. The study's implications highlight pedagogical transformations, gender disparity, and the potential for technology in early childhood education. This could inform policy directions and foster collaborations for innovative education.*

Keywords: *early childhood, STEAM education, visual analysis, knowledge map*

Yumeng Li, Corrienna Abdul Talib
University of Technology Malaysia, Malaysia

Introduction

High-level innovative talent is the key to national competitiveness. In the 1980s, the US National Science Board (National Science Board, NSB) proposed 'STEM (Science, Technology, Engineering, Mathematics) education integration' and developed it into a national strategy. In 2006, Professor Georgette Yakman of the United States and his team added Arts as an essential humanistic factor to form the current concept of STEAM (Science, Technology, Engineering, Arts, and Mathematics) (Yakman, 2014). At present, STEAM education has been widely recognized by the education community (Connor, 2015). In recent years, STEAM education has received widespread attention from all over the world (Dejarnette, 2018; Tippett & Milford, 2017). Studies have shown that STEAM is a valuable resource for early childhood education and is very beneficial to young children (Clements & Sarama, 2016; Moomaw, 2016; Moomaw & Davis, 2010; Tippett & Milford, 2017).

As the number of publications on early childhood STEAM (EC STEAM) education has increased dramatically, the research has evolved in its engagement with multiple subject matters, keeping in sync with the ensuing change and development. While such a change broadens the idea, on the other hand, keeping oneself up-to-date with evolution makes it a daunting and challenging experience. Therefore, it is demanding enough for researchers and educators to comprehend the concept and to note its evolutionary trajectory simultaneously. This should hinder the progress that EC STEAM is expected to make in the near future. Currently, many review papers have been written from multiple vantage points, for instance, the use of STEAM, the impact of STEAM learning (Wahyuningsih et al. 2020), and Art and Creativity Research (Perignat & Katz-Buonincontro, 2019). A comparative study of Thai and international research (2019) is also primarily comprehensive. The main research methods used are literature review (Wahyuningsih et al., 2020), Perignat and Katz-Buonincontro (2019), the content analysis method

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(Aysun & Hasibe, 2017), and the quantitative (coding system) and qualitative methods. Due to the limitations of the research method, a significant research gap can be found as existing literature on the subject is very limited. In addition, since the research on STEAM involves many disciplines, it is difficult to cover the entire research horizon and identify STEAM's research trend in one review article. Besides, there is a large degree of subjectivity in the selection of literature for evaluation (Xie et al. 2020). To fill this gap, bibliometric analysis, first proposed by Pritchard in 1969 (Fairthorne, 1969), uses mathematical and statistical methods to determine the state and future directions of a particular field of study. Thus, this research will emulate the objectivity and extent inherent in such methods to examine high-impact publications. The study performs cluster and network analysis, using Hiscite and CiteSpace applications to execute bibliometric investigation. In conclusion, the article also builds a knowledge map of EC STEAM education that facilitates readers' objective and thorough understanding of the overall STEAM education scenario. The map helps understand the relationships between the multiple facets and aids in understanding the traits and trends of EC STEAM education.

Focus and Objectives

This study aims to conduct a scientometric analysis of academic publications in EC STEAM from 2008-2023, systematically studying various topics and related information in this field. More specifically, the main objectives of this research were as follows:

1. Determine the research status, such as analysing the scientific growth pattern of publications, prolific journals, and citation structure of literature, among others.
2. Identify key research topics and research results for influential articles.
3. Analyse co-citation and co-occurrence networks to infer the knowledge landscape, research fronts and trends of EC STEAM.
4. Build a knowledge map using the visual analysis of the literature as a foundation.

Research Methodology

Sample and Data

Web of Science (WoS) provides researchers with online subscription-based indices (SCI, SSCI, SCIE, ESCI), providing categorization by year, subject, document type, publication type, source type, keyword occurrences, and country-by-country analysis of search results. This study uses the core data of the WoS database as the data source, with a total of 179 publications. They are systematically exported from the Web of Science database.

Measures of Variables

CiteSpace is a literature visualization tool that provides rich functions for researchers to identify knowledge links between publications, enabling users to analyse data by references, authors, sources, countries, and keywords. CiteSpace Version 6.2 was used for this study. Another analysis software used in this article was HistCite. It is a citation chronology visualization software developed jointly by Dr. Eugene Garfield and MG Science Publishing Company, which can graphically display the relationship between documents in a particular field, quickly map the development history of a specific field, locate important literature and the latest important literature in this field, as well as essential scientists and institutions. The author used HistCite to display the development history of the EC STEAM field graphically, used CiteSpace co-occurrence and co-citation map analysis to display the development trend of EC STEAM, and summarized and sorted out the research direction and hotspots of EC STEAM based on an in-depth reading of classic literature. Figure 1 represents the main analysis items and tools used in this study.

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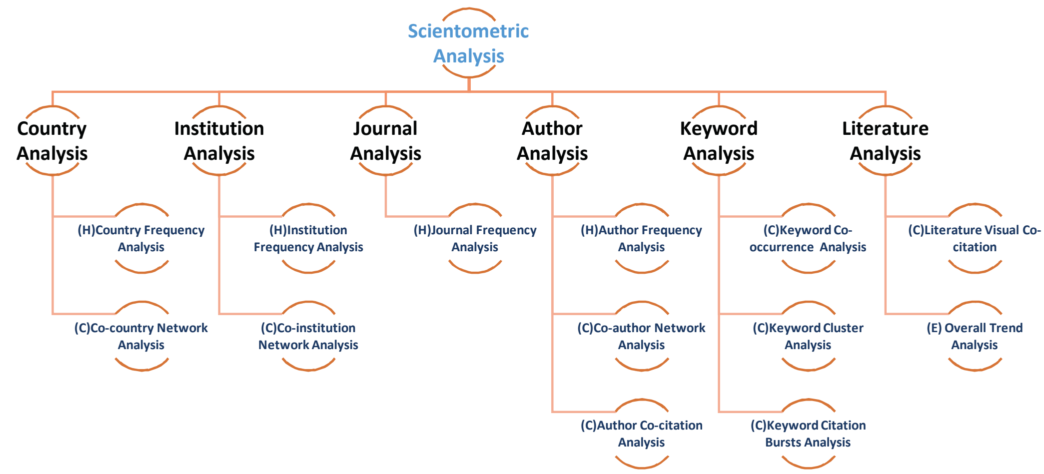
Figure 1
Research Framework



Note. *E represents Excel; H represents HistCite; C represents CiteSpace.
Note: The consideration period for evaluated literature is 15 years (i.e., 2008-2023), with one year being selected as a time slice for analysis.

Data Analysis Procedure with Search Strategy

This review focuses on the papers on "STEM for young children" and "STEAM for young children." At the same time, the search strategy of (citation topics meso) "education & education research" was selected, and a total of 183 articles were collected on April 2, 2023. To ensure the accuracy of the data, the researcher reviewed the titles and abstracts of all articles separately, and 156 articles met the requirements of the collected data. Then, through HistCite's document co-citation analysis function, 23 highly cited articles were added, so a total of 179 publications were collected for the analysis. The data were exported in "plain text" by selecting the "Full Record and Cite References" option for subsequent analysis by CiteSpace.

Research Results

Literature Analysis

Overall Trend Analysis of Published Papers

This section deals with the trend in the number of studies on EC STEAM. The trend line was drawn with the help of Microsoft Excel (Figure 2), charting the number of publications in the corresponding year between 2008 and 2016. It shows a general upward trend since 2008, with a major slope break following the year 2016. However, the publication took a downward spiral between 2018 and 2019, only to take to a newer height between 2021 and 2022. Such an unprecedented increase took place despite the global pandemic when accessing physical research infrastructure was nearly impossible. This surge, however, could be attributed to two factors: either the research community's zeal to conduct adequate research even during episodes of global restriction or utilizing that time to prepare a robust research blueprint for pursuing it as the global restrictions were gradually withdrawn. At the outset, this change in the number of publications corresponds to the development trend of STEM education research. All the United States Presidents since the 1990s have taken a keen interest in the propagation and the development of STEAM education; they have also appealed for the achievement of national competitiveness through STEAM education. In keeping hooked to the presidential aspirations, the government officially passed the "STEAM Education Act of 2015" on October 7, 2015. These developments reaffirm the critical position of STEAM education. At the end of 2018, a five-year plan strategy was established for the successful implementation of STEAM education at

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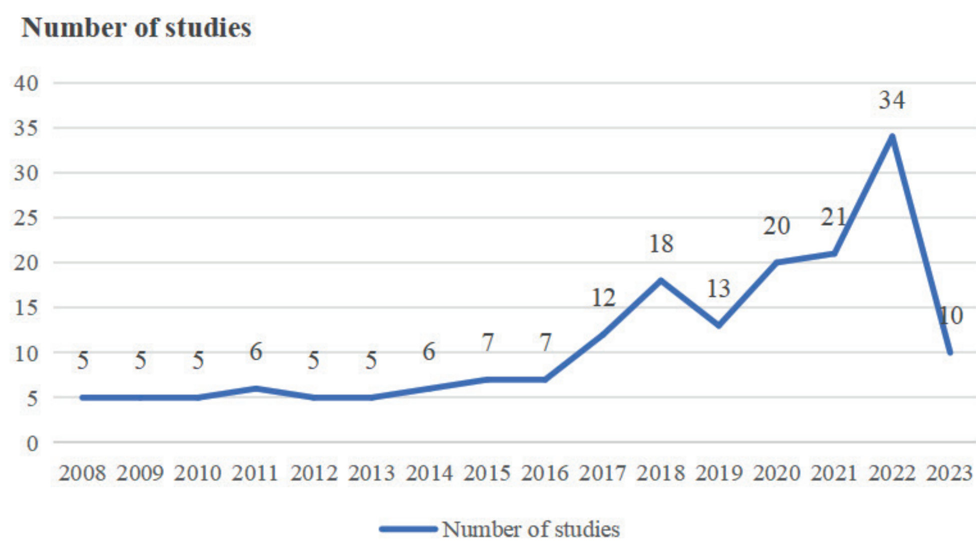
the international level. The United States devoted its efforts to the federal government, combined with industry, government, academia, and Congress, to announce the implementation of STEAM education, which is regarded as a development that is critical to the country's competitiveness. Such initiatives found global stimulus and contributed to a substantial increase in research articles on STEAM education in 2015 and 2016.

Figure 2
Trends of EC STEAM papers based on the Web of Science during 2008-2023



Document co-citation visual analysis

The top 30 documents (based on citation count) were collected and sorted by LCS (local citation score). A citation chronology map was prepared (Figure 3) with the help of the visual analysis tool - HistCite. As shown in Figure 3, the most relevant documents published between 2008 and 2023 are frequently cited and form a close relationship with each other. The author of the three most cited articles is –Jamil, whose work on teachers was published in 2018. It was followed by an article written on Empirical Research on Robotic Activities by Kazakoff and was published in 2018. The third highly cited paper was written by Park in 2017, which engages with teacher's beliefs. The research has grown even more significantly in 2017–2018. The graph illustrates how the number of publications increased dramatically in 2017. This year coincided with the growing interest in teachers' beliefs within the larger concerns of EC STEAM. The earliest node in this regard, as seen in Figure 3, is Article 10. This article by Brophy et al. (2008) employed an analytical frame to study P-12 engineering education. To have an in-depth analysis, these articles were further classified to chalk out the thematic ideas inherent in them (Table 1 Appendix).

The thematic categorization of 30 highly cited articles hints at the prevailing current research on EC STEAM education that has a relatively great influence and also underlines the future development trend. The following seven thematic categories are extracted:

1) EC STEAM subject research: STEAM education is a comprehensive form of education that includes science, technology, engineering, arts, and mathematics. In early childhood, each of these subjects adds to the growth of enquiry among children. To substantiate that, a survey (Maltese, 2010) shows that early scientific interest is a significant endeavour for development. Engineering is the foundation of STEM, and some studies have noted that engineering education can be carried out in early childhood education and is very important in contemporary times (Bagiati & Evangelou, 2015; Brophy et al., 2008). Young children's innate curiosity and desire to inquire and explore the world not only form the cornerstone of early childhood development (Brophy et al. 2008) but also allow them to be creative, innovative and improvisers, much like engineers (Tippett and Milford, 2017). In technology and computational thinking, the primary learning centres have been around robotics since early childhood (Sullivan & Bers,

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2016; Bers et al., 2014; Sullivan & Bers, 2018; Kazakoff, 2013). Research by Master et al. (2017) notes that incorporating non-academic social factors (such as group membership) into current STEM curricula may be an effective way to increase STEM motivation in young children. The five disciplines in early childhood STEAM education are interrelated and mutually reinforcing to constitute the integral core of STEAM education. In addition to the above disciplines, STEAM education often incorporates other disciplines as a supplement. For example, Strawhacker and others (2020) carried out bioengineering-related STEAM activities, which they certainly argue have the potential to engage young learners in the context of real-world challenges in scientific inquiry and engineering design.

2) Research on EC STEAM teachers: In STEAM education, teachers play a vital role. Jamil (2018) identifies early childhood teachers as primary adopters and implementers of changing educational models. Their belief in new approaches is an invaluable resource guiding educational innovation, whose value gets amplified when practised in classrooms. At the same time, preschool teachers also need to have experience in implementing STEAM education, for which they need to be trained in their knowledge, ability, and teaching methods (Alghamdi, 2023). Training affects beliefs in the implementation of STEAM education for in-service preschool teachers and preservice teachers. (Alghamdi, 2023). It also significantly improves their knowledge pool (Park, 2017) and ability to teach (Chen et al., 2021). Despite the increasing emphasis on teacher training, teachers still encounter various problems in carrying out STEAM activities, as they face practical constraints of time, family and peer support, resources, differences in each student's ability to grasp, and safety concerns (Wan et al., 2021). However, more concerning is the teachers' lack of professional knowledge and skills in various STEAM disciplines. It makes it difficult for them to plan courses based on STEM education (Yildirim, 2021) and to carry out integrated education based on real-life relevancy (Alghamdi, 2023).
3) EC STEAM curriculum research: In addition to teacher training, curriculum development is also a good way to promote the development and promotion of STEAM education. It is one of the crucial recourses to several difficulties and problems faced in the development and implementation of STEAM education. Scholarly research has substantiated this concern with suggestions for developing curriculum frameworks. For example, Dubosarsky et al. (2018) explain the research conducted by the Seeds of STEM team to build a curriculum for children belonging to culturally and linguistically diverse backgrounds. It further explains the modes inherent in developing curriculum frameworks, the perfection of its implementation, and its ultimate effectiveness. Brenneman et al. (2019) devised a professional development model that enables preschool educators to deliver rich and high-quality STEM learning experiences.
4) EC STEAM parent research: In addition to retrofitting teacher training and course moderation, parent's support for pursuing STEM is equally important. Numerous studies (Tay et al., 2018; Tippett & Milford, 2017) indicate that young children and their parents have fairly positive attitudes toward STEM learning. In addition to educational value, the economic value of STEM learning to their families is also recognized. Parents believe that learning STEM can pave their children's path to future economic prosperity. At the same time, parents also need more training on how to work with their children in STEM activities and build support for their children's learning (Wan et al., 2021).
5) EC STEAM in different countries: Although STEAM education originated in the United States, it has set off a wave in education all over the world. Research on STEAM in different countries helps to understand its application and effects in different cultural contexts, such as Australia (Simoncini & Lasen, 2018).
6) Informal STEAM activities: In addition to formal STEAM education, informal STEAM education also acts as an important cornerstone (Marcus, 2018). Investigation of ways to support young children's STEM learning and knowledge transfer through informal learning experiences, as in museums, suggests its far-reaching implications. Thus, providing impetus for establishing informal practices as an important tool for the propagation of STEM education.
7) Gender difference: Gender differential also forms one of the key subject matters of research as STEM education is mostly science-based and technical. Master et al. (2017) pointed out the existence of a large and persistent gender gap in science, technology, engineering, and mathematics. They underlined activities that ought to provide more opportunities for young girls to experience technical activities, which consequently will increase interest in STEAM education.

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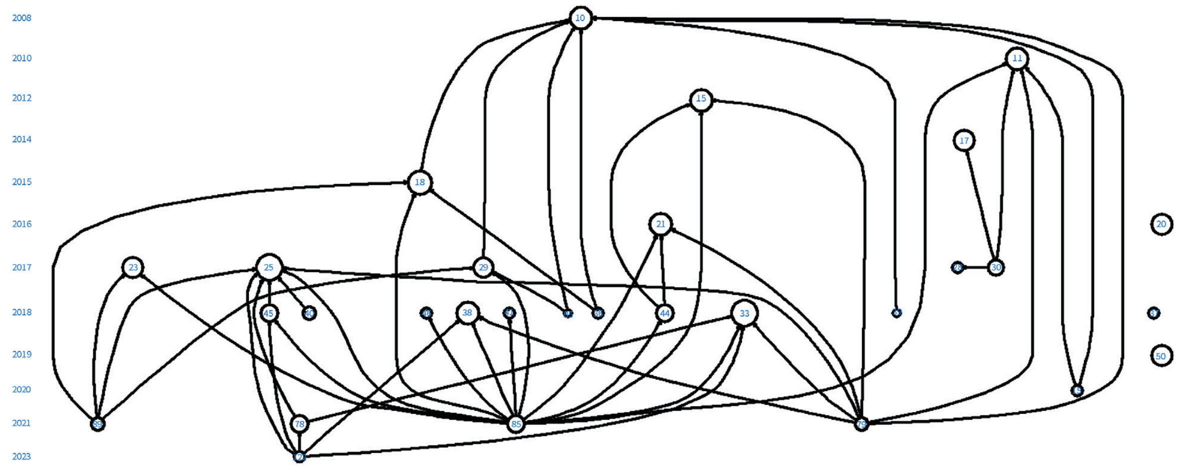
Figure 3
Citation network of EC STEAM research on the Web of Science



Keyword Analysis

Note: *Year (number of studies) is presented in the left column. Each circle represents an article, and the number in the box is the article's ID.

Analysis of EC STEAM Keyword Co-Occurrence

Keyword co-occurrence analysis is an effective way to clarify scientific knowledge structure and hotspots and discover research trends. This article has employed the CiteSpace application to generate a keyword co-occurrence graph (Figure 4); it depicts the keyword map of EC STEAM research from 2008 to 2023, in which a total of 211 high-frequency words and 829 connecting lines are charted. Normatively, the higher the frequency of keyword citations, the more the research content is valued. The betweenness centrality measures the frequency with which a node in the knowledge graph acts as an intermediary for other nodes to connect. Keywords with a central value exceeding 0.1 (see Table 2) have a greater influence (Fang et al., 2017). In co-occurrence analysis, nodes with high frequency and high concentration are usually considered key nodes, indicating that they have a strong influence on the whole network. By studying these key nodes, the rich information behind the nodes can be mined. Since EC STEAM started in 2008, science and design have been relatively active keywords, which underlines the fact that research on EC STEAM often focuses on scientific inquiry applications and engineering design. Since 2017, some keywords, such as gender, knowledge, achievement, educational robotics, identity, experience, and curriculum, have appeared more frequently, indicating that studies have begun to focus on gender differences, STEAM education emotional identity, experiences, and knowledge gain. In addition, curriculum research has gradually begun, with educational robots as relatively more often used technologies and matter of educational content. However, the centrality is low on these topics, which also means that no new hotspots have been formed in these research areas. The reason for the absence of hot spots is the limited promotion and development of EC STEAM practice and research during this period. Besides, the practical trials and research by teachers and researchers remained small on a scale.

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Figure 4
Keyword Co-Occurrence Network of EC STEAM

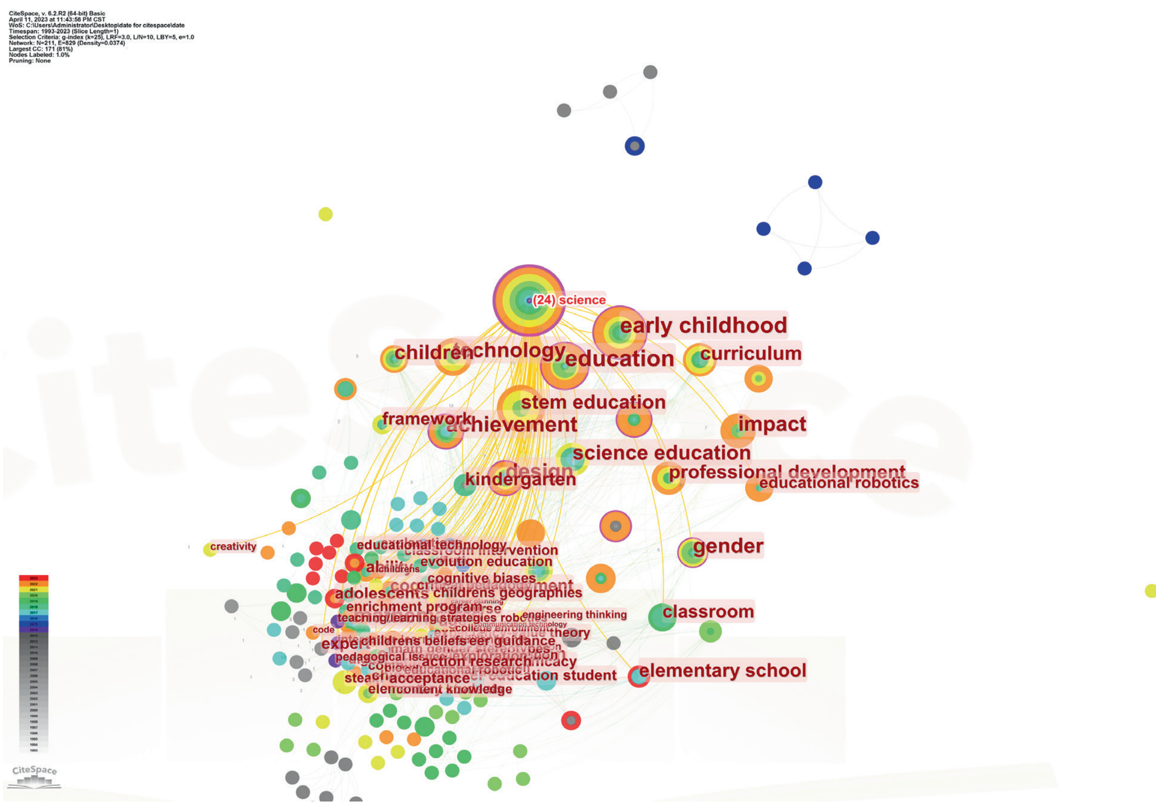

Table 2
Keywords of High Frequency and High Betweenness in EC STEAM during 2008-2023

No.	Keyword	Year	Betweenness	Frequency
1	Science	2008	0.32	24
2	Gender	2017	0.16	5
3	Education	2017	0.14	13
4	Knowledge	2017	0.14	7
5	Early Childhood	2014	0.13	17
6	Achievement	2017	0.12	6
7	Design	2008	0.111	6
8	Students	2008	0.10	5

Keyword Cluster Analysis

The CiteSpace clustering function is employed to extract information using keywords. The logarithmic likelihood ratio (LLR) is used as a calculation method to obtain clustering results, which produces eight effective clustering labels (see Figure 5). Among them, the silhouette score above 0.5 indicates that the clustering result is reasonable, and the modularity Q value of 0.5885 (above the threshold of 0.3) indicates that the clustering structure is reasonable. For the convenience of discussion, this article puts #0 (i.e., early childhood) and #3 (i.e., early childhood education) together to reduce the redundancy error. Cluster analysis and discussion of keywords can help teachers and researchers systematically and deeply understand the research content of EC STEAM.

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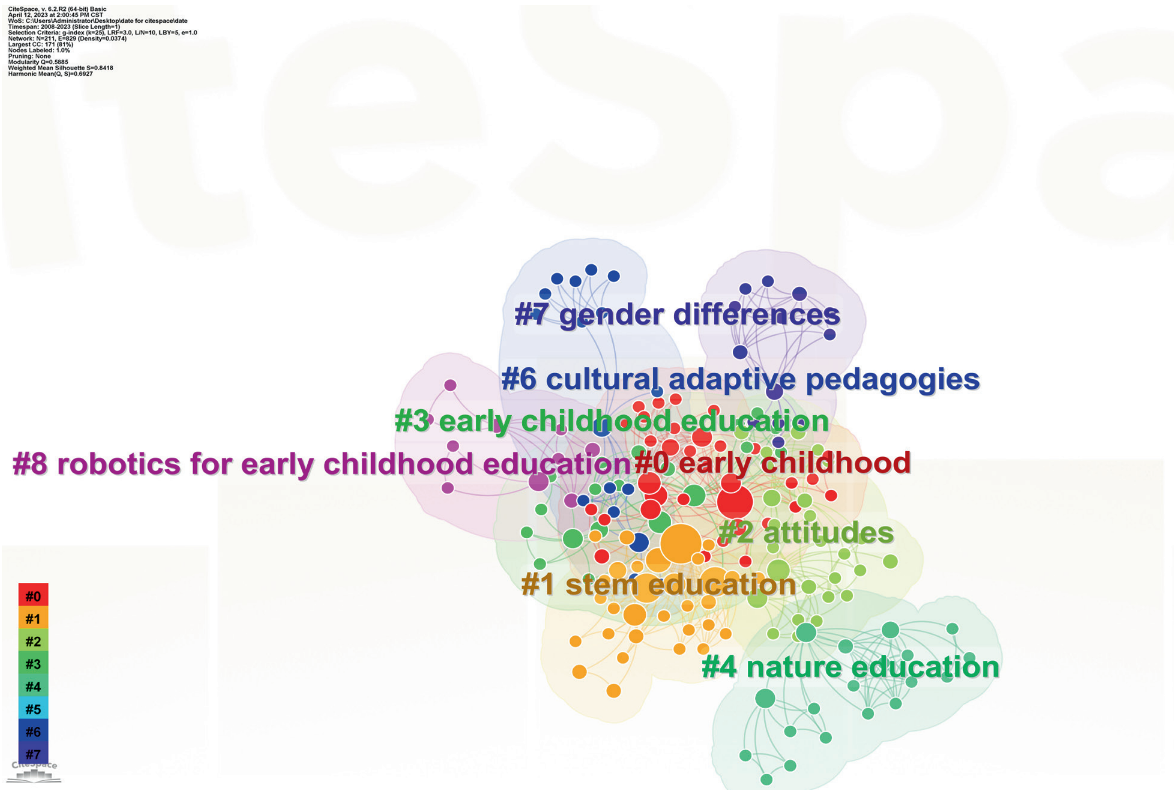
Figure 5
Keyword Cluster Analysis
0)early childhood
3)early childhood education



Children between the ages of three and six are considered to be in their early childhood. There is a widespread belief that STEAM education is too advanced for young students. This idea appears to be a common misconception. It is completely at odds with the wealth of academic studies that highlight children's innate curiosity and aptitude (for instance, see Trundle & Saçkes, 2015). In their study, Tippett and Milford (2017) collected data through classroom observations and surveys with multiple stakeholders (teachers, students, and parents) to examine how STEM activities were integrated into Pre-K. The findings support the inclusion of STEM-based learning in young children. In early childhood education, games (Hollenstein, 2022), stories (Emmons, 2018), and robots (discussed later) are fundamental modes through which young children are made more interested in STEM. For EC education, STEAM activities can promote the development of children's knowledge, ability and thinking in all aspects, including mathematics, as mentioned above (Hollenstein, 2022), computational thinking, robotics, programming, and problem-solving abilities (Bers et al., 2014), scientific knowledge (Emmons, 2018), and artistic and social-emotional aspects (Garner, 2018). STEAM education also helps to develop young children's scientific inquiry ability (Schiefer, 2017; Brophy, 2008) and can also promote young children's collaborative problem-solving (CPS) behaviour (Herro, 2021). Due to the age-specific nature of EC, STEAM education also relies heavily on the guidance of teachers and the support of parents. Early childhood education professionals play an important role in supporting young children's interest and participation in STEM education (Simoncini & Lasen, 2018). Teachers need professional development on how to integrate STEM into the preschool curriculum and how to design experiences that support classroom learners to provide them with a high-quality education. Brenneman's (2019) research designed a teaching model for teachers to carry out STEAM activities better. In early childhood education, parents play an important role in family education. Tay (2018) pointed out that parents have a positive attitude toward STEAM education.

1) STEM Education

STEM (Science-Technology-Engineering-Mathematics) education has received significant attention in recent years. This has not only increased interest and learning in these fields but also encouraged children and young

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people to pursue careers in these fields. Early exposure to STEM innovations and learning are important predictors of children's future participation in STEM careers (Correia, 2022). STEAM education is proposed to cultivate comprehensive talent for future development. Studies have shown that STEAM education can have a positive impact on the job choices of various groups, such as girls (Emembolu, 2020) and students in rural areas (Brownlee, 2021). Carrying out STEAM research at the outset can effectively influence learners' future career choices at an early stage.

2) Attitude

In STEAM education, the knowledge and skills related to the subject are essential, and there is a certain degree of complexity in its comprehension. This implicates a need for persistent motivation, interest, and learning enthusiasm to remain in the field. Maltese (2010) demonstrates that interest in science should begin in early childhood by examining scientists' and graduate students' first experiences in science. Master et al. (2017) pointed out that improving children's enthusiasm for STEM from an early age is an effective way to improve children's STEM motivation, and it can also improve children's self-efficacy.

4) Natural Education

Some aspect of STEAM education also draws its relevance from natural and atmospheric sciences, such as learning about Climate Change (Trott, 2020) – the author has investigated how climate change learning and actions affect children's cognitive, emotional, and behavioural engagement with science. Between 2015 and 2020, Speldewinde and Campbell (2021) implemented STEM education in Jungle Kindergarten to find out that nature, being an essential element of STEAM education, is also a significant factor in cultivating children's interest in science.

6) Cultural Adaptive Pedagogies

Studies on STEAM education often consider the importance of sociocultural background, thereby insisting on adding S (social) components to STE (science-technology-environment) education (Zoller, 2011). Smith (2022), while pursuing a critical analysis of the state of science education in the Netherlands, provides a concrete example of a culturally relevant and sustaining pedagogies (CR-SP) and community-based STEAM program for young children and their parents in the north of the Netherlands. It counters the prevalent European hegemonic argument by locating Dutch society as the mixing pot of European and Caribbean cultures.

7) Gender Differences

In STEAM education, because science, technology, and engineering are all scientific and technical disciplines, there are often gender differences. Conlon's (2023) survey found that boys are more likely to engage in military, manual labour, and mathematics/computer science careers, while girls are more likely to be caregivers in stay-at-home parenting, education, and animal care. Master et al.'s (2017) survey shows a significant and persistent gender gap between boys and girls in Science, Technology, Engineering and Mathematics (STEM) Participation; this gap is much more significant in technical fields such as computer science and engineering than in mathematics and science.

8) Robotics for Early Childhood Education

Educational robots are a relatively important component of STEAM, especially for young children. In robotics education, we find different types of concepts, methods and goals surrounding robotic technologies in addition to several educational robots. Sullivan (2016) noted that robotics provides a fun and tangible way for children to get exposed to technology and engineering experiences during the foundational stages of early childhood. Robotics education also provides learners with hands-on experience in understanding technology, machine language, and systems (Eguchi, 2014). Research (Ferrada-Ferrada, 2020) has shown that starting in preschool, children are able to acquire basic robotics and programming skills.

In summary, as the visual analysis of literature cross-citation consumes time, the cluster analysis of keywords is more economical in terms of time. From the cluster analysis, we can see that carrying out STEAM education in the early childhood stage can affect the future employment direction of young children (especially girls) and can also stimulate children's interest, curiosity, and self-efficacy. It also helps them in their careers and allows them to keep learning and improving continuously. STEAM education is of great value to the overall development of young children, and we should study and practice it from all aspects.

Keyword Citation Burst Analysis

Business reflects the increase in the frequency of document citations in a certain period. Through the detection of burstiness (Fig. 6), we can determine the research hotspots during that period. Using the CiteSpace burst detection algorithm, it can be seen that the research frontier of EC STEAM is divided into three stages:

1) 2008-2015 is a stage of relatively slow development, and the research hotspots are mainly focused on students, performance, and representations.

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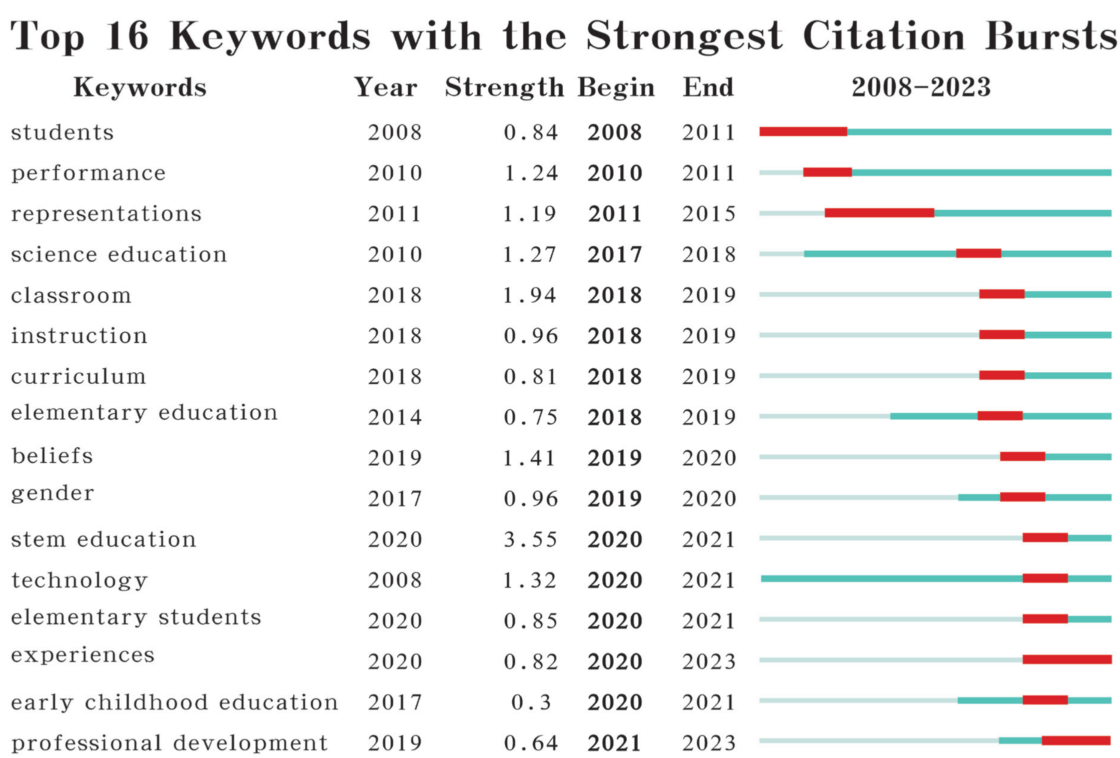
2) Since 2017, research has begun to emphasize science education and technology subjects and takes a keen interest in the classroom, curriculum, and gender. In addition, it emphasizes elementary education, elementary students, and early childhood education. It is during this moment that it begins to pay attention to the significant role of teachers – instruction and beliefs.
3) From 2020 to the present, there has been a new research trend which takes keen note of children's experience and requires professional development in STEAM.

This emphasizes the experiential nature of EC STEAM activities and the requirements for activities. The development of EC STEAM education has shifted from emphasizing the teaching of STEAM knowledge and skills to emphasizing young children's inquiry and experience. It demonstrates EC STEAM education's increasing ability to pay attention to learner characteristics, which is related to their physical and mental development. Thus, it prioritizes better influence of STEM that accentuates children's faculty development.

Figure 6
Top 16 Keywords in EC STEAM with the Most Robust Citation Burst



Author Analysis

320 Authors in HistCite

Using HistCite software analysis (Table 3, see Appendix), it was found that there are 179 articles in the current database, four of which are written by the author Marina Umaschi Bers. The total citations for her research are 245, which signifies a relatively high-yielding and influential author. In addition, the author Ceylan has their articles and is also a relatively productive author. Authors Cheryan, Master, Meltzoff, Sullivan, Brophy, Klein, Moscatelli, Portsmore, and Rogers have relatively high local citation scores and international citation scores and are relatively influential authors. In Table 3, there are links to the introductions of highly productive authors, mainly including names, work units, research fields and published articles.

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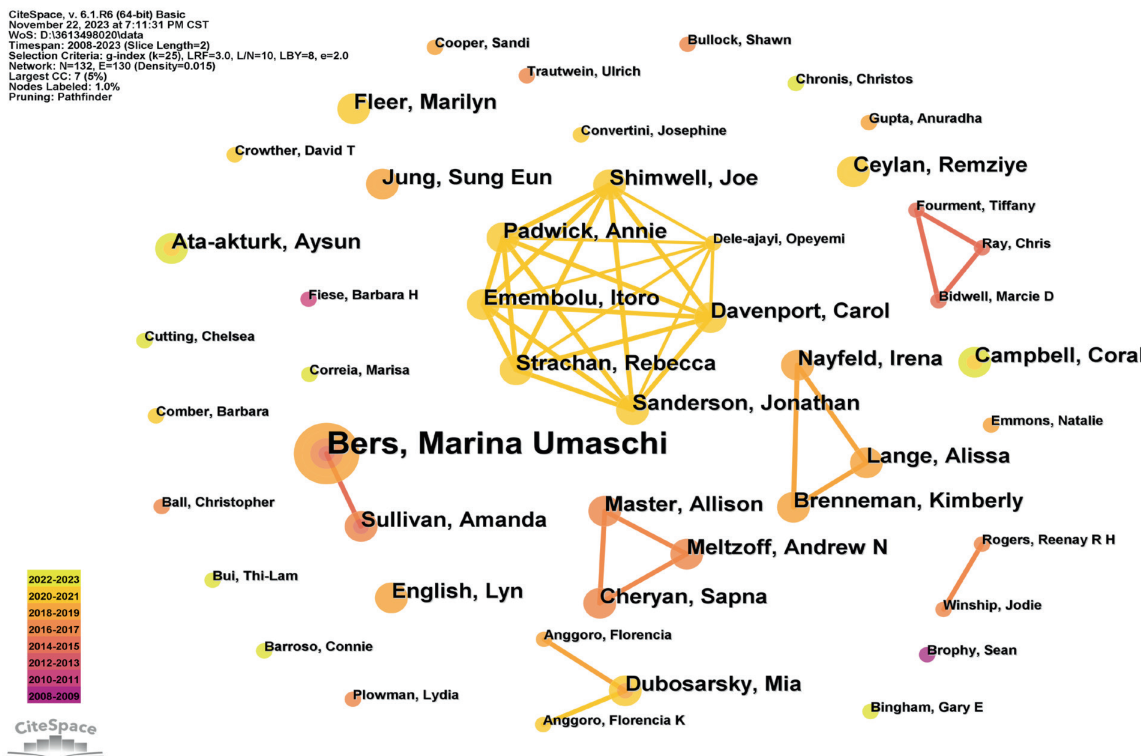
Coauthor network

Using CiteSpace, the coauthor network diagrams can be generated. Coauthor networks are used to analyse joint research in a specific research field. The larger the nodes in the graph, the more publications are published, and the thicker the connecting lines, the closer and more robust the collaboration between authors. As shown in Figure 7, the CiteSpace analysis results show that the rate of collaboration among authors is meagre. A relatively stable and sizeable academic team has yet to be formed.

Figure 7
Author Co-Occurrence Analysis



Author Co-Citation Analysis

Author co-citation maps (Fig. 8) are generated using CiteSpace software. The analysis of author co-citations yielded a total of 321 nodes and 892 network lines, as shown in Figure 8. The larger the node in the graph, the more frequently it is referenced. Clements (14), Bers (13), Sullivan (12), and Eshach et al. (10) have the most cited and strongly centred results and show that they have played a significant role in STEAM education research.

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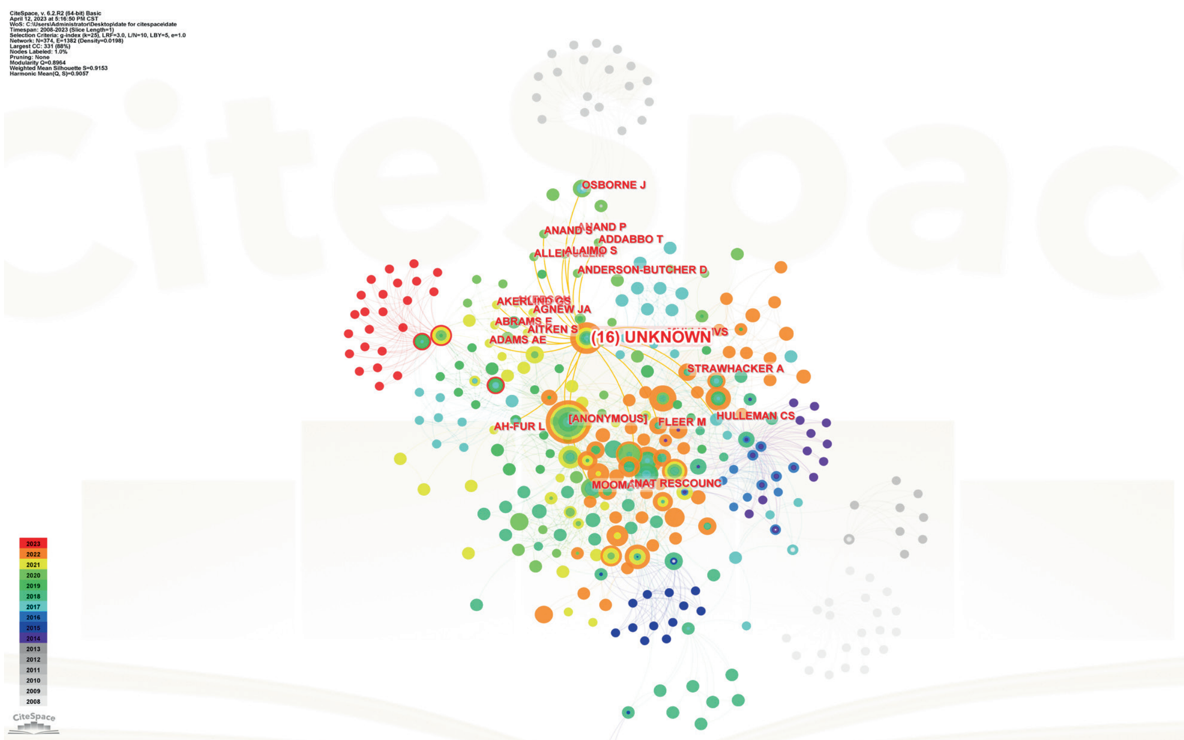
Figure 8
Author Co-Citation Analysis



Journal Analysis

Using HistCite software analysis, a total of 79 journals were used, among which the "Early Childhood Education Journal" published the most articles (7) and consequently received relatively more citations. "European Early Childhood Education Research Journal" and "International Journal of Technology and Design Education" (3) published more articles. At the same time, "The Journal of Engineering Education" had only one article, but its citations were from more significant and critical journals.

Institutional analysis

Number of institutions

Among the large number of institutions that have contributed to research in STEAM education research, Tufts University, Queensland University, Purdue University, and Texas A&M University have published more than three articles each. Their citation scores are relatively high, thereby becoming high-yielding and influential institutions. However, the University of Washington, despite publishing two articles, shows a considerably high citation score.

Joint research institution network

CiteSpace analysis (Figure 9) shows that there are 119 research institutions and 126 cooperation links in the joint research institution network. Figure 10 shows that most of the nodes are isolated points, indicating that almost all research results were done by a single author. Only a few organizations have conducted collaborative research, signifying a weak intensity of collaboration. In terms of the number of publications, the top three are Tufts University (7), Queensland University of Technology (QUT) (5), and Texas A&M University System (5). In this study, the maximum number of publications by any institute is only seven, which is a relatively small number of publications. This indicates that the research on EC STEAM by these institutes is not extensive vis-à-vis the global concern.

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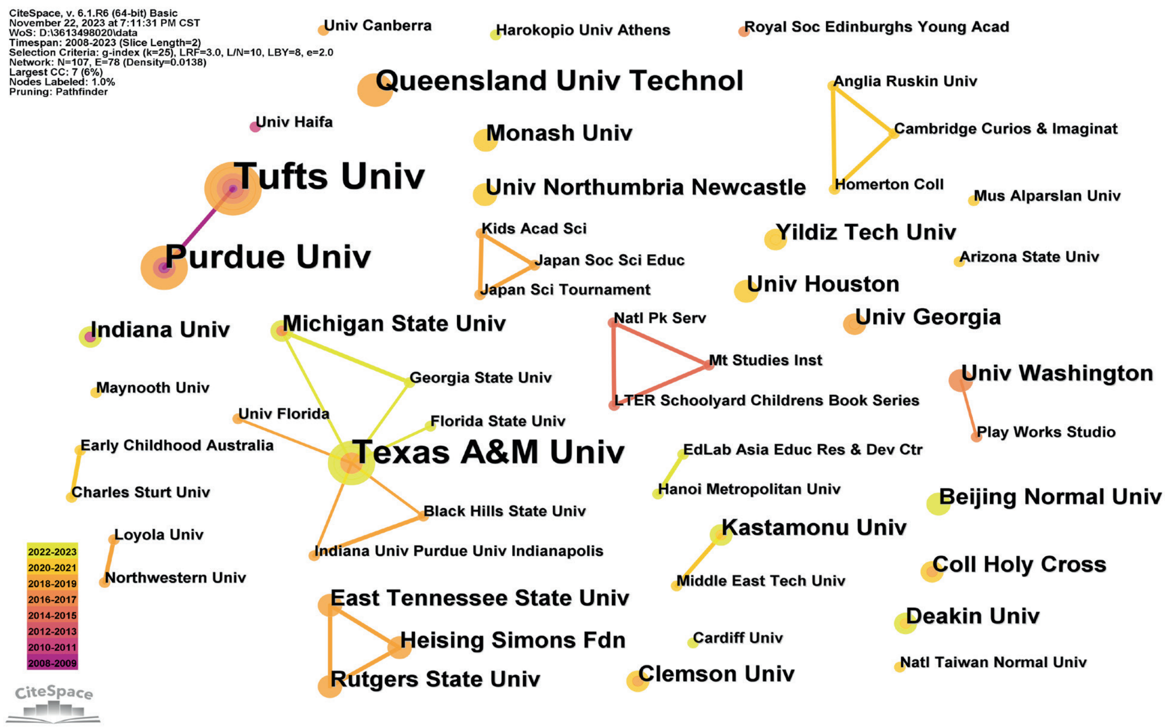
Figure 9
Co-occurrences of the Institutions



Country Analysis

Analysis of National Literature Citation Rate

The scholars in the USA have published the most papers in the field of EC STEAM - 47 papers. Their citation score is also the highest (1124), signifying their notable influence in this field. Australia (14), Turkey (13), the UK (9), and the People's Republic of China (5) are distantly ranked in comparison to the USA but have recognizable citation strengths. Although South Korea has only one article, it has a very high citation score, hinting at some influence it commands.

National (regional) network

CiteSpace was used to draw a national cooperation network map. The size of the node (Figure 10) represents the degree of cooperation. The larger the node, the more the country's cooperation with other countries. It shows that there are a total of 25 countries and regions and nine cooperation links. The countries with the highest number of items are the United States (46), Australia (12), Turkey (7), United Kingdom (4), Spain (4), Canada (3), China (3), and Greece (3). Using node concentration as a metric, it can be seen that the United States, Australia, and the United Kingdom have played critical roles in this area of research. Betweenness centrality represents a wide range of national cooperation objects at essential nodes in the international cooperation network. The higher the betweenness centrality is ranked, the more significant the contribution to the formation of the network pattern and structural stability. Table X shows that the USA has the highest centrality (0.09), followed by Australia and the UK (0.04), and the others are all 0.00, indicating that there are few transnational (regional) links during the research process. While links between countries and regions often exist, as shown by the collaborative lines in the network, the strength of the links is weak. It suggests that the endeavour to establish such linkages across countries and regions still needs to be more stable.

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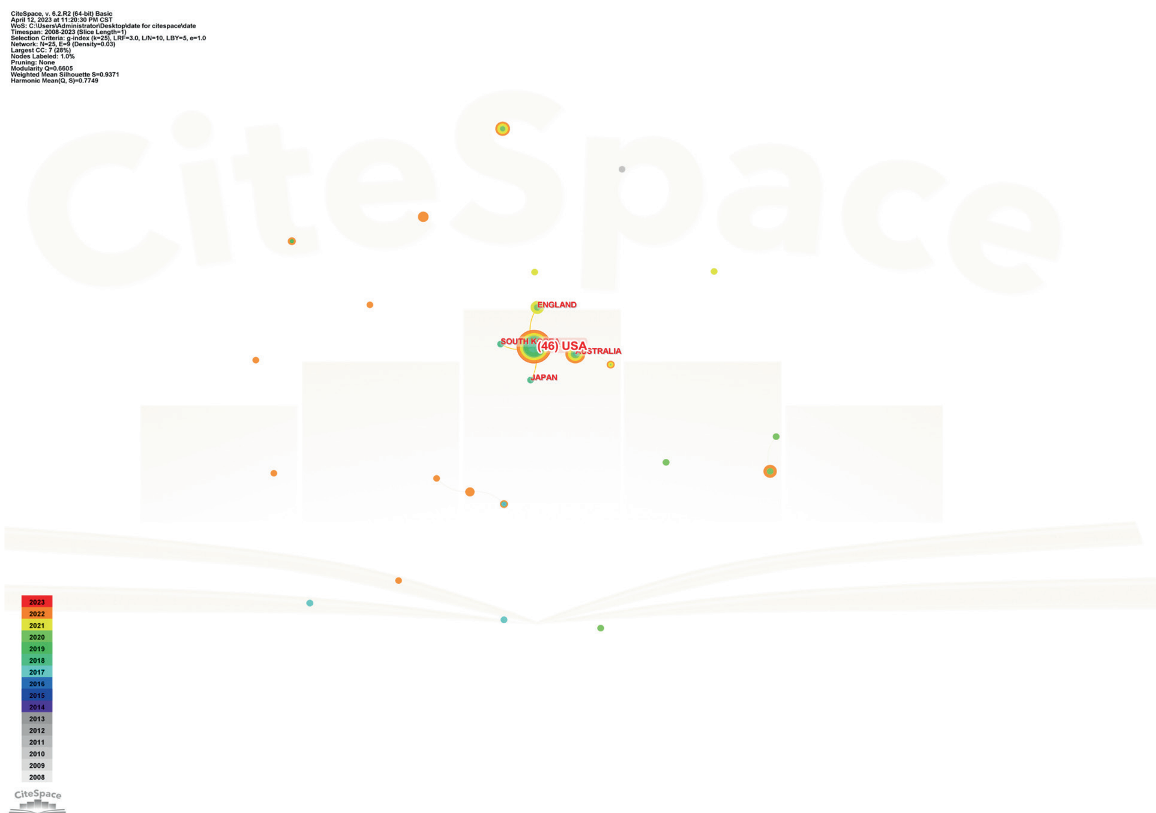
Figure 10
Co-occurrences of Countries/Regions



Analysis

The examination of research patterns relating to Early Childhood STEAM education reveals interesting facets across the years. The available evidence indicates a notable increase in the quantity of research conducted on this specific topic starting in 2008. The observed pattern indicates an increasing preference for probing the possibilities of including STEAM principles in early childhood education. The data also finds noteworthy fluctuations in research intensity, wherein there are visible increases and decreases that align with global events, such as the COVID-19 pandemic. This phenomenon exemplifies the tenacity and flexibility of the academic community, which persisted in the face of difficult situations.

Keywords have a crucial role in comprehending the thematic landscape of research on early childhood STEAM education. The research shed light on the significant terms, their patterns of co-occurrence, and the formation of these clusters. The analysis highlights the changing emphasis of research over some time. Between 2008 and 2015, the research primarily focused on fundamental elements, including students, performance, and representations. This initial study possibly established the basis for further inquiries.

One notable finding relates to the transition towards a broader emphasis on several dimensions of education, encompassing science education, technology-related courses, classroom dynamics, curriculum creation, and gender disparities. This evolutionary process is in accordance with the broader pedagogical transition towards comprehensive and inclusive education. Significantly, there has been a visible movement in focus within the educational landscape towards topics such as experiential learning, emotional identity, and professional development. This shift talks about the departure from the customary emphasis on the acquisition of knowledge and skills to a move towards the cultivation of inquiry, curiosity, and the efficacy of students and instructors alike.

The concept of Citation Burst Analysis (CBA) refers to a methodological approach used in academic research to analyse the temporal patterns of citations within scholarly literature. The examination of citation bursts offers a noteworthy understanding of the temporal dynamics of research key points. The boundary of three discrete phases

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signifies the development and advancement of the Early Childhood STEAM research domain. The early stages of this phenomenon were primarily focused on conducting fundamental research. However, as time progressed, there was a shift towards prioritizing pedagogical methods, using technology, and gaining a more comprehensive understanding of the learner's experiences. The aforementioned temporal study underscores the mutability inherent in the research landscape. The subjects experience fluctuations in both prominence and impact as a result of altering educational paradigms and societal demands.

The analysis of authors, journals, and institutions enhances comprehension of the critical scholars who are crucial in shaping research in the field of Early Childhood STEAM education. The study highlights the scholarly contributions of notable and essential academics like Marina Umaschi Bers and Remziye Ceylan. The contributions made by individuals in this interdisciplinary subject are indicative of the wide range of skills that are necessary. The analysis of the coauthor network unveils visible patterns of collaboration, highlighting instances of both unaccompanied and restricted joint endeavours. This implies potential avenues for cultivating broader research partnerships to further the communication of knowledge and encourage innovation.

The examination of journals and institutions sheds insight into the key channels and centres of research relating to Early Childhood STEAM. Prominent scholarly journals such as "The Early Childhood Education Journal," "European Early Childhood Education Research Journal," and "International Journal of Technology and Design Education" play a crucial role in the dissemination of research findings. The analysis highlights the significant contribution of institutions such as Tufts University, Queensland University, and Texas A&M University in generating research with substantial influence. The extent of collaborative networks among institutions appears to be constrained, indicating the potential for expanding collaborations in order to improve the quality and extent of research.

The analysis of national and regional contributions to research on Early Childhood STEAM education finds interesting trends of influence and collaboration. The United States' pre-eminence in publishing and citation score highlights its position as a frontrunner. Nevertheless, the extent of collaborations among countries and regions still needs to be expanded, suggesting the possibility for enhanced international partnerships. The acknowledgement of additional significant contributions, namely from Australia, Turkey, the United Kingdom, and China, highlights the international scope of research in early childhood STEAM education.

The study provides a thorough examination of Early Childhood STEAM education research, focusing on its development, prominent topics, notable participants, and worldwide trends. The patterns indicate a transition towards comprehensive approaches that incorporate experiential learning, gender issues, teacher responsibilities, and pedagogical innovation. As the discipline progresses, a number of implications arise:

The pedagogical transformation refers to the shift from a traditional knowledge-centred approach to a more experiential learning model, which is in line with educational paradigms that encourage active participation and inquiry. The transition above has significant consequences for the preparation of teachers, the development of educational programs, and the allocation of resources.

Gender equity refers to the acknowledgement of distinctions between genders and the undertakings made to rectify any inequalities. It demonstrates the academic dedication to foster an all-inclusive educational milieu. Further investigation is necessary to explore more extensively the practical approaches for nurturing equality in STEAM disciplines.

The current lack of extensive collaboration among authors, institutions, and nations indicates the potential for cultivating interdisciplinary and transnational research relationships. Collaborative endeavours have the potential to advance the dissemination of knowledge and bring innovation from multiple vantage points.

The incorporation of technological courses and educational robots highlights the significance of technology in augmenting early childhood education. Conducting an inquiry into the effectiveness and influence of these technologies on educational achievements might yield significant scholarly perspectives.

The implications for policy are evident in the examination of publication patterns and the impact of policy measures, such as the "STEAM Education Act of 2015," indicating a correlation between educational policy and research inclinations. Further investigation is necessary to delve into this connection in order to provide valuable insights for policy-making.

In conclusion, the examination of research patterns and dynamics in Early Childhood STEAM education highlights the progressive nature of the discipline, its multidisciplinary nature, and its capacity to influence the educational domain. The analysis yields valuable insights that can serve as a basis for making informed decisions, identifying future research avenues, and fostering collaborative endeavours to improve the quality of early childhood education and equip young learners for a future characterized by dynamism and innovation.

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Discussion

The study on Early Childhood STEAM education presents a wide-ranging scientometric analysis of research conducted between 2008 and 2023. The study's employing the Web of Science database ensures a comprehensive and structured approach to data collection while acknowledging the potential limitations of any single database. It includes, inter alia, restricted coverage of non-English journals or journals that might offer unique perspectives on the subject matter. Besides, while CiteSpace and HistCite are robust visualization tools, their selection might introduce certain biases or limitations in capturing the entire research landscape.

The observed surge in research activity from 2008 aligns with global trends toward incorporating STEAM into early childhood education. However, the study might benefit from a more intense exploration of the impact of specific global events like COVID-19 pandemic, on research focus. Understanding how such events shaped research trajectories may offer valuable insights into the field's status. The evolution of keyword clusters over time offers a compelling view of the changing emphasis of research. However, the study could investigate the contextual contingencies behind these shifts. For instance, by exploring the role of societal changes or educational policies as they influence the evolution of research topics.

While acknowledging influential scholars and key institutions is commendable, a deeper exploration into their specific contributions and methodologies could provide richer insights. Understanding the methodologies, theories, and approaches that these scholars and institutions have employed could highlight crucial trends or innovative practices in Early Childhood STEAM education. Moreover, while identifying patterns of collaboration among authors and institutions, the study further explores the quality and impact of these collaborations. Investigating the nature of collaborative research and its contributions to the field could offer valuable insights into the effectiveness of interdisciplinary studies.

The study's emphasis on national and regional contributions is insightful which highlights dominant countries and emerging contributors. However, the analysis could benefit from a more detailed examination of cultural, societal, or policy factors that influence research priorities and approaches in different regions. This could provide a deeper understanding of the global contextual influences on Early Childhood STEAM education. Exploring interdisciplinary intersections beyond the realms of science, technology, engineering, arts, and mathematics (STEAM) within Early Childhood Education could uncover new dimensions and perspectives essential for holistic development.

The present study provides valuable insights into the dynamic nature of Early Childhood STEAM education research. In addition, effectively exploring contextual influences and overcoming potential limitations could further enrich and deepen our understanding of this multidisciplinary field. Collaboration among researchers, interdisciplinary approaches, and a nuanced understanding of global contexts will be instrumental in shaping the future trajectory of research in Early Childhood STEAM education.

Conclusion and Suggestions

This study conducted a visual bibliometric analysis of the literature by employing Hiscite and CiteSpace applications. Then, it methodically analysed and interpreted the research content and information, such as authors, institutions, journals, and countries of origin. This article used a diagram to help explain the direction of research on STEAM education. In conclusion, the EC STEAM knowledge map (See Appendix) is an organic flow diagram that ties together the elements necessary to deliver effective STEAM education.

The number of scholarly pieces collated and studied in this essay is on the higher side vis-à-vis the existing literature. Most importantly, the selection of literature is objective, and the information extracted from it is comprehensive and exhaustive.

The observed trends highlight how the field has evolved from knowledge to a comprehensive approach that encourages experiential learning, involves teachers, and promotes gender equality. This transformation supports thinking and the broader societal need for innovative and well-rounded education.

The emergence of clusters, keywords and patterns of activity reflects how this field responds to evolving educational paradigms and global events. The contributions made by authors, institutions and countries emphasize the nature of research while also presenting opportunities for interdisciplinary cooperation on a broader scale.

Several implications can be drawn from this analysis. Firstly, the necessity for transformation, integration of technology into childhood education and an approach that prioritizes equity. Secondly, the impact of efforts in driving innovation and strengthening research outcomes. Lastly, it underscores the relationship between academia and educational administration by highlighting how policy initiatives influence research trends.

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As Early Childhood STEAM education continues to evolve, this analysis serves as a guiding reference for researchers, educators, policymakers, and institutions. It emphasizes the importance of adopting an approach that nurtures a learner's natural curiosity while developing critical thinking skills, creativity, and problem-solving abilities.

These insights are potent enough for developing a dynamic, inclusive, and impactful early childhood STEAM education that empowers the upcoming generation to thrive in a world that is constantly evolving.

The study takes the initiative to provide some suggestions. Firstly, the current state of STEAM education for young children is dynamic and multifaceted, with constant interaction of various facts of learning and evolution. We can only continue to support the growth of early childhood STEAM education by synthesizing the content and importance of all aspects in understanding and conducting STEAM education. Secondly, in keeping with the global requirement, the government should provide support for policies and funds. Thirdly, there must be a system of resource pooling for a shareable knowledge environment to prosper. Children's STEAM education will attain more impact if high-quality educational resources are disseminated universally through the Internet. Fourthly, employing more diversified education methods will have a positive outcome. Making course contents colourful, employing virtual and augmented reality, and emphasizing practical experiments and field exploration can make STEAM education more acceptable to curious young minds. Fifthly, the student evaluation must not only be based on grades but must also focus on evaluating their various abilities - practical aptitude, innovation ability, and teamwork skills. Sixthly, keen interest ought to be taken in training teachers who impart STEAM education to children. Lastly and most importantly, the economic, social, and global relevance of STEAM education for children needs to be presented to the parents. They are the ones who determine the career trajectory of their children by opting for schools, paying for their education, and creating a learning environment at home. The prescriptions mentioned above can only be materialized with the parent's consent.

Research work, being a benchmark, dictates covered distance and yet-to-be-covered distance at once. To further the cause of global outreach, more collaborative research endeavours are required. Collaborations enable a transactional space where learning from each other's experiences seeps through the policy prescriptions for a larger good.

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Conflicts of Interest

The author declares no conflicts of interest associated with this research.

Ethical approval

This study is a literature review and does not involve human life science and medical research, so an ethical review is not applicable.

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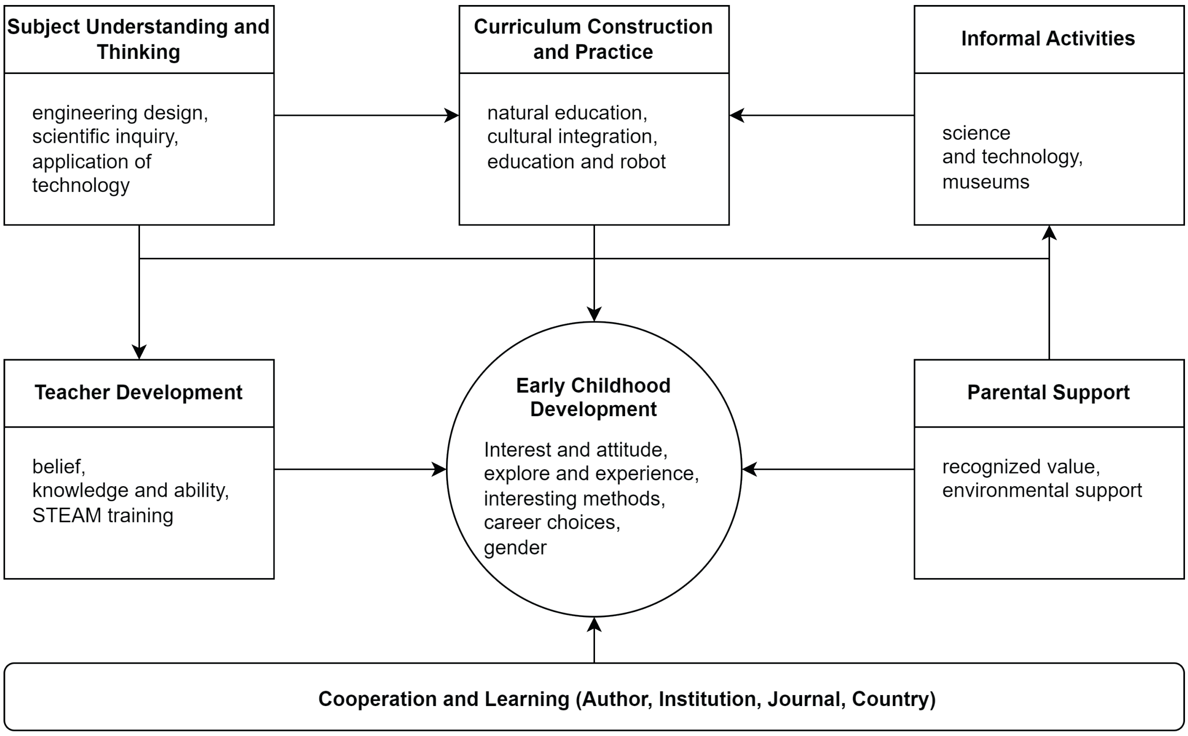
Appendix
Knowledge Map for EC STEAM Education



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Yumeng Li
(Corresponding author)
Faculty of social sciences and humanities, School of education, University of Technology Malaysia (Universiti Teknologi Malaysia), 81310, Johor, Bahru, Malaysia.
E-mail: liyumeng@graduate.utm.my
ORCID: https://orcid.org/0009-0004-4533-8248

Corrienna Abdul Talib
Faculty of social sciences and humanities, School of education, University of Technology Malaysia (Universiti Teknologi Malaysia), 81310, Johor, Bahru, Malaysia.
E-mail: corrienna@utm.my
ORCID: https://orcid.org/0000-0003-2230-3670