International Journal of Child-Computer Interaction 44 (2025) 100736

Contents lists available at ScienceDirect

International Journal of Child-Computer Interaction

journal homepage: www.elsevier.com/locate/ijcci

Review article

Exploring STEM (science, technology, engineering and mathematics) toys in kindergarten: Teachers' pedagogical approaches, perspective and effect on Children's brain development: A systematic literature review

Mahendra Prasad 'Pandey'

School of Education and Humanities, IFTM University, Lodhipur Rajput, Moradabad, 244102, India

ARTICLE INFO

Keywords:
STEM toys
Kindergarten
PRISMA-2020
Problem-solving
Critical thinking
Verbal communication

ABSTRACT

This systematic literature review explores pedagogical approaches of kindergarten teachers' to facilitate children's play with STEM toys. This review summarises teachers' perspectives on the utilisation of STEM toys in children studying in kindergarten and describes the outcomes of children's development resulting from playing with STEM toys. The present systematic literature search was performed in accordance with the PRISMA-2020 checklist. The search engines used were Google Scholar, PubMed, PubMed Central, Scopus, and other journal databases including ScienceDirect, Springer, Taylor & Francis etc. for papers published between 2010 and 2024. These searches yielded 2352 peer-reviewed articles. The application of the selection and rejection criteria led to the formation of a shortlisting 32 papers, following the initial evaluation. The findings revealed the various approaches that teachers can employ during play sessions with STEM toys while teaching. Kindergarten teachers take on the roles of facilitators and mediators, promote collaborative work, and encourage children to perform experiments and learn from failure. Furthermore, the findings of this study revealed that kindergarten teachers generally maintain favourable and constructive perspectives regarding the utilisation of STEM toys. The results underscore positive impacts on cognitive abilities of children like problem-solving and critical thinking, and socio-emotional skills like verbal communication from using STEM toys. Comprehensive teacher training is emphasised to identify methodologies that complement the technology, maximizing teaching-learning benefits for children's brain development.

1. Introduction

Many countries, including the United States, Canada, United Kingdom, China, Germany, Japan, South Korea, Singapore, Sweden, Finland, the Netherlands, Norway, Denmark, Australia, New Zealand, Hong Kong and others, have incorporated STEM toys into their kindergarten curriculum (Yang & Li, 2018). STEM toys are considered educational toys designed to effectively teach children about STEM concepts as this concept is one of the most effective and interactive ways of teaching (He et al., 2021). Many consider such toys valuable tools for early childhood education, especially for kindergarten children. The use of STEM toys in kindergarten classrooms can help children develop a growth mindset and resilience (Wenz-Gross et al., 2018). Thorough hands-on experimentation and exploration, children learn to embrace challenges, persevere despite setbacks, and view failures as opportunities for learning and growth. This mindset is crucial for building children's confidence and motivation to tackle complex problems in the future (DeCaro et al., 2015). Additionally, STEM toys can play a significant role in promoting diversity and inclusion in early childhood education (Ogunlade, 2023). This diversity in toy selection can help break down stereotypes and encourage children from diverse backgrounds to engage with STEM subjects ("Vasil Levski et al., 2022. STEM toys are available in various forms, including building sets, puzzles, games, and electronic kits etc (Coyle & Liben, 2020). Building sets like LEGO Mindstorms combine the engineering principles with robotics to allow children to build and programme their own robots (Basso & Innocenti, 2015). At the same time coding toys such as the Ozobot Bit involve colour-coded markers to introduce children to basic programming concepts (Fojtik, 2017). Chemistry sets like Thames & Kosmos Chem C3000 provide children with the materials and instructions to conduct safe and engaging chemistry experiments at home (Lawlor, 2016). The specific learning outcomes of different types of STEM toys are shown in Fig. 1.

Incorporating such advanced tools into the kindergarten curriculum

E-mail address: mahendra.prasad@iftmuniversity.ac.in.

https://doi.org/10.1016/j.ijcci.2025.100736
Received 22 May 2024; Received in revised form 26 December 2024; Accepted 6 February 2025
Available online 5 April 2025

enhances the cognitive abilities of children including computational science and mental competencies, by encouraging active thinking and problem-solving approach (Lamb et al., 2015). These toys not only facilitate the development of basic science processes but also encourage exploration and experimentation at an early age (Hassan Ghandourah, 2022, pp. 1–10). Play-based learning using STEM toys has been proven effective for promoting children's cognitive and social development (Pyle & Bigelow, 2015). Moreover, the appropriate integration of technology and computers in kindergarten classrooms can enhance children's learning experiences and enable them to work at their own pace with adult support (Toren et al., 2008). When STEM toys are employed into kindergarten activities, it is crucial to consider the teaching staff's familiarity with technology and their pedagogical approaches (Rasyid et al., 2021). The implementation of STEM toys in kindergarten education depends on the pivotal role of teachers (Leung & Hu, 2019). Therefore, gaining insight into pedagogical approaches and perspectives of teachers is essential for comprehending the utilisation and application of STEM toys. Despite the increased emphasis on the utilisation of scientific, technological, robotic, and mathematical related critical thinking in kindergarten education (Tippett & Milford, 2017; Uhlířová et al., 2022; Zviel-Girshin et al., 2020), more emphasis is to be placed on teachers' pedagogical approaches and perspectives in relation to the implementation of these activities.

At the age of 4–6 years, children learn best through hands-on, play-based experiences that allow them to explore concepts concretely (Rasyid et al., 2021). Intellectual skills include spatial awareness, in which children learn how to fit pieces together to improve spatial reasoning and visualisation abilities (Gallagher & Grimm, 2018; Kewalramani et al., 2020; Yalçın & Erden, 2021). It is important to note that certain coding toys promote collaboration and cooperation while working together to solve challenges (Latip et al., 2020; Yuill et al., 2014). Every category of STEM toys focuses on distinct facets of child development, encompassing physical abilities like precise motor control and cognitive abilities like problem-solving and logical reasoning.

Researchers must ensure that STEM toys, teacher training programmes, and research opportunities are accessible to all students and educators, regardless of socioeconomic status, geographic location, or cultural background. Addressing equity concerns requires ensuring that all individuals have equal access to learning opportunities and opportunities for professional growth. Efforts should be made to safeguard the privacy and confidentiality of individuals participating in research studies, particularly when gathering sensitive data of educational

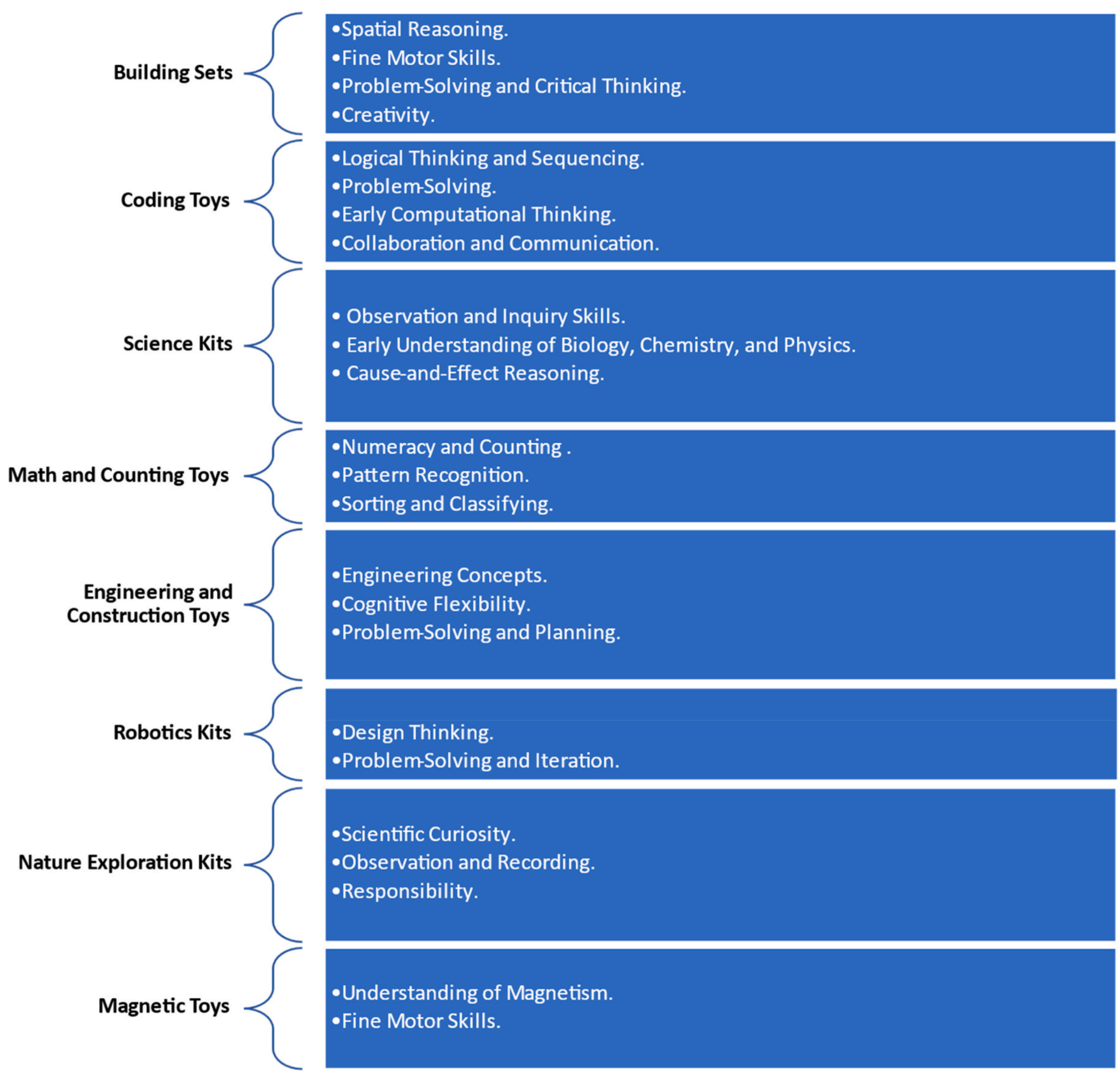

Fig. 1. Specific learning outcomes of different types of STEM toys (Alme & Reime, 2021; Ashar & Idamayanti, 2023; Dooma et al., 2024; Eloy et al., 2020, pp. 280–283; Nam et al., 2019; Samara & Kotsis, 2024; Silva et al., 2023; Westwood, 2021; Zhou & Kocabas, 2020, pp. 1105–1106).

achievements, instructional methods, or personal details. Compliance with data protection regulations and ethical guidelines when managing and storing data (Clements et al., 2021; Talaue, 2014).

The problem statement behind exploring STEM toys focuses on understanding the pedagogical approaches that kindergarten teachers employ to engage children with these toys, aiming to address the knowledge gap regarding their integration into early childhood education. This study seeks to examine teachers' perspectives on STEM toys and how such play activities contribute to children's brain development by fostering essential 21st-century skills like problem-solving, critical thinking, and verbal communication. Given the growing use of STEM toys in kindergarten, there remains limited research on how specific teaching strategies—such as interactive scaffolding and the use of visual aids and physical demonstrations—impact cognitive, social, and emotional outcomes in young learners. This systematic review addresses this gap by exploring the influence of various instructional techniques on skill development, knowledge transfer, and sustained motivation. Through insights into teachers' roles in guiding these activities, the study aims to highlight best practices for maximizing STEM toy benefits in early education.

2. Corresponding investigations

Over the past few years, there has been a growing trend in systematic reviews related to advancing scientific understanding of the utilisation of STEM toys. The literature review indicates the previous studies that depicted the variety of focal points, including some specifically geared towards evaluating the effectiveness of diverse technologies incorporated into STEM toys intended for the development of children. The role of role-playing in fostering girls' engagements is highlighted. Additionally, it has been noticed that long-term scientific interventions at home positively impact science literacy skills in deaf children, which emphasised the significance of STEM activities in early childhood education (Ha et al., 2023). An exploration of the integration of STEM and maker concepts in Malaysian primary schools has been undertaken to address existing challenges in science education. Utilising the PRISMA checklist, eight implementations and six practises from 13 selected articles were identified, highlighting their significance in fostering future skills and transversal competencies in primary education. It has been detected that the convergence of maker culture with STEM offers a promising avenue for innovative, student-centred learning experiences, potentially revolutionising science education in primary schools (Balakrisnan, 2023).

While conducting a literature review on STEM toys, researchers focused on 12 articles from 2007 to 2022. Their findings inclined towards environmental sustainability within science discipline. Their study revealed the tendency towards assuming an Apollonian child perspective, emphasising virtuous traits emerging from sustainability engagement, while suggesting a need for more explicit integration of STEM/STEAM knowledge and skills into ECEfS curricula (Rodrigues-Silva & Alsina, 2023). In another systematic review, an examination of STEM and STEAM educational interventions from 2010 to 2020 was conducted to assesses their impact on student creativity. Despite their differences, both approaches demonstrated positive effects on student creativity, challenging the notion that STEAM is inherently superior to STEM in terms of fostering creativity based on empirical evidence (Alexandre et al., 2022).

Abu Khurma et al., (2022) examined the incorporation of engineering subjects into elementary STEM education, focusing on learning techniques and frameworks. The findings highlighted the hurdles in teaching approaches for STEM subjects and suggested opportunities for educators to enhance teaching methods. Their study emphasised the importance of attributes in developing fundamental competencies within STEM disciplines and calls for future applications to include experimental support for inquiry-based learning activities. In another study, examines 14 empirical interventions from 2010 to 2020 examined, focusing on STEM and STEAM educational approaches along with their impact on student creativity. The findings suggested diverse forms of interventions using these approaches, including the prevalent use of Likert-type tests for creativity evaluation, and evidence of positive effects on student creativity in STEM and STEAM. Contrary to some claims, some researchers have indicated that there is no clear advantage of implementing STEAM over STEM for fostering student creativity based on empirical evidence (Aguilera & Ortiz-Revilla, 2021). A systematic review was conducted by researchers including 30 years of research on smart toys for children aged 3–12 and they were categorised on the basis of their technological and educational affordance. The findings revealed four main technological affordance and various educational objectives, including transversal competencies like problem solving and collaboration. The analysis highlighted a shift in focus from transversal skills to STEM and computational thinking in recent years, reflecting evolving trends in smart toy development (Komis et al., 2021). Recently one study aimed to analyse studies on robotics programming for children aged 1–8 years and early childhood educators. The study aimed to understand how robotics programming contributes to integration of technology and engineering into STEM education. In one study, a total of 23 studies were taken under consideration which elaborated that, educational robotics shows promise in enhancing early childhood STEM education by facilitating technology and engineering integration through computer programming (Çetin & Demircan, 2020). In another study, 154 peer-reviewed articles from 2007 to 2018 were reviewed which explored the fact that STEM education, conceptualised learners and learning reflect the underlying assumptions influenced by macrosystemic discourses. Using critical discourse analysis, the study called for diversification of STEM research, challenging disciplinary hegemonies, and shifting focus away from human capital discourse (Takeuchi et al., 2020). The studies analysing 28 publications from 2010 to 2017 that focused on augmented reality's role in supporting STEM learning were reviewed. This study examined the characteristics of augmented reality applications, instructional strategies, and evaluation approaches. Findings indicated a prevalence of simulation activities, with suggestions for future research emphasising the need for metacognitive scaffolding and support for inquiry-based learning, as well as integration with blended instructional strategies like the flipped classroom model (Ibáñez & Delgado-Kloos, 2018). At a time when 28 publications from 2010 to 2017 were reviewed that focused on augmented reality's role in supporting STEM learning. This study examined the characteristics of augmented reality applications, instructional strategies, and evaluation approaches. Findings indicated about simulation activities, with suggestions for future research with emphasis on the need for metacognitive scaffolding and support for inquiry-based learning, as well as integration with blended instructional strategies like the flipped classroom model (Rosenzweig & Wigfield, 2016).

The use of robotic construction kits (RCKs) in P–12 STEM education, focusing on their role as computational manipulative has been studied. Findings exhibited four key insights. The insights include RCKs because they have dual applications, support additional routes of learning and aid in evolving problem-solving abilities (Sullivan & Heffernan, 2016).

The two identified pedagogical approaches, going beyond simple descriptions includes Nuanced Pedagogical Framework and Interactive scaffolding. Integrating both approaches within a Blended Learning Framework may yield the best outcomes for students. For instance, teachers could use visual aids to introduce a concept and then transition into interactive scaffolding to deepen understanding. This combination allows children to first grasp the foundational knowledge visually and then apply and explore that knowledge collaboratively, thus maximizing cognitive and social-emotional learning outcomes.

Additionally, incorporating principles from differentiated instruction can further enhance these approaches.

The classification of teachers' approaches into "Interactive scaffolding" and "Scaffolding uses visual aids and physical demonstration" in the present study appears to have been inferred through a combination of a systematic literature review and the authors' interpretations of the studies reviewed. To fully understand the pedagogical approaches in this review, it is essential to examine the underlying beliefs influencing the authors' classification of scaffolding methods and their effectiveness in STEM education. These foundations guide the choice of teaching strategies and shape expectations for learning outcomes in early childhood development.

2.1. Reflection of authors' pedagogical beliefs

The classification of these two types of scaffolding approaches suggests that the author value interactive and experiential learning methods. They likely believe in the importance of actively engaging students and using diverse teaching tools to support learning. While these approaches are widely supported by certain educational theories, other pedagogical frameworks may offer different perspectives. For example, a strictly cognitive or behaviouralist approach might focus more on direct instruction and reinforcement rather than interaction and exploration. The authors' inference of these principles appears to be shaped by his theoretical leanings towards social constructivists and experiential learning theories. The author has synthesized these approaches based on a combination of the reviewed literature and his interpretation of what constitutes effective teaching in early childhood STEM education.

Major Research Questionnaire for the Present Review.

This study was driven by the following research questions.

Q1. What perspectives do kindergarten teachers hold regarding STEM toys?

Q2. What pedagogical approaches do kindergarten teachers employ to facilitate children's engagement with STEM toys?

Q3. What is anticipated as outcomes that are associated with children's skill development following their interaction with STEM toys?

3. Methodology

In this systematic literature review, we adhered to the PRISMA-2020 checklist to address the aforementioned major research questions (Fig. 2).

3.1. Data Collection

The search engines Google Scholar, PubMed, PubMed Central and Scopus, as well as various journal databases such as ScienceDirect, Springer, Taylor & Francis were used in the present study. These databases were selected to screen literature about the use of STEM toys in kindergarten.

The time frame for literature collection was 14 years from 2010 to 2024. The reason behind the initiation of this study in 2010 was a fact that in the second decade of 2000s, development of STEM toys for kindergarten children came into existence.

Keywords including: "STEM toys OR STEM coding kits OR STEM science kits OR STEM Education" AND (Kindergarten OR Kindergarten Institute OR Early Childhood Centre) AND (Teachers OR Teaching) were used to screen various studies pertaining to the present investigation.

3.2. Methodology adopted for the analysis of the selected papers

The analysis of selected papers in the manuscript was conducted using a narrative synthesis and thematic analysis approach. The systematic review followed a rigorous selection and rejection process to ensure the inclusion of relevant studies. The detailed summary is as follows.

3.2.1. Selection and rejection criteria

3.2.1.1. Selection criteria. The study focuses on kindergarten children, specifically those aged 4–6 years. It examines teacher perspectives on the use of STEM toys within this age group. The study must be written in English and presented as an article. Additionally, it should be published in a peer-reviewed journal or as part of peer-reviewed conference proceedings.

3.2.1.2. Rejection criteria. Studies that do not pertain to the kindergarten context, i.e., those involving children outside the 4 to 6 age range, will be excluded. Additionally, studies that describe activities conducted solely by researchers without teacher involvement are not considered. Articles that have not undergone peer review are also excluded. Moreover, studies that are meta-analyses or discourse analyses, as well as those that are chapters within a book, do not meet the criteria for

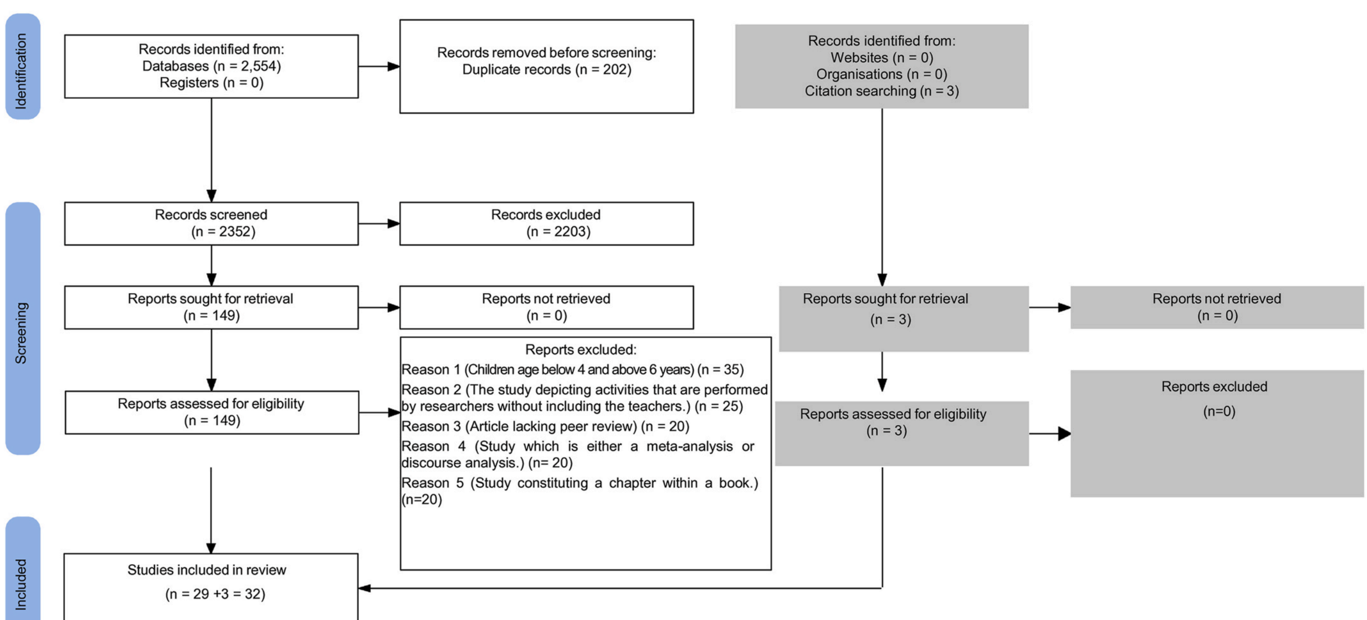

Fig. 2. PRISMA 2020 flow diagram depicting the process for new systematic reviews, incorporating searches of databases and citations (Haddaway et al., 2022).

inclusion.

3.2.2. Identification and screening

The identification phase involved searching databases, resulting in 2554 records, from which 202 duplicates were removed. In the screening phase, 2352 records were evaluated, and 2203 were excluded. All 149 reports sought for retrieval were successfully retrieved. After assessing these reports for eligibility, 120 were excluded for various reasons, such as context mismatch, lack of teacher involvement, and absence of peer review. Ultimately, 29 studies were included in this phase.

3.2.3. Additional records

In addition to the primary search, three records were identified through citation searching. All three studies were screened, retrieved, and deemed eligible, resulting in a total of 29 + 3 = 32.

3.2.4. Data mining and analysis

This study employed narrative synthesis and thematic analysis. It scrutinised collected studies across various dimensions, including methodology, instruments, areas of interest, types of activities, participant count, study duration, materials, training, pedagogical approaches, teachers' perspectives, and anticipated skills acquired by the children. To ensure thoroughness and consistency, the analysis was carefully reviewed and approved at each stage by the author. Data extracted from the 32 studies as presented in Fig. 3., Fig. 4 and Fig. 5 present the research inquiries.

3.2.5. Descriptive statistics and findings

The descriptive statistics of the selected studies revealed a diverse geographical distribution, with 15 countries. Most studies were published in the last four years, peaking in 2020. The studies included 17 qualitative, 8 quantitative, and 7 mixed-methods research designs. The number of teachers involved in these studies ranged from 1 to 150, with most studies involving 1–10 teachers. Similarly, the number of students ranged from 1 to 150, with most studies involving 41–50 students.

This structured approach ensured a thorough and systematic review of the literature, providing a solid foundation for understanding the impact of STEM toys on early childhood education from a pedagogical perspective.

3.3. Use of artificial intelligence (AI) tools

AI tools were employed to aid the systematic literature review process. The primary AI tools used were Zotero Software, R Discovery Platform, and Rayyan Software.

3.3.1. Zotero Software

Zotero Software was used to manage the references and avoid duplication when downloading full texts from various journal databases. This tool helped streamline the organisation and management of bibliographic data, ensuring that the author could efficiently handle several references without redundancies(Courraud, 2014).

3.3.2. The R Discovery Platform

The R Discovery Platform, which is an AI-driven literature survey tool, was used to perform extensive literature searches. This platform provides a comprehensive database of scientific publications and facilitates the identification of relevant papers based on topic-specific keywords. It was notably effective in analysing papers using keyword searches and contributed significantly to the literature screening process by quickly narrowing down a vast array of potential sources (Secinaro et al., 2021).

3.3.3. Rayyan Software

Rayyan Software was another AI tool used in the study. It was used to import and screen the literature. Rayyan aided in the systematic review by allowing the researchers to screen papers based on their titles and abstracts, facilitating the selection and rejection process according to predefined criteria. This tool streamlined the initial screening process, thereby making it more efficient and systematic(Van Der Mierden, 2019).

Collectively, these AI tools enhanced the efficiency and accuracy of the systematic review by managing the references, conducting comprehensive literature searches, and streamlining the screening process(Van Dijk et al., 2023).

In the present study, the selection and rejection criteria were very specific, focusing solely on kindergarten children (ages 4–6) and teacher perspectives on the use of STEM toys. This narrow focus naturally limited the number of eligible studies. The studies needed to depict activities performed in a real classroom setting by teachers, rather than

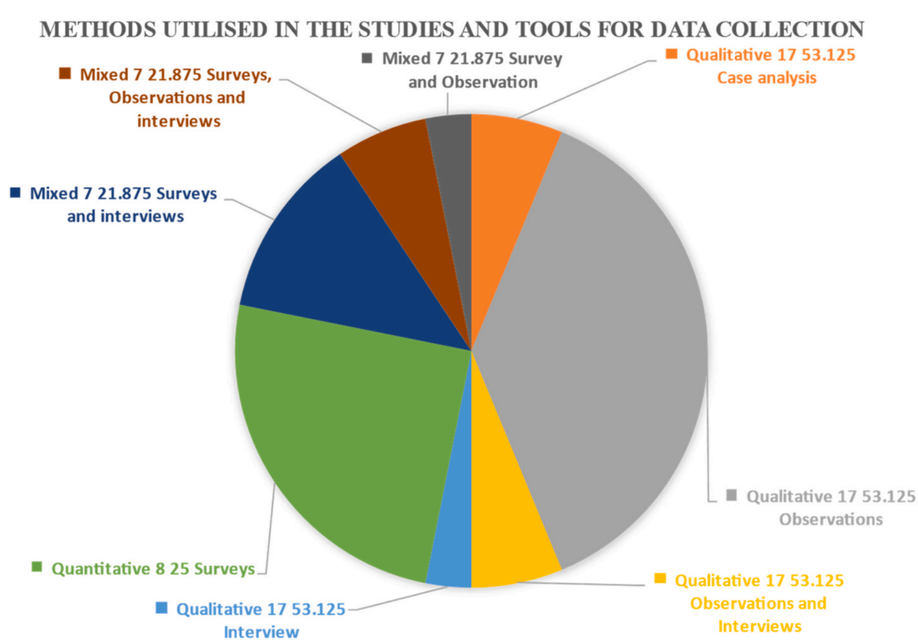

Fig. 3. Methods utilised in the studies and tools for data collection.

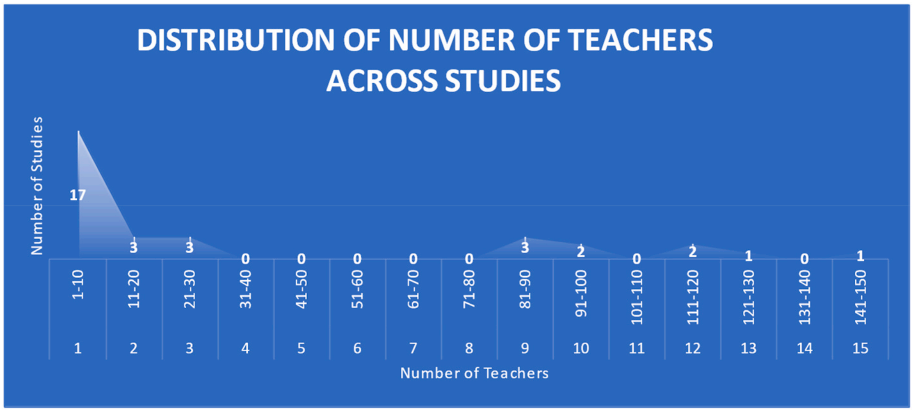

Fig. 4. Distribution of Number of Teachers across studies.

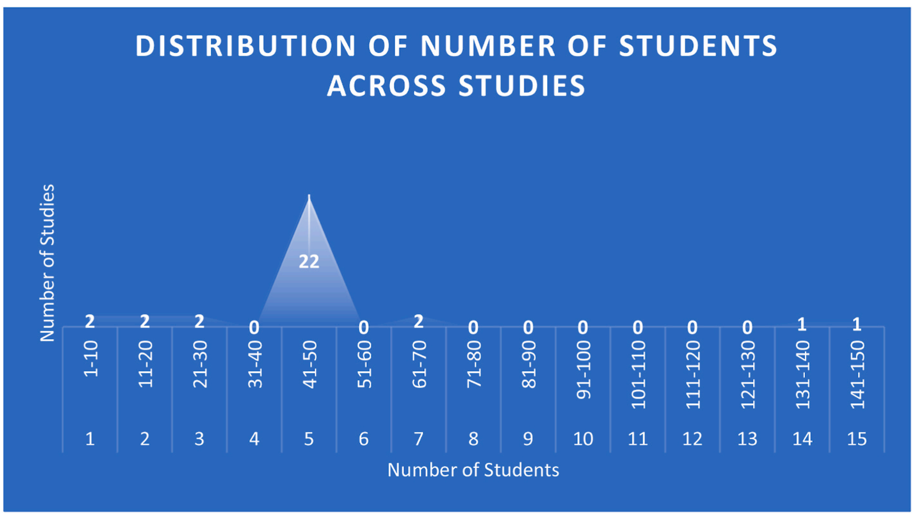

Fig. 5. Distribution of Number of students across studies.

by researchers or in a controlled experimental environment. This further limited the number of suitable papers. Although AI tools facilitated the initial stages of literature search and management, the final validation and consensus on the included studies required thorough manual review by the author. Each stage involved careful consideration and decision-making to ensure that only relevant and high-quality studies were selected. The exclusion of non-peer-reviewed articles, meta-analyses, discourse analyses, and book chapters further refined the selection.

Thus, the combination of strict criteria, high relevance and quality standards, the need for context-specific studies, and the requirement for manual validation contributed to the limited number of papers analysed, despite the use of AI tools.

3.4. Criteria for selecting final 32 studies

The detailed explanation of the criteria used to select the final 32 studies is as follows and is explained in Fig. 2. In Part A, during the identification phase, 2554 records were identified from the databases, and 202 duplicate records were removed. In the screening phase, 2352 records were screened, and 2203 were excluded. Out of the 149 reports sought for retrieval, all were successfully retrieved. During the eligibility phase, 149 reports were assessed for eligibility. However, several reports were excluded for various reasons: 35 studies had a context not corresponding to kindergarten (i.e., children below the age group of 4–6), 25 studies depicted activities performed by researchers without involving teachers, 20 articles lacked peer review, 20 studies were either meta-analyses or discourse analyses, and 20 studies constituted chapters within books. Ultimately, 29 studies were included in the review. In Part B, three records were identified through citation search, but none were identified from registers, websites, or organisations. All three records were screened, and none were excluded. All three reports sought for retrieval were successfully retrieved and assessed for eligibility. All three were included in the review. In total, 29 studies from Part A and 3 studies from Part B were included in the final review, resulting in **29 + 3 = 32 studies.**

4. Findings of the research

4.1. Common traits and statistical descriptions of selected studies

Common traits and statistical descriptions of the 32 selected studies were analysed. The findings revealed notable diversity in global representation, including 15 distinct countries. The papers from different countries were from the United States (6 studies), Canada (5 studies), the United Kingdom (3 studies), China (2 studies), Germany (2 studies), and Japan (1 study).

Although the timeframe selected for the present study was from 2010 to 2024, however the findings were confined to the study publications predominantly within the last four years, with a peak of publication in the year 2020. However, it is worth noting that the representation of 2024 is limited because it only includes data for the first 3 months of the year.

The study of the present context involved 17 papers of qualitative nature however 8 papers of quantitative nature were employed in the present investigation (Fig. 3).

For the study, a total of teachers ranging from 1 to 150 was considered, and 17 studies were in the range of 1–10 as the number of teachers. Among the studies conducted, total 7 did not have role of teachers. Three were considered most frequent as it appeared three times. Findings are presented in Fig. 4.

When students' perspectives were taken into consideration, the number of students varied from 1 to 150. In total, 22 studies were falling within the category 41–50. Among the studies, total 8 studies were of such type in which zero involvement of students was reported. The observations are presented in Fig. 5.

The reported learning outcomes in studies involving smaller groups of teachers and students tend to highlight more positive outcomes, including enhanced cognitive abilities like problem-solving and critical thinking, as well as improved social-emotional skills such as communication and collaboration. The studies suggest that small to medium group sizes (4–6 students per teacher) are optimal for STEM toy activities, as they strike a balance between fostering collaboration and allowing individualized teacher support, maximizing the effectiveness of learning outcomes.

In larger groups, teachers may face challenges in providing individualized attention, leading to more surface-level engagement and fewer opportunities for deep, exploratory learning. As a result, learning outcomes in larger group settings may focus more on basic knowledge acquisition rather than advanced problem-solving and critical thinking. Therefore, the optimal group size for STEM toy activities is likely smaller to medium-sized groups, where teachers can engage closely with students and scaffold learning effectively.

In the present study, typological diversity was taken under consideration and for the same reason, it was noticed as difficult to compile the information about the time period of studies and specific activities in a meaningful manner that was meaningful within the broader context.

The subsequent section presents an insight into the synthesis of the findings derived from the analysis of the 32 studies, aligning them with their respective research questions.

The research questions in the present study are as follows:

Q1. What perspectives do kindergarten teachers hold regarding STEM toys?

In order to investigate the research query, the author examined the 21 articles selected for the literature review, which focused on kindergarten teachers' perspectives regarding the integration of STEM toys into their classrooms.

In research conducted by several researchers *viz.* (Aldemir & Kermani, 2017; He et al., 2021; Rasyid et al., 2021; Samara & Kotsis, 2023; Torres-Crespo et al., 2014), it was observed that teachers acknowledged the importance and advantages of integrating STEM toys into the kindergarten curriculum. Teachers have also confirmed that STEM toys can help students teach various subjects (Pollard et al., 2018). The approach characterized by its independence from the previous knowledge of teachers irrespective of their nature.

On the basis of research conducted by six researchers (Geng et al., 2019; Giamellaro & Siegel, 2018; Hamad et al., 2022; Ramli et al., 2017; Saçkes, 2014; Tao, 2019) it was observed that teachers were prepared to implement and utilise STEM toys despite lacking expertise or targeted experience.

Regarding teachers' perceptions of their own abilities, 2 studies (Lestari & Kurniati, 2021; Nikolopoulou & Tsimperidis, 2023) portrayed teachers as sufficiently autonomous and confident in their capacity to use STEM toys for teaching.

In 2 studies done by researchers in the education field, it was observed that (Barak, 2014; Drigas & Kokkalia, 2014), teachers initially expressed uncertainty regarding their use of technology in teaching. However, they subsequently reported feeling optimistic about its utilisation after receiving proper training and having experience teaching with technology.

In 2 other studies (Evagorou, 2024; Hasanah et al., 2021) supportive training for teachers implementing STEM toys in kindergartens emerged as a crucial factor in enhancing their overall confidence.

In another study (Leung & Hu, 2019), kindergarten teachers stated the requirement for training, materials, curriculum, infrastructure, and technical support that are necessary to ease the integration of play with STEM toys in kindergarten settings. Notably, few studies (Martínez-Borreguero et al., 2022; Yıldırım et al., 2022) have reported negative aspects from the teachers' perspectives regarding teaching with STEM toys in kindergarten.

Various recommendations did arise to bolster faculty members' confidence and ensure adequate preparation for incorporating STEM toys into their kindergarten teaching endeavours.

This could be linked to the voluntary nature of the recruitment process for teachers participating in the study—specifically, either as a self-selected sample or as volunteers (Chaisri Khureerung & Thao-Do, 2022), teachers who are eager to participate in research activities to learn effectively about STEM toys so that they implement their learning while teaching kindergarten children (Keung et al., 2020) or teachers with previous experience in teaching via STEM toys (Lestari & Kurniati, 2021) or those committed to larger STEM projects (Shumway et al., 2023).

Q2. What pedagogical approaches do kindergarten teachers employ to facilitate children's engagement with STEM toys?

Out of 32 studies, 30 outlined diverse pedagogical strategies which were utilised for integrating activities involving STEM toys in kindergarten classrooms. The research confirmed the utilisation of various pedagogical strategies, with an emphasis on flexibility in incorporating STEM toys, delivering contextually relevant pedagogy, and possibly leveraging technology. Fig. 3 depicts each study, providing a comprehensive list of the teachers' pedagogical approaches, which encompass numerous techniques grouped into respective categories, as detailed below.

4.2. Interactive scaffolding

The present study suggests that "Interactive scaffolding" involves active teacher engagement to facilitate children's learning experiences, particularly in STEM contexts. This includes tailored scaffolding personalized to individual students and, fostering critical thinking and problem-solving skills. For instance, the use of open-ended questions to encourage exploration and autonomous learning is highlighted as a key strategy under this approach. The concept of interactive scaffolding aligns with Vygotskian theories of social constructivism, in which learning is seen as a socially mediated process. The emphasis on teacher-student interactions and the co-construction of knowledge reflects this theoretical orientation. The author is influenced by these theories, which emphasize the importance of social interaction in learning.

Furthermore, in one study it was observed that analysing both student and teacher discourse during engineering design tasks in kindergartens can offer valuable insights into the interactions that take place during STEM activities, thereby contributing to skill development (Tank et al., 2018). Moreover, in another study, it was examined how kindergarten teachers coordinate mathematical activities facilitated by technology, emphasising the roles of agency and mediation in teaching practises. Understanding how teachers organise activities with STEM toys can provide valuable insights into skill development through interactive demonstrations (Carlsen et al., 2016).

Another approach involved is questioning and prompting, where teachers generally ask open-ended questions with the aim of providing prompts to encourage children's exploration, problem-solving, and reasoning skills. For instance (Nayfeld et al., 2011), found that teachers' use of open-ended questioning during STEM activities can promote children's autonomous exploration and learning.

4.2.1. Critical aspects of "interactive scaffolding"

Interactive scaffolding is claimed for developing cognitive and socio-emotional skills, although variables can restrict its use. It requires instructor skill and continual monitoring of each child's growth trajectory, which can be problematic in high-student-teacher ratio settings. Teachers may need training on interactive scaffolding, especially when integrating new STEM technologies or toys. Some teachers may struggle to adapt this strategy to diverse learners with different developmental stages, learning styles, and cultural backgrounds, resulting in inconsistent learning outcomes (Belland et al., 2017). Teachers may only employ scaffolding superficially in large classrooms since they cannot provide individualized help (Eshach et al., 2011).

Another key problem is equity. Interactive scaffolding is personalized, but children from low-income households or without STEM toys at home may struggle to keep up with others who have greater STEM experience outside of class. Teachers uninformed of educational disparities may widen them (Clements et al., 2021). Teacher-led scaffolding may inhibit children's spontaneous, imaginative play, which is essential for growth(Friedrich et al., 2018).

4.3. Scaffolding using visual aids and physical demonstration

This category includes methods in which teachers use visual resources and physical demonstrations to enhance student understanding. This approach makes abstract ideas more tangible and accessible, especially for young learners. The use of visual aids and demonstrations is a common pedagogical strategy, particularly in STEM education. This reflects a belief in the effectiveness of multimodal teaching strategies in addressing diverse learning styles. The emphasis on visual and physical aids could be tied to theories that support experiential and hands-on learning.

Research has revealed that visual aids play a significant role in the learning process. By incorporating visual resources and physical demonstrations, teachers can develop students interest and engage children in exploring STEM concepts, including evolution and adaptation, leading to a deeper understanding of scientific principles (Walldén & Larsson, 2024).

Incorporating interactive visual aids, such as 3D animations and dynamic visualisations, can offer children immersive learning experiences that stimulate curiosity and creativity, ultimately aiding in the development of critical thinking skills and problem-solving abilities through hands-on exploration and experimentation. These tools not only enhance engagement with STEM concepts but also foster a deeper understanding of complex scientific principles (Belli et al., 2024).

This pedagogical approach aims to make abstract STEM concepts more tangible and accessible to young learners by providing visual representations and hands-on experiences (Jourdain & Sharma, 2016). These techniques also benefit children who struggle with verbal expression or lack confidence in approaching teachers, the process enabled them to explore and understand STEM concepts independently (Jourdain & Sharma, 2016).

Recent research has discussed the impact of specific gestures on children's skill development, highlighting the importance of interactional resources in aiding children's comprehension of target constructions (Tozlu Kılıç & Balaman, 2023). Furthermore, by leveraging technology-mediated inquiry and model-based lessons, it can be observed that teachers can help children reimagine the world around them and help them develop a deeper understanding of scientific concepts (Samarapungavan et al., 2023).

The importance of teacher-child interactions, using modelling and demonstration, in fostering children's academic, language, and social-emotional gains in prekindergarten classrooms was highlighted (Pentimonti et al., 2010).

4.3.1. Critical aspects of "Scaffolding Using Visual Aids and physical demonstration"

While visual aids and practical demonstrations in scaffolding can enhance learning, they also present notable drawbacks. Excessive reliance on visual aids may impair children's verbal communication skills and limit autonomous problem-solving, as they can overly simplify complex topics and discourage verbal reasoning. Effective cognitive development requires a balanced use of visual aids alongside activities that promote language skills and verbalization (Stadskleiv et al., 2018). Although 3D animations and dynamic visualizations can spark creativity and curiosity as stated earlier, they may overwhelm younger children, who often lack the cognitive maturity to grasp abstract STEM concepts (Forbes et al., 2021). To avoid confusion, teachers must select visual aids suited to children's developmental stages, ensuring they do not hinder hands-on exploration—an activity crucial for fine motor skill development, creativity, and independent thinking.

Accessibility challenges further complicate the use of advanced visual aids and technology-based demonstrations. Kindergartens with limited funding or inadequate technology infrastructure may struggle to provide such resources, exacerbating educational disparities between socioeconomic groups (Ip et al., 2016). Additionally, if not carefully integrated, physical demonstrations and visual aids can encourage passive learning, where kindergarten children become mere observers rather than active participants (Jarraya et al., 2019).

4.4. Relationships between variables and comparison of different pedagogical approaches

In exploring relationships between variables and comparing different pedagogical approaches, we can examine how teaching strategies like Interactive Scaffolding and Scaffolding Using Visual Aids and Physical Demonstration impact learning outcomes and children development in early STEM education. Interactive Scaffolding is particularly effective for fostering problem-solving and critical thinking, allowing children to engage in exploratory learning through open-ended questions and feedback. This method encourages autonomy and deep cognitive processing, with teacher guidance gradually reducing as students take more responsibility for their learning, thereby enhancing their cognitive abilities (Stright et al., 2009). In contrast, Scaffolding Using Visual Aids is better suited for building foundational knowledge, supporting spatial reasoning and motor skills by making abstract concepts tangible through models and diagrams. This method facilitates sensory-rich learning but may limit deeper cognitive engagement without supplementary interactive activities (Park, 2022). Socially, Interactive Scaffolding promotes collaboration and communication more effectively by encouraging peer interaction and group problem-solving, which fosters skills like teamwork, empathy, and negotiation (Morcom, 2014). Scaffolding with Visual Aids, on the other hand, emphasizes individual comprehension and may result in more passive learning unless integrated with interactive questioning(Pesco & Gagné, 2017). In terms of engagement and motivation, Interactive Scaffolding fosters intrinsic motivation as children are actively involved in their learning, making decisions and learning through trial and error, which supports a growth mindset(Fund & Madjar, 2018). Scaffolding with Visual Aids, while engaging for visual learners, is more teacher-directed and may not promote the same level of self-directed motivation (Van Uum et al., 2017). Interactive Scaffolding also excels in promoting knowledge transfer and deep learning, as children apply learned concepts across different contexts and develop metacognitive skills (Copp et al., 2019). In contrast, Scaffolding Using Visual Aids tends to support surface-level learning, aiding in knowledge retention but potentially limiting broader application of concepts (Walldén & Larsson, 2024). Teacher expertise is a key variable in both approaches. Interactive Scaffolding requires teachers to assess and adjust support based on each child's progress, making it resource-intensive (Eshach et al., 2011), while Scaffolding Using Visual Aids is more accessible in terms of teacher workload, making it useful in classrooms with larger class sizes. However, its effectiveness may be reduced without the integration of interactive strategies (Van De Pol et al., 2015).

Q3. What is anticipated as outcomes that are associated with children's skill development following their interaction with STEM toys?

To explore the pedagogical approaches of kindergarten teachers related with use of STEM toys, the author examined relevant skills in children when applicable. In this process, 22 studies on the development of children's skills were noted. Among them, 18 studies observed such development, while 3 studies anticipated such development. When we say "anticipated," We are generally referring to studies that identified a change in children's skills, whereas by "expected," we mean studies that reported teachers' perspectives on the potential development of children's skills.

Significantly, among the 18 studies that observed these skills, 12 studies utilised a qualitative approach, implying that skill variation was not determined using quantitative instruments. Out of the remaining 6 studies, 4 studies employed mixed methods, while only 2 used a quantitative method. Regarding studies anticipating the development of children's, 2 studies used quantitative methods and 1 study used qualitative methods. However, studies that employed quantitative methods relied on data gathered from surveys conducted with teachers.

Based on the studies included, the author investigated whether different skills are acquired by children through the use of STEM toys. The author categorised these findings into two primary groups; those related to cognitive skills and those related to socio-emotional skills.

Cognitive skills typically encompass mental abilities (Zhou, 2022), while social and emotional skills pertain to the capacity to regulate thoughts, emotions, and behaviours (Roberton et al., 2012).

Unlike to cognitive abilities like literacy or numeracy, social and emotional skills primarily focus on individuals' management of emotions, self-perception, and interactions with others, rather than solely indicating their innate ability to process information to students (Kovas et al., 2013; Lopes et al., 2011; Van Kleef, 2010).

It is to state that within socio-emotional skills and collaboration, communication stands out as the most prominently nurtured attributes attribute of students through the engagement in STEM toy activities. It was observed that the gendered packaging of STEM toys can influence children's play and learning outcomes, indicating that toy design and marketing can affect how children engage with STEM concepts, as found by (Coyle & Liben, 2020). Certain modes of play, including block play, can promote spatial skill development, which is essential for success in STEM fields, highlighting that interactions with specific types of STEM toys can contribute to the development of skills crucial for STEM disciplines, as suggested by (Coyle & Liben, 2016).

5. Analysis of effectiveness of various approaches to specific learning outcomes

Although each approach—teacher-led instruction, guided exploration, and collaborative activities—offers distinct benefits for STEM learning outcomes, their effectiveness can be maximised when strategically combined to create engaging and comprehensive learning experiences for kindergarten students. It is important to observe how well different methods, like teacher-led instruction and group activities, work. These methods can help students learn certain things when used together in STEM education (Eckhoff, 2017). Alternatively, guided exploration is more effective because it enables students to discover concepts through hands-on exploration and experimentation. This fosters creativity, enhances problem-solving abilities, and facilitates more profound comprehension through exploration(Hollenstein et al., 2022). Guided exploration is particularly well-suited to subjects that require exploration and discovery, such as exploratory coding projects and biology experiments. Overall, the effectiveness of each approach—teacher-led instruction, guided exploration, and collaborative activities—can be optimised by strategically combining them to create comprehensive and engaging learning experiences for students, even though each approach offers distinct benefits for STEM learning outcomes(Cravens & Hunter, 2021; Eckhoff, 2017). STEM toys are beneficial because they provide a stimulating environment that encourages the development of cognitive and socio-emotional skills in children through hands-on exploration, experimentation, and problem-solving activities. These skills are beneficial for academic excellence as well as for preparing children for future challenges in this scenario. These abilities not only facilitate academic success, but also equip children with the necessary skills to confront future obstacles in a rapidly changing world where STEM literacy and skills are critical(Garner et al., 2018).

6. Practical recommendations for teachers

To effectively use STEM toys to promote learning and development in kindergarten classrooms, teachers can adopt various practical strategies (Leung & Hu, 2019). First, they should assume the roles of facilitators and mediators, encouraging children to explore STEM toys independently and with their peers. For instance, by using building sets like LEGO Mindstorms, teachers can ask open-ended questions that prompt children to think critically and solve problems creatively(Wijaya et al., 2010). Additionally, they should promote experimentation by encouraging children to try different solutions and learn from their failures. With chemistry sets like Thames & Kosmos Chem C3000, teachers can guide children through safe experiments, and encourage them to hypothesise and test outcomes (Fahrenkamp-Uppenbrink, 2015). Promoting collaborative work is another essential strategy. Teachers can implement group activities that require children to work together, share ideas, and solve problems collectively(Zhang et al., 2010). Using coding toys like Ozobot Bit, teachers can assign group tasks where each child plays a specific role, fostering teamwork and communication skills (Shumway et al., 2023). Teachers can incorporate STEM toys into hands-on activities, setting up stations with different toys like puzzles, building sets, and electronic kits, allowing children to rotate and experience various STEM concepts through play (Leung & Hu, 2019). Additionally, STEM toys can complement thematic units. During a space unit, for example, teachers can use building sets to construct rockets or planets, integrating STEM concepts with other subjects like literacy and art. Developing a growth mindset in children is vital(Hachey et al., 2022). Teachers should encourage a classroom culture in which challenges are seen as opportunities for growth. When children encounter difficulties with STEM toys, paise for their efforts and perseverance helps them develop resilience and a positive attitude towards problem-solving(Leung & Hu, 2019). Furthermore, creating opportunities for children to reflect on what went wrong and how they can improve is important. After a failed experiment, teachers can facilitate discussions on alternative approaches and lessons learned. An inclusive learning environment is essential(Donaldson, 2019). Teachers should provide various STEM toys that cater to different interests and abilities. For example, while some children may prefer building sets, others may be more engaged with coding toys or electronic kits(Leung & Hu, 2019; Shumway et al., 2019). Selecting STEM toys that reflect the diverse backgrounds of the children in the classroom ensures that all children see themselves as represented and feel included(Sanders & Downer, 2012). Professional development for teachers is also necessary. By implementing these strategies, teachers can effectively use STEM toys to enhance children's cognitive, socio-emotional, and developmental skills, supporting early STEM education and preparing children for future academic success in a rapidly evolving digital society.

7. Examples of effective use of STEM toys

Effective use of STEM toys in classrooms can significantly enhance children's learning and development(Leung & Hu, 2019). For example, building sets like LEGO Mindstorms allow children to build and programme robots, which helps them develop engineering principles and robotics skills (Afari et al., 2017). Coding toys such as Ozobot Bit allow children to use colour-coded markers to create paths for the robot, thereby introducing them to basic programming concepts. Teachers can challenge students to create complex paths or solve mazes, to enhance their logical thinking and sequencing skills. This hands-on approach helps children understand coding in a tangible and engaging manner (Shumway et al., 2019). Chemistry sets like Thames & Kosmos Chem C3000 provide children with the opportunity to conduct safe and engaging chemistry experiments. Through these experiments, children learn about chemical reactions and scientific methods (Fahrenkamp-Uppenbrink, 2015). Teachers can guide experiments related to classroom themes, such as creating simple volcanoes during a geology unit, thus making the learning experience relevant and exciting (Utami et al., 2022). These practical applications of STEM toys in the classroom can greatly contribute to children's cognitive and socio-emotional development, fostering deeper interest in science and technology.

8. Conclusion

The present systematic literature review identified the various pedagogical approaches used by kindergarten teachers to facilitate children's play with STEM toys, including the roles of facilitators and mediators, promoting collaborative work, and encouraging experimentation and learning from failure. The present study concluded that the utilisation of STEM toys in kindergarten classrooms can enhance children's cognitive skills and socio-emotional skills. The research included studies from different countries, with a peak of publication in 2020, suggesting enhanced interest in the present topic. The search for relevant articles was conducted using various databases resulting in 2352 peer-reviewed articles. The selection process resulted in 32 relevant studies being included in the review, meeting quality standards and providing comprehensive findings. This study employed a narrative synthesis and thematic analysis to analyse the findings of the selected studies.

The findings of this systematic review highlight the various pedagogical approaches used by kindergarten teachers to facilitate children's engagement with STEM toys, promoting positive cognitive and socio-emotional development. However, it is important to acknowledge certain limitations that temper the overall positive portrayal of STEM toys in early education. One significant concern is the risk of reinforcing gender stereotypes, as many STEM toys are marketed primarily towards boys, which could limit their appeal to girls and perpetuate gender biases in STEM fields. Additionally, the complexity of some STEM toys may overwhelm younger children, leading to frustration and disengagement rather than fostering curiosity and problem-solving skills.

Finally, while the focus on teachers' perspectives provides valuable insights, it limits the generalizability of the findings to other educational contexts or student age groups. Further research is needed to explore the broader implications of STEM toy use, particularly in diverse socio-economic settings and across different cultural contexts. Addressing these drawbacks and limitations is crucial to ensure that the integration of STEM toys in early childhood education is both equitable and effective in fostering holistic child development.

The future scope and potential of STEM toys for children aged 4 to 6 in kindergarten settings are promising, as these educational tools increasingly gain recognition for their role in fostering early cognitive development and engagement in STEM. STEM toys are designed to provide hands-on, immersive learning experiences that stimulate both sides of the brain, promoting logical reasoning and creativity simultaneously. By encouraging children to explore concepts such as basic physics, engineering principles, and problem-solving through play, these toys help develop critical skills that are essential for future learning and career opportunities. Moreover, STEM toys facilitate social interaction and collaboration among peers, because children often work together to build and create, thereby enhancing their social and emotional intelligence. The integration of technology into these toys, such as coding and interactive elements, further enriches the learning experience, making it adaptable to individual learning styles. However, challenges such as accessibility and the need to combat gender stereotypes in STEM fields remain crucial for ensuring that all children benefit from these educational resources.

When emphasising on limitations and drawbacks of STEM toys, it is crucial to consider the various biases and limitations that may arise in teachers' pedagogical methods and viewpoints. Historically, STEM toys have often been marketed primarily towards boys, potentially reinforcing gender stereotypes about the suitability of certain subjects and activities. This bias can inadvertently influence teachers' encouragement of specific children to engage with these toys. Moreover, STEM toys may reflect western cultural norms, creating a misalignment with the students' diverse backgrounds and overlooking the importance of incorporating various cultural perspectives on education and play. Kindergarten teachers often face time constraints and must balance multiple curricula demands, which can shape their perspectives on integrating STEM learning activities into their teaching. Although these toys offer numerous benefits for children aged 4 to 6, they also have notable limitations. Some may be too complex for the target age group, leading to frustration rather than engagement.

Furthermore, the literature review's selection criteria and methodology may have introduced certain limitations, such as the exclusion of non-English articles and studies published before 2010. Addressing these biases and limitations is essential to ensure effective and inclusive use of STEM toys in early childhood education, maximizing their developmental potential and promoting equitable access for all children. This systematic review embarks on kindergarten teachers' STEM toy engagement strategies to promote cognitive and socio-emotional development. However, there are constraints that temper the positive representation of STEM toys in early education. Many STEM toys are marketed to boys, which may limit their attraction to girls and reinforce STEM gender biases. The complexity of some STEM toys may frustrate and disengage younger children, rather than encouraging curiosity and problem-solving.

11. Selection and participation of children

The systematic literature review emphasizes the importance of involving children in activities that revolve around STEM (Science, Technology, Engineering, and Mathematics) toys, as well as the significance of their participation in such activities. The analysis demonstrates that kindergarten teachers have a crucial function in this procedure, serving as facilitators and mediators to direct children's engagements with these instructional playthings. Teachers facilitate cooperative endeavors among students, motivating them to engage in experimentation and derive knowledge from their setbacks, thereby cultivating an atmosphere conducive to the growth of analytical reasoning and the acquisition of problem-solving abilities. The review, which carefully selected 32 significant studies from a pool of 2352 peer-reviewed articles, shows that teachers generally have a positive view of integrating STEM toys. They observe significant benefits for children's cognitive and socio-emotional development. To optimize these advantages, the study emphasizes the importance of providing thorough teacher training in efficient methodologies, ensuring that the use of STEM toys is both influential and beneficial to children's cognitive development.

Data availability statement

All relevant data have been cited in the manuscript. No new data generated since this is a review article.

Funding

No funding was received to assist with the preparation of this manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The author would extend his sincere gratitude to the management of IFTM University, Moradabad, for their invaluable support and assistance in crafting the review article.

Data availability

The authors do not have permission to share data.

References

Abu Khurma, O., Al Darayseh, A., & Alramamneh, Y. (2022). A framework for incorporating the "learning how to learn" approach in teaching STEM education. *Education Sciences, 13*(1), 1. https://doi.org/10.3390/educsci13010001

Aguilera, D., & Ortiz-Revilla, J. (2021). STEM vs. STEAM education and student creativity: A systematic literature review. *Education Sciences, 11*(7), 331. https://doi.org/10.3390/educsci11070331

Aldemir, J., & Kermani, H. (2017). Integrated STEM curriculum: Improving educational outcomes for Head Start children. *Early Child Development and Care, 187*(11), 1694–1706. https://doi.org/10.1080/03004430.2016.1185102

Alexandre, S., Xu, Y., Washington-Nortey, M., & Chen, C. (2022). Informal STEM learning for young children: A systematic literature review. *International Journal of Environmental Research and Public Health, 19*(14), 8299. https://doi.org/10.3390/ijerph19148299

Alme, H., & Reime, M. A. (2021). Nature kindergartens: A space for children's participation. *Journal of Outdoor and Environmental Education, 24*(2), 113–131. https://doi.org/10.1007/s42322-021-00081-y

Ashar, A., & Idamayanti, R. (2023). The concept learning science skills in kindergarten age children. *ARRUS Journal of Social Sciences and Humanities, 3*(3), 360–369. https://doi.org/10.35877/soshum1893

Balakrisnan, V.-. (2023). Maker-centred learning approach to craft STEM education in primary schools: A systematic literature review. *ASM Science Journal, 18*, 1–9. https://doi.org/10.32802/asmscj.2023.1430

Barak, M. (2014). Closing the gap between attitudes and perceptions about ICT-enhanced learning among pre-service STEM teachers. *Journal of Science Education and Technology, 23*(1), 1–14. https://doi.org/10.1007/s10956-013-9446-8

Basso, M., & Innocenti, G. (2015). Lego-bike: A challenging robotic lab project to illustrate rapid prototyping in the mindstorms/simulink integrated platform. *Computer Applications in Engineering Education, 23*(6), 947–958. https://doi.org/10.1002/cae.21666

Belland, B. R., Walker, A. E., & Kim, N. J. (2017). A bayesian network meta-analysis to synthesize the influence of contexts of scaffolding use on cognitive outcomes in STEM education. *Review of Educational Research, 87*(6), 1042–1081. https://doi.org/10.3102/0034654317723009

Belli, D., Lischi, G., Pardini, G., Milazzo, P., & Domenici, V. (2024). A free interactive digital tool to introduce particle model of matter and thermal particle motion at middle school level. *Journal of Chemical Education, 101*(2), 647–652. https://doi.org/10.1021/acs.jchemed.3c00986

Carlsen, M., Erfjord, I., Hundeland, P. S., & Monaghan, J. (2016). Kindergarten teachers' orchestration of mathematical activities afforded by technology: Agency and mediation. *Educational Studies in Mathematics, 93*(1), 1–17. https://doi.org/10.1007/s10649-016-9692-9

Çetin, M., & Demircan, H.Ö. (2020). Empowering technology and engineering for STEM education through programming robots: A systematic literature review. *Early Child Development and Care, 190*(9), 1323–1335. https://doi.org/10.1080/03004430.2018.1534844

Chaisri Khureerung, A., & Thao-Do, T. P. (2022). Enhancing pre-service teachers' understanding of science teaching through STEM activities integrated inquiry learning with Thai context. *Journal of Educational Issues, 8*(2), 257. https://doi.org/10.5296/jei.v8i2.20030

Clements, D. H., Vinh, M., Lim, C.-I., & Sarama, J. (2021). STEM for inclusive excellence and equity. *Early Education & Development, 32*(1), 148–171. https://doi.org/10.1080/10409289.2020.1755776

Copp, S. B., Cabell, S. Q., & Invernizzi, M. A. (2019). Kindergarten teachers' use of writing scaffolds to support children's developing orthographic knowledge. *Literacy Research and Instruction, 58*(3), 164–183. https://doi.org/10.1080/19388071.2019.1617374

Courraud, J. (2014). Zotero: A free and open-source reference manager. *Medical Writing, 23*(1), 46–48. https://doi.org/10.1179/2047480614Z.000000000190

Coyle, E. F., & Liben, L. S. (2016). Affecting girls' activity and job interests through play: The moderating roles of personal gender salience and game characteristics. *Child Development, 87*(2), 414–428. https://doi.org/10.1111/cdev.12463

Coyle, E. F., & Liben, L. S. (2020). Gendered packaging of a STEM toy influences children's play, mechanical learning, and mothers' play guidance. *Child Development, 91*(1), 43–62. https://doi.org/10.1111/cdev.13139

Cravens, X. C., & Hunter, S. B. (2021). Assessing the impact of collaborative inquiry on teacher performance and effectiveness. *School Effectiveness and School Improvement, 32*(4), 564–606. https://doi.org/10.1080/09243453.2021.1923532

DeCaro, D. A., DeCaro, M. S., & Rittle-Johnson, B. (2015). Achievement motivation and knowledge development during exploratory learning. *Learning and Individual Differences, 37*, 13–26. https://doi.org/10.1016/j.lindif.2014.10.015

Donaldson, M. (2019). Harnessing the power of fantastic attempts: Kindergarten teacher perspectives on student mistakes. *The Journal of Educational Research, 112*(4), 535–549. https://doi.org/10.1080/00220671.2019.1598329

Dooma, J. L. E., Mantes, J., Misajon, R. M., De Mesa, J. R., Dandan, C. J. A., Santos, J. M., & Faustino, J. B. (2024). Development of MATH-erials for teaching numeracy in early childhood. *International Journal of Research Publication and Reviews, 5*(5), 5529–5542. https://doi.org/10.55248/gengpi.5.0524.1261

Drigas, A., & Kokkalia, G. (2014). ICTs in kindergarten. *International Journal of Emerging Technologies in Learning (iJET), 9*(2), 52. https://doi.org/10.3991/ijet.v9i2.3278

Eckhoff, A. (2017). Partners in inquiry: A collaborative life science investigation with preservice teachers and kindergarten students. *Early Childhood Education Journal, 45*(2), 219–227. https://doi.org/10.1007/s10643-015-0769-3

Eloy, A., Cruz, D., Thennakoon, K., & Grant, W. (2020). Buildagram: A constructionist environment for spatial reasoning. *Proceedings of the 2020 ACM interaction design and children conference*. Extended Abstracts. https://doi.org/10.1145/3397617.3402037

Eshach, H., Dor-Ziderman, Y., & Arbel, Y. (2011). Scaffolding the "scaffolding" metaphor: From inspiration to a practical tool for kindergarten teachers. *Journal of Science Education and Technology, 20*(5), 550–565. https://doi.org/10.1007/s10956-011-9323-2

Evagorou, M. (2024). Engaging kindergarten pre-service teachers in the design and implementation of STEM lessons. *Frontiers in Education, 9*, Article 1277835. https://doi.org/10.3389/feduc.2024.1277835

Fahrenkamp-Uppenbrink, J. (2015). A kid's guide to chemistry MEL chemistry starter kit: $73.80, individual sets: $11.95. https://doi.org/10.1126/science.aad9017.

Fojtik, R. (2017). The Ozobot and education of programming. *New Trends and Issues Proceedings on Humanities and Social Sciences, 4*(5). https://doi.org/10.18844/prosoc.v4i5.2666

Forbes, A., Falloon, G., Stevenson, M., Hatzigianni, M., & Bower, M. (2021). An analysis of the nature of young students' STEM learning in 3D technology-enhanced makerspaces. *Early Education & Development, 32*(1), 172–187. https://doi.org/10.1080/10409289.2020.1781325

Friedrich, N., Wishart, K., & Stagg Peterson, S. (2018). Supporting emergent writers through guided play in a kindergarten classroom. *Journal of Childhood Studies*, 58–64. https://doi.org/10.18357/jcs.v43i2.18578

Gallagher, D., & Grimm, L. R. (2018). Making an impact: The effects of game making on creativity and spatial processing. *Thinking Skills and Creativity, 28*, 138–149. https://doi.org/10.1016/j.tsc.2018.05.001

Garner, P. W., Gabitova, N., Gupta, A., & Wood, T. (2018). Innovations in science education: Infusing social emotional principles into early STEM learning. *Cultural Studies of Science Education, 13*(4), 889–903. https://doi.org/10.1007/s11422-017-9826-0

Geng, J., Jong, M. S.-Y., & Chai, C. S. (2019). Hong Kong teachers' self-efficacy and concerns about STEM education. *The Asia-Pacific Education Researcher, 28*(1), 35–45. https://doi.org/10.1007/s40299-018-0414-1

Giamellaro, M., & Siegel, D. R. (2018). Coaching teachers to implement innovations in STEM. *Teaching and Teacher Education, 76*, 25–38. https://doi.org/10.1016/j.tate.2018.08.002

Ha, V. T., Hai, B. M., Mai, D. T. T., & Hanh, N. V. (2023). Preschool STEM activities and associated outcomes: A scoping review. *International Journal of Engineering Pedagogy (iJEP), 13*(8), 100–116. https://doi.org/10.3991/ijep.v13i8.42177

Hachey, A. C., An, S. A., & Golding, D. E. (2022). Nurturing kindergarteners' early STEM academic identity through makerspace pedagogy. *Early Childhood Education Journal, 50*(3), 469–479. https://doi.org/10.1007/s10643-021-01154-9

Haddaway, N. R., Page, M. J., Pritchard, C. C., & McGuinness, L. A. (2022). *PRISMA2020*: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and Open Synthesis. *Campbell Systematic Reviews, 18*(2), Article e1230. https://doi.org/10.1002/cl2.1230

Hamad, S., Tairab, H., Wardat, Y., Rabbani, L., AlArabi, K., Yousif, M., Abu-Al-Aish, A., & Stoica, G. (2022). Understanding science teachers' implementations of integrated STEM: Teacher perceptions and practice. *Sustainability, 14*(6), 3594. https://doi.org/10.3390/su14063594

Hassan Ghandourah, E. S. (2022). *Effects of a proposed unit based on the STEM approach in developing fundamental science processes for kindergarteners in makah Al-mukarramah*. Education Research International. https://doi.org/10.1155/2022/4398637, 2022.

He, X., Li, T., Turel, O., Kuang, Y., Zhao, H., & He, Q. (2021). The impact of STEM education on mathematical development in children aged 5-6 years. *International Journal of Educational Research, 109*, Article 101795. https://doi.org/10.1016/j.ijer.2021.101795

Hollenstein, L., Thurnheer, S., & Vogt, F. (2022). Problem solving and digital transformation: Acquiring skills through pretend play in kindergarten. *Education Sciences, 12*(2), 92. https://doi.org/10.3390/educsci12020092

Ibáñez, M.-B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education, 123*, 109–123. https://doi.org/10.1016/j.compedu.2018.05.002

Ip, P., Rao, N., Bacon-Shone, J., Li, S. L., Ho, F. K., Chow, C., & Jiang, F. (2016). Socioeconomic gradients in school readiness of Chinese preschool children: The mediating role of family processes and kindergarten quality. *Early Childhood Research Quarterly, 35*, 111–123. https://doi.org/10.1016/j.ecresq.2015.10.005

Jarraya, S., Wagner, M., Jarraya, M., & Engel, F. A. (2019). 12 Weeks of kindergarten-based yoga practice increases visual attention, visual-motor precision and decreases behavior of inattention and hyperactivity in 5-year-old children. *Frontiers in Psychology, 10*, 796. https://doi.org/10.3389/fpsyg.2019.00796

Jourdain, L., & Sharma, S. V. (2016). Language challenges in mathematics education for English language learners: A literature review. *Waikato Journal of Education, 21*(2). https://doi.org/10.15663/wje.v21i2.269

Keung, C. P. C., Yin, H., Tam, W. W. Y., Chai, C. S., & Ng, C. K. K. (2020). Kindergarten teachers' perceptions of whole-child development: The roles of leadership practices and professional learning communities. *Educational Management Administration & Leadership, 48*(5), 875–892. https://doi.org/10.1177/1741143219864941

Kewalramani, S., Palaiologou, I., & Dardanou, M. (2020). Children's engineering design thinking processes: The magic of the ROBOTS and the power of BLOCKS (electronics). *Eurasia Journal of Mathematics, Science and Technology Education, 16*(3). https://doi.org/10.29333/ejmste/113247

Komis, V., Karachristos, C., Mourta, D., Sgoura, K., Misirli, A., & Jaillet, A. (2021). Smart toys in early childhood and primary education: A systematic review of technological and educational affordances. *Applied Sciences, 11*(18), 8653. https://doi.org/10.3390/app11188653

Kovas, Y., Voronin, I., Kaydalov, A., Malykh, S. B., Dale, P. S., & Plomin, R. (2013). Literacy and numeracy are more heritable than intelligence in primary school. *Psychological Science, 24*(10), 2048–2056. https://doi.org/10.1177/0956797613486982

Lamb, R., Akmal, T., & Petrie, K. (2015). Development of a cognition-priming model describing learning in a STEM classroom: Development of a cognition-priming model. *Journal of Research in Science Teaching, 52*(3), 410–437. https://doi.org/10.1002/tea.21200

Latip, A., Andriani, Y., Purnamasari, S., & Abdurrahman, D. (2020). Integration of educational robotic in STEM learning to promote students' collaborative skill. *Journal of Physics: Conference Series, 1663*(1), Article 012052. https://doi.org/10.1088/1742-6596/1663/1/012052

Lawlor, B. (2016). Science at play: Yesterday, today, and tomorrow. *Chemistry International, 38*(3–4). https://doi.org/10.1515/ci-2016-3-407

Lestari, M., & Kurniati, E. (2021). STEM flexibel model in kindergarten. *PAEDAGOGIA, 24*(2), 94. https://doi.org/10.20961/paedagogia.v24i2.53774

Leung, W. M., & Hu, X. (2019). "We want STEM": Exploring digital toys in a Hong Kong kindergarten. *JOURNAL OF EDUCATION AND HUMAN DEVELOPMENT, 8*(4). https://doi.org/10.15640/jehd.v8n4a11

Levski, V., School, S., Pelin, E., & Grigorova, I. (2022). STEM in the classroom (the role of technology and gamification as part of the educational process). *Vocational Education, 24*(4), 397–411. https://doi.org/10.53656/voc22-452stem

Lopes, P. N., Nezlek, J. B., Extremera, N., Hertel, J., Fernández-Berrocal, P., Schütz, A., & Salovey, P. (2011). Emotion regulation and the quality of social interaction: Does the ability to evaluate emotional situations and identify effective responses matter?: Emotion regulation ability. *Journal of Personality, 79*(2), 429–467. https://doi.org/10.1111/j.1467-6494.2010.00689.x

Martínez-Borreguero, G., Naranjo-Correa, F. L., & Mateos-Núñez, M. (2022). Cognitive and emotional development of STEM skills in primary school teacher training through practical work. *Education Sciences, 12*(7), 470. https://doi.org/10.3390/educsci12070470

Morcom, V. (2014). Scaffolding social and emotional learning in an elementary classroom community: A sociocultural perspective. *International Journal of Educational Research, 67*, 18–29. https://doi.org/10.1016/j.ijer.2014.04.002

Nam, K. W., Kim, H. J., & Lee, S. (2019). Connecting plans to action: The effects of a card-coded robotics curriculum and activities on Korean kindergartners. *The Asia-Pacific Education Researcher, 28*(5), 387–397. https://doi.org/10.1007/s40299-019-00438-4

Nayfeld, I., Brenneman, K., & Gelman, R. (2011). Science in the classroom: Finding a balance between autonomous exploration and teacher-led instruction in preschool settings. *Early Education & Development, 22*(6), 970–988. https://doi.org/10.1080/10409289.2010.507496

Nikolopoulou, K., & Tsimperidis, I. (2023). STEM education in early primary years: Teachers' views and confidence. *Journal of Digital Educational Technology, 3*(1), ep2302. https://doi.org/10.30935/jdet/12971

Ogunlade, I. (2023). A novel pedagogical tool for childhood education in STEM and STEAM towards achieving sustainable development goals in africa. *SFU Educational Review, 15*(1). https://doi.org/10.21810/sfuer.v15i1.6175

Park, S. (2022). A study on visual scaffolding design principles in web-based learning environments. *Electronic Journal of e-Learning, 20*(2), 180–200. https://doi.org/10.34190/ejel.20.2.2604

Pentimonti, J. M., Zucker, T. A., Justice, L. M., & Kaderavek, J. N. (2010). Informational text use in preschool classroom read-alouds. *The Reading Teacher, 63*(8), 656–665. https://doi.org/10.1598/RT.63.8.4

Pesco, D., & Gagné, A. (2017). Scaffolding narrative skills: A meta-analysis of instruction in early childhood settings. *Early Education & Development, 28*(7), 773–793. https://doi.org/10.1080/10409289.2015.1060800

Pollard, V., Hains-Wesson, R., & Young, K. (2018). Creative teaching in STEM. *Teaching in Higher Education, 23*(2), 178–193. https://doi.org/10.1080/13562517.2017.1379487

Pyle, A., & Bigelow, A. (2015). Play in kindergarten: An interview and observational study in three Canadian classrooms. *Early Childhood Education Journal, 43*(5), 385–393. https://doi.org/10.1007/s10643-014-0666-1

Ramli, A. A., Ibrahim, N. H., Surif, J., Bunyamin, M. A. H., Jamaluddin, R., & Abdullah, N. (2017). Teachers' readiness in teaching stem education. *Man in India, 97*(13), 343–350.

Rasyid, A., Sugandi, M. K., Gaffar, A. A., Jatisunda, M. G., Santoso, E., & Nahdi, D. S. (2021). Teaching STEM through play in kindergarten: Analysis towards pre-service early childhood teachers preparing the lesson plan. *Journal of Physics: Conference Series, 1764*(1), Article 012130. https://doi.org/10.1088/1742-6596/1764/1/012130

Roberton, T., Daffern, M., & Bucks, R. S. (2012). Emotion regulation and aggression. *Aggression and Violent Behavior, 17*(1), 72–82. https://doi.org/10.1016/j.avb.2011.09.006

Rodrigues-Silva, J., & Alsina, Á. (2023). STEM/STEAM in early childhood education for sustainability (ECEfS): A systematic review. *Sustainability, 15*(4), 3721. https://doi.org/10.3390/su15043721

Rosenzweig, E. Q., & Wigfield, A. (2016). STEM motivation interventions for adolescents: A promising start, but further to go. *Educational Psychologist, 51*(2), 146–163. https://doi.org/10.1080/00461520.2016.1154792

Saçkes, M. (2014). How often do early childhood teachers teach science concepts? Determinants of the frequency of science teaching in kindergarten. *European Early Childhood Education Research Journal, 22*(2), 169–184. https://doi.org/10.1080/1350293X.2012.704305

Samara, V., & Kotsis, K. T. (2023). A teaching intervention for magnetism using STEM in kindergarten. *International Journal of Professional Development, Learners and Learning, 5*(2), Article ep2312. https://doi.org/10.30935/ijpdll/13667

Samara, V., & Kotsis, K. T. (2024). Use of the artificial intelligence in teaching the concept of magnetism in preschool education. *Journal of Digital Educational Technology, 4*(2), Article ep2419. https://doi.org/10.30935/jdet/14864

Samarapungavan, A., Bryan, L. A., Staudt, C., Sapkota, B., Will Pinto, H. E., Broadhead, J. M., & Kimball, N. (2023). Using t echnology-mediated inquiry to help young learners reimagine the visible world through simple particle models. *Journal of Research in Science Teaching, 60*(2), 390–422. https://doi.org/10.1002/tea.21802

Sanders, K., & Downer, J. (2012). Predicting acceptance of diversity in pre-kindergarten classrooms. *Early Childhood Research Quarterly, 27*(3), 503–511. https://doi.org/10.1016/j.ecresq.2011.12.001

Shumway, J. F., Clarke-Midura, J., Lee, V. R., Hamilton, M. M., & Baczuk, C. (2019). Coding toys in kindergarten. *Teaching Children Mathematics, 25*(5), 314–317. https://doi.org/10.5951/teacchilmath.25.5.0314

Shumway, J. F., Welch, L. E., Kozlowski, J. S., Clarke-Midura, J., & Lee, V. R. (2023). Kindergarten students' mathematics knowledge at work: The mathematics for programming robot toys. *Mathematical Thinking and Learning, 25*(4), 380–408. https://doi.org/10.1080/10986065.2021.1982666

Silva, E. F., Dembogurski, B. J., & Semaan, G. S. (2023). A literature review of computational thinking in early ages. *International Journal of Early Years Education, 31*(3), 753–772. https://doi.org/10.1080/09669760.2022.2107491

Stadskleiv, K., Batorowicz, B., Massaro, M., Van Balkom, H., & Von Tetzchner, S. (2018). Visual-spatial cognition in children using aided communication. *Augmentative and Alternative Communication, 34*(1), 68–78. https://doi.org/10.1080/07434618.2017.1422017

Stright, A. D., Herr, M. Y., & Neitzel, C. (2009). Maternal scaffolding of children's problem solving and children's adjustment in kindergarten: Hmong families in the United States. *Journal of Educational Psychology, 101*(1), 207–218. https://doi.org/10.1037/a0013154

Sullivan, F. R., & Heffernan, J. (2016). Robotic construction kits as computational manipulatives for learning in the STEM disciplines. *Journal of Research on Technology in Education, 48*(2), 105–128. https://doi.org/10.1080/15391523.2016.1146563

Takeuchi, M. A., Sengupta, P., Shanahan, M.-C., Adams, J. D., & Hachem, M. (2020). Transdisciplinarity in STEM education: A critical review. *Studies in Science Education, 56*(2), 213–253. https://doi.org/10.1080/03057267.2020.1755802

Talaue, F. T. (2014). Social equity and access to a philippine STEM school. *Theory Into Practice, 53*(1), 33–40. https://doi.org/10.1080/00405841.2014.862120

Tank, K. M., Rynearson, A. M., & Moore, T. J. (2018). Examining student and teacher talk within engineering design in kindergarten. *European Journal of STEM Education, 3*(3). https://doi.org/10.20897/ejsteme/3870

Tao, Y. (2019). Kindergarten teachers' attitudes toward and confidence for integrated STEM education. *Journal for STEM Education Research, 2*(2), 154–171. https://doi.org/10.1007/s41979-019-00017-8

Tippett, C. D., & Milford, T. M. (2017). Findings from a pre-kindergarten classroom: Making the case for STEM in early childhood education. *International Journal of Science and Mathematics Education, 15*(S1), 67–86. https://doi.org/10.1007/s10763-017-9812-8

Toren, Z., Maiselman, D., & Inbar, S. (2008). Curriculum integration: Art, literature and technology in pre-service kindergarten teacher training. *Early Childhood Education Journal, 35*(4), 327–333. https://doi.org/10.1007/s10643-007-0197-0

Torres-Crespo, M. N., Kraatz, E., & Pallansch, L. (2014). From fearing STEM to playing with it: The natural integration of STEM into the preschool classroom. *SRATE Journal, 23*, 8–16.
Tozlu Kılıç, E., & Balaman, U. (2023). Facilitating students' learning of a target construction through teacher interactional resources in EFL kindergarten classrooms. *Tesol Quarterly, 57*(2), 656–669. https://doi.org/10.1002/tesq.3209
Uhlířová, M., Laitochová, J., & Adedokun, D. (2022). Developing mathematical pre-literacy and robotic toys from the perspective of school practice. *Education and New Developments 2022 – Volume, I*, 244–246. https://doi.org/10.36315/2022v1end055
Utami, F., Husain, A., & Muzakki, M. (2022). Implementation of natural phenomena theme collage activities in early childhood learning. *Southeast Asian Journal of Islamic Education, 4*(2), 171–179. https://doi.org/10.21093/sajie.v4i2.3781
Van De Pol, J., Volman, M., Oort, F., & Beishuizen, J. (2015). The effects of scaffolding in the classroom: Support contingency and student independent working time in relation to student achievement, task effort and appreciation of support. *Instructional Science, 43*(5), 615–641. https://doi.org/10.1007/s11251-015-9351-z
Van Der Mierden, S. (2019). Software tools for literature screening in systematic reviews in biomedical research. *ALTEX*. https://doi.org/10.14573/altex.1902131
Van Dijk, S. H. B., Brusse-Keizer, M. G. J., Bucsán, C. C., Van Der Palen, J., Doggen, C. J. M., & Lenferink, A. (2023). Artificial intelligence in systematic reviews: Promising when appropriately used. *BMJ Open, 13*(7), Article e072254. https://doi.org/10.1136/bmjopen-2023-072254
Van Kleef, G. A. (2010). The emerging view of emotion as social information: Emotion as social information. *Social and Personality Psychology Compass, 4*(5), 331–343. https://doi.org/10.1111/j.1751-9004.2010.00262.x
Van Uum, M. S. J., Verhoeff, R. P., & Peeters, M. (2017). Inquiry-based science education: Scaffolding pupils' self-directed learning in open inquiry. *International Journal of Science Education, 39*(18), 2461–2481. https://doi.org/10.1080/09500693.2017.1388940
Walldén, R., & Larsson, P. N. (2024). Visual resources and interaction in Grade 4 science teaching—moving in and out of discourse when exploring concepts of evolution and adaption. *Science Education, 108*(2), 608–636. https://doi.org/10.1002/sce.21849
Wenz-Gross, M., Yoo, Y., Upshur, C. C., & Gambino, A. J. (2018). Pathways to kindergarten readiness: The roles of second step early learning curriculum and social emotional, executive functioning, preschool academic and task behavior skills. *Frontiers in Psychology, 9*, 1886. https://doi.org/10.3389/fpsyg.2018.01886
Westwood, P. S. (2021). Numeracy in preschool and kindergarten years. In P. S. Westwood (Ed.), *Teaching for numeracy across the age range* (pp. 27–37). Singapore: Springer. https://doi.org/10.1007/978-981-16-3761-2_3.
Wijaya, T. K., Gunawan, & Hermawan, A. T. (2010). Beyond lego mindstorms: Analytical and experimental minds. \"*International Journal of Applied Research on Information Technology and Computing*\"\"\", *1*(1), 141. https://doi.org/10.5958/j.0975-8070.1.1.009
Yalçın, V., & Erden, Ş. (2021). The effect of STEM activities prepared according to the design thinking model on preschool children's creativity and problem-solving skills. *Thinking Skills and Creativity, 41*, Article 100864. https://doi.org/10.1016/j.tsc.2021.100864
Yang, W., & Li, H. (2018). A school-based fusion of east and west: A case study of modern curriculum innovations in a Chinese kindergarten. *Journal of Curriculum Studies, 50*(1), 17–37. https://doi.org/10.1080/00220272.2017.1294710
Yıldırım, B., Akcan, A. T., & Öcal, E. (2022). TEACHERS' perceptions and STEM teaching activities: Online teacher professional development and employment. *Journal of Baltic Science Education, 21*(1), 84–107. https://doi.org/10.33225/jbse/22.21.84
Yuill, N., Hinske, S., Williams, S. E., & Leith, G. (2014). How getting noticed helps getting on: Successful attention capture doubles children's cooperative play. *Frontiers in Psychology, 5*. https://doi.org/10.3389/fpsyg.2014.00418
Zhang, M., Passalacqua, S., Lundeberg, M., Koehler, M. J., Eberhardt, J., Parker, J., Urban-Lurain, M., Zhang, T., & Paik, S. (2010). "Science talks" in kindergarten classrooms: Improving classroom practice through collaborative action research. *Journal of Science Teacher Education, 21*(2), 161–179. https://doi.org/10.1007/s10972-009-9161-8
Zhou, L. (2022). Which matters more, cognitive or non-cognitive ability? *Science Insights Education Frontiers, 12*(1), 1607–1609. https://doi.org/10.15354/sief.22.co017
Zhou, L., & Kocabas, S. (2020). *Kindergarten students' spatial thinking: Practices on debugging of building blocks. Mathematics education across cultures: Proceedings of the 42nd meeting of the north American chapter of the international group for the psychology of Mathematics education*. https://doi.org/10.51272/pmena.42.2020-176
Zviel-Girshin, R., Luria, A., & Shaham, C. (2020). Robotics as a tool to enhance technological thinking in early childhood. *Journal of Science Education and Technology, 29*(2), 294–302. https://doi.org/10.1007/s10956-020-09815-x