The Impact of AI Educational Robots on Early Childhood Mathematics Education: A Systematic Literature Review

Yuxi Zhang

Universiti Kebangsaan Malaysia, Kuala Lumpur, Malaysia

Abstract

Early childhood mathematics education faces persistent challenges, including limited student engagement and difficulties in fostering foundational mathematical thinking through traditional methods. Artificial intelligence (AI)-powered educational robots have emerged as innovative tools to support early math learning by offering interactive, personalized, and developmentally appropriate experiences. This systematic literature review, conducted by PRISMA guidelines, highlights the pedagogical potential of AI robotics in early mathematics education and recommends future research employing longitudinal and cross-cultural designs, as well as a line with PRISMA guidelines, examined 28 empirical studies published between 2016 and 2025, sourced from Scopus, Web of Science, and other academic databases. The included studies focused on typically developing children aged 3–6 years and explored outcomes related to mathematical learning, computational thinking, cognitive development, and engagement. Findings indicate that AI educational robots can significantly enhance early numeracy skills, spatial reasoning, executive functions, and learner motivation, particularly when integrated within STEAM-based and project-based learning frameworks. However, limitations such as small sample sizes, short intervention durations, and lack of cultural and contextual diversity persist across the literature. This review underscores the pedagogical potential of AI robotics in early mathematics education and calls for future research employing longitudinal and cross-cultural designs, as well as more robust integration of robotics into authentic classroom environments to support scalable and sustainable implementation.

Keywords

Artificial Intelligence, Educational Robots, Early Childhood Education, Mathematics Learning, Computational Thinking

1. Introduction

The integration of AI educational robots in early childhood mathematics education has shown promising results in enhancing mathematical skills and cognitive development. These robots serve as engaging tools that facilitate learning by making abstract concepts more tangible and interactive for young children. The use of AI in educational settings not only improves mathematical performance but also positively influences children's attitudes towards math.

Studies have demonstrated that children exposed to AI educational robots show significant improvements in early math skills compared to those who engage in traditional learning methods. For instance, the "I Love Math with Robots" program resulted in higher math scores among preschool children in the experimental group compared to the control group [1]. AI-driven educational tools, such as the Zebra AI app, have been effective in enhancing both cognitive and attitudinal aspects of math learning, covering basic concepts like pattern recognition and shape identification [2].

AI educational robots contribute to the development of computational thinking skills, which are crucial for problem-solving and algorithmic thinking. This is particularly evident in studies where AI-generated contexts were used to teach robotics, resulting in improved computational thinking among preservice teachers [3].

The integration of AI in early education also supports the development of sequencing and self-regulation skills, as evidenced by research on kindergarteners using AI educational approaches [4].

Beyond mathematics, AI educational robots have been shown to enhance other cognitive skills such as theory of mind and self-regulation, indicating a holistic impact on early childhood development [4]. The use of AI in education encourages a positive attitude towards technology and learning, fostering an environment where children are more engaged and motivated to learn [5].

While the benefits of AI educational robots in early childhood mathematics education are evident, it is important to consider the need for balanced pedagogical approaches. Different AI educational methods, such as direct instruction and cooperative play, offer unique advantages and should be tailored to meet diverse learning needs. Further research is necessary to explore the long-term impacts of AI integration in various educational contexts and to develop comprehensive curricula that maximize the potential of these technologies.

Macrides, Miliou, and Angeli [6] provide a systematic review highlighting the significance of programming education for children aged 3-8, underscoring how educational tools and approaches influence learning and pedagogical benefits. This foundational work suggests that incorporating programming and robotics can foster early computational skills, which are integral to mathematics learning.

Building on this, Chaldi and Mantzanidou [7] explore the role of educational robotics within STEAM education in early childhood, demonstrating how programmable robots like Bee-Bot® serve as engaging tools to develop communication skills and problem-solving abilities. Their findings imply that robotics can effectively support the development of foundational skills necessary for understanding mathematical concepts through interactive and hands-on experiences.

Empirical investigations further elucidate the connection between robotics and mathematics learning. Shumway et al. [8] and Welch, Kozlowski, Clarke-Midura, and Lee [9] analyze kindergarten students' engagement with robot coding toys, revealing that children demonstrate various mathematics concepts and skills during programming tasks. Their semiotic mediation perspective indicates that such activities facilitate the overlapping of mathematics and programming knowledge, thereby promoting early numeracy and problem-solving skills.

Alam [10] discusses a conceptual framework for assessing computational thinking through educational robotics, emphasizing the potential of robots to create powerful educational scenarios that support STEM learning, including mathematics. The synthesis underscores the advantages of integrating robotics to foster critical thinking and engineering skills alongside mathematical understanding.

In the context of remote and parent-supported learning, Haas et al. [11] examine how technology-enhanced STEAM activities, including robotics, influence young learners' motivation and perceptions. Their findings suggest that parental involvement and technological support can enhance engagement with robotics-based mathematics activities, even in remote settings.

Advancements in AI technologies further expand the scope of robotics in early childhood mathematics education. Okur, Sahay, Alba, and Nachman [12] introduce a spoken dialogue system designed to support play-based learning of basic math concepts, illustrating how AI can facilitate interactive and personalized learning experiences. Similarly, Su et al. [13] investigate the effects of cooperative play and direct instruction with AI tools on kindergarteners' computational thinking and self-regulation, indicating that AI-driven activities can positively impact mathematical reasoning and related skills.

Teacher perceptions and the practical implementation of educational robots are also critical. Ani-Rus et al. [14] assess teachers' perceptions of AI applications and robotic toys, highlighting their recognition of the benefits these tools bring to early education. David et al. [15] further explore teachers' knowledge of educational robotics, emphasizing the importance of teacher readiness in effectively integrating robotics into mathematics instruction.

Finally, the broader impact of AI-powered robots on emotional and social development is addressed by Berrezueta-Guzman et al. [16], who evaluate how such robots support emotional self-regulation, engagement, and collaboration among preschoolers. These aspects are essential for holistic mathematics learning, as they influence motivation and sustained engagement with mathematical tasks.

In summary, the literature indicates that AI educational robots serve as valuable tools in early childhood mathematics education by fostering engagement, supporting the development of mathematical concepts, and enhancing computational thinking. Their successful integration depends on effective pedagogical strategies, teacher preparedness, and supportive environments that leverage AI's interactive and adaptive capabilities.

Research questions:

- What types of AI educational robots have been used to support early childhood mathematics education?
- What impact do these robots have on children's mathematical learning outcomes?
- What are the key benefits, limitations, and challenges identified in existing studies?

2. Methodology

A systematic literature search was conducted using two electronic databases: Scopus and Web of Science. The search strategy employed Boolean operators to combine the following keywords: ("AI educational robot") AND ("early childhood") AND ("mathematics" OR "math learning"). This combination was designed to capture studies focusing on the integration of artificial intelligence-powered educational robots in early childhood mathematics education. The search aimed to identify peer-reviewed literature that addressed both technological and pedagogical dimensions of AI applications in preschool math learning environments.

Inclusion and Exclusion Criteria

This review focused on empirical studies that investigated the use of artificial intelligence (AI)-powered educational robots in early childhood mathematics education. To ensure the relevance and quality of the included studies, a set of strict eligibility criteria was established. Studies were included based on the following criteria:

Published in English between 2016 and 2025.

including quantitative, qualitative, or mixed-methods research designs.

Focused on typically developing children aged 3 to 6 years.

Evaluated the educational application or instructional effects of AI-powered educational robots.

Studies were excluded if they met any of the following conditions:

Focused on non-AI toys or general educational technologies that did not involve AI components.

Aimed at the education of robots themselves, or focused on AI or robotics training courses for students.

Targeted special needs children or populations outside the general preschool demographic.

Concentrated primarily on preschool teachers as the main research subjects rather than on children.

To ensure transparency in the selection process, a PRISMA flow diagram was employed to present the identification, screening, eligibility assessment visually, and final inclusion of studies in this review.

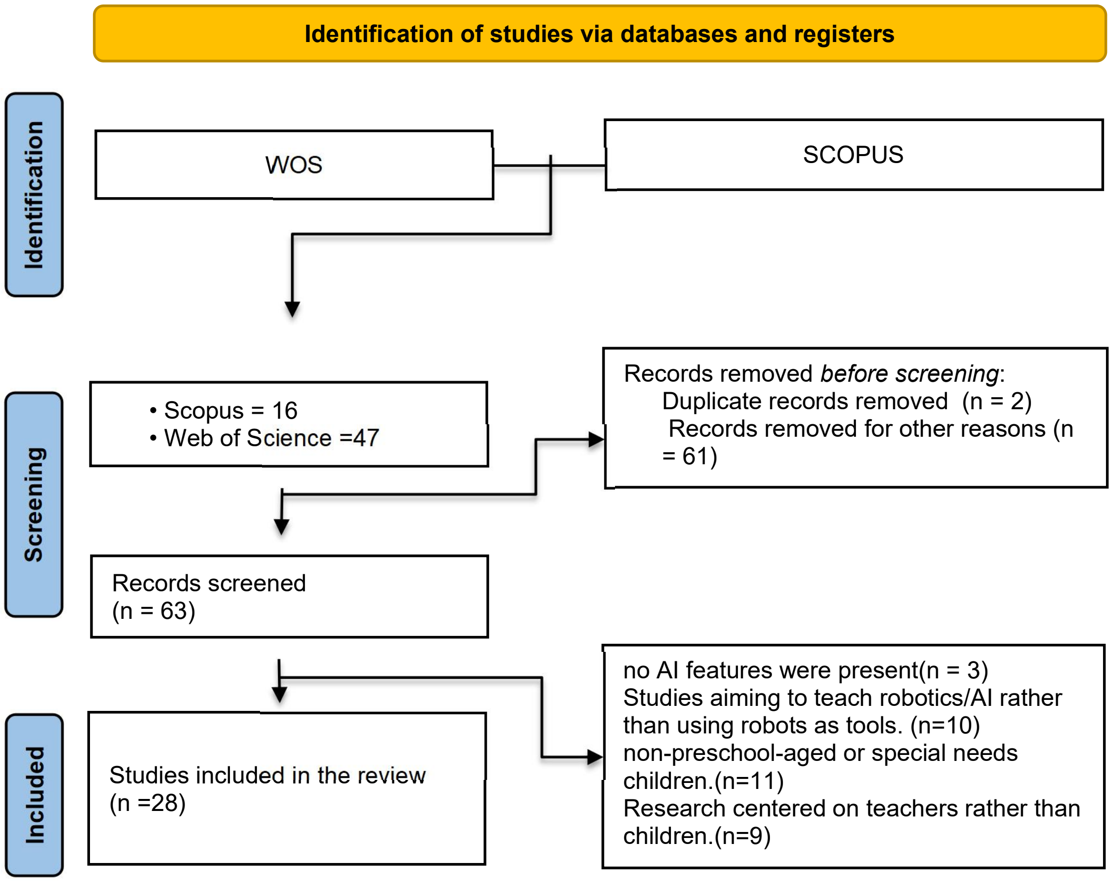

Figure 1. PRISMA flow diagram

Figure 1 shows the PRISMA flow diagram, which is a visual representation of the systematic process used in a literature review. It outlines the steps involved in identifying, screening, and selecting studies for inclusion in the review. The diagram typically includes stages such as the total number of studies identified, the number screened for eligibility, the number excluded, and the final number of studies included for analysis. The PRISMA flow diagram helps to ensure transparency and reproducibility in the systematic review process by clearly illustrating the study selection process.

2.1 Search Strategy

This study adopts a systematic literature review method and follows the PRISMA process. The databases searched include Scopus and Web of Science, with the search period set from January 2016 to 2025. The current study draws data from a broader scoping review and adheres to the five-stage methodological framework proposed by Arksey and O'Malley [15]. It also follows the PRISMA Extension for Scoping Reviews [16], which provides a checklist to guide researchers interested in exploring a topic comprehensively and identifying gaps in the literature.

A structured two-phase search strategy was conducted to identify relevant literature. In the initial phase, a comprehensive search was carried out in two major academic databases: Web of Science (WoS) and Scopus. The search terms were developed based on a combination of key concepts relating to artificial intelligence, educational robots, mathematics education, and early childhood, incorporating both index terms and free-text keywords. Boolean operators

“AND” and “OR” were used to combine search terms effectively. For example, terms such as(educational robot) AND (“mathematics OR math learning) AND (early childhood) were used to capture a broad yet targeted range of studies.

In total, the Web of Science search yielded 47 records, and the Scopus search returned 16. After removing 2 duplicate records, a total of 61 unique studies remained. These studies were then screened based on predefined inclusion and exclusion criteria, which focused on empirical research involving AI-assisted robotic tools in early childhood mathematical learning contexts. As a result, 19 articles from WoS and 9 articles from Scopus met the inclusion criteria and were included in the final review.

All search results were managed using EndNote 20 (The EndNote Team, 2013), which also facilitated duplicate removal and citation organization.

3. Results

3.1 Types and Functions of Educational Robots

A broad spectrum of AI and programmable robots has been adopted in early childhood mathematics education. These include AI-powered and social robots, which are capable of interacting socially and providing personalized feedback, such as those in Abram [19], Dinler [18], that support inclusive, affective, and emotionally responsive learning environments.

Programmable Robots for Spatial and Logical Development: Widely studied tools like Blue-Bot, Bee-Bot, Cubetto, and MatataBot [20] served as tactile and visual platforms for algorithmic learning and directional sequencing.

R-Learning and STEAM-Focused Robots: IRobi Q, featured in Kim & Song [21], enabled multimodal engagement with integrated content from mathematics, engineering, and art, fostering problem-solving and creativity.

Custom and Tangible Block-Based Systems: Systems like e-ProBotLab [23] and C-Block [22] provided hands-on, project-based experiences combining robotics with programming via tangible media.

Parent-Child Home-Based Learning Platforms: Chin [24] introduced DIY projects, low-cost kits, and block programming integrated with story-driven tasks for scaffolding home-based coding and mathematics engagement.

3.2 Impact on Learning Outcomes

Educational robots demonstrated multidimensional effects on mathematical and cognitive development:

Math Achievement Gains: Emen-Parlatan et al. [25] showed significant improvement in preschoolers’ math scores after an 8-week intervention using robots, suggesting robotics' effectiveness for structured early numeracy instruction.

Spatial and Symbolic Thinking: Studies like Palmér and Seckel et al confirmed that robots help children connect movement with symbolic representations like maps and grids.

Computational Thinking and Programming Fluency: Alam [26] emphasized that robotics-based programming improved abstraction, decomposition, and algorithmic thinking at foundational stages.

Executive Function and Cognitive Skills: Di Lieto et al. [27] found significant gains in preschoolers' working memory and inhibitory control after participating in Bee-Bot programming sessions.

Critical Thinking and STEM Integration: Mariappan et al. and Hu et al. [28] found robotics-based learning fostered inquiry, reasoning, and interdisciplinary thinking, especially when combined with project-based learning (PBL).

3.3 Impact on Motivation and Engagement

Robotic learning environments elevated young learners’ motivation through:

Playful and Emotional Engagement: Interactive narratives, role-play, Chin, and visual/auditory feedback sustained interest and reduced math anxiety.

Agency and Autonomy: Children exhibited increased initiative, persistence, and self-directed problem-solving when manipulating robot behavior or debugging sequences [29].

Positive Learning Attitudes: Hu et al. revealed a correlation between enhanced attitudes and improved STEM outcomes, reinforcing the motivational role of robotics in math contexts.

3.4 Teachers and Parents’ Attitudes

Teachers’ Views and Needs: While supportive of educational robotics, educators expressed a need for more professional development, curriculum alignment, and ease of integration [30].

Parents’ Role and Collaboration: Research by Haas et al. [31] and Chin highlighted the critical role parents play in mediating learning, especially in remote or home-based scenarios.

Barriers to Implementation: Berciano-Alcaraz et al. [32] observed that even with enthusiasm, limitations such as children’s cognitive development stages and tool complexity required adult scaffolding.

3.5 Challenges and Gaps

Despite promising results, several key limitations persist: Technological Barriers: Many robots offer limited natural language interaction and adaptive learning, as noted by Dinler and Di Lieto et al.

Developmental Suitability: Younger learners often struggle with symbolic abstraction or multistep planning, as reported by Berciano-Alcaraz et al.

Equity and Inclusion: Access disparities in low-resource settings limit widespread adoption. Gender biases and curricular stereotypes still influence who engages and how.

Methodological Constraints: A large proportion of studies remain small-scale, short-duration trials with minimal replication by Palmér and Emen-Parlatan.

Skill Narrowness: Many studies focus only on entry-level tasks like sequencing, neglecting complex mathematical reasoning or metacognitive processes.

4. Discussion

The integration of AI and robotics into early mathematics education has demonstrated substantial potential in shaping both foundational cognitive skills and positive dispositions toward learning. From spatial reasoning and computational logic to executive function and creative design, educational robots serve as versatile, context-rich tools. Findings from Emen-Parlatan et al., Di Lieto et al. and Alam confirm that these tools not only enhance academic performance but also strengthen soft cognitive competencies and STEM readiness [33].

Moreover, the inclusion of parents and thoughtful design of home-based tools by Chin bridge formal and informal learning contexts supports holistic development [34]. However, challenges such as teacher readiness, technological limitations, and curriculum alignment must be addressed to scale adoption effectively. The literature urges a shift from enrichment models to integrative pedagogies that embed robotics into core instruction while fostering inclusive participation [35].

The table summarizes 28 studies on educational robotics, detailing the author(s), year, country, research design, sample, robot type, and data collection methods. It highlights the use of various robots, ranging from simple ones like Bee-Bot to advanced AI-driven robots, in diverse educational settings. Data collection methods range from observations and interviews to tests and surveys, showing the diverse approaches in the field [36].

Author(s) Year	Country	Design	Sample	Robot Type	Data Collection
Abram (2025)	USA	Qualitative	N/A	AI Social Robot	Case Narrative
Dinler (2024)	Turkey	Theoretical/Review	N/A	Intelligent Educational Robots (IER)	Literature Review
Tolksdorf et al. (2021)	Germany	Experimental	N/A	AI Robots	Observations, Performance Assessment
Palmér (2017)	Sweden	Intervention	Preschool children	Programmable Robot	Observations, Interviews
Nebot et al. (2018)	Spain	Exploratory	3 pairs of students	Bee-Bot	Video Analysis, Task Observation
Seckel et al. (2023)	Spain	Systematic Review	25 studies	Bee-Bot (reviewed)	Thematic Analysis
Kim & Song (2017)	South Korea	Developmental	Early childhood students	IRobi Q	Teaching Model Implementation
Karachristos et al. (2018)	Greece	Design and Evaluation	Students	e-ProBotLab	User Tests, Surveys
Mariappan et al. (2017)	Malaysia	Design-based	Children (4–7)	C-Block	Prototype Testing
Chin (2025)	USA	Practical Guide	Parents and Children	DIY + Block Programming	Case Projects
Emen-Parlatan et al. (2023)	Turkey	Quasi-experimental	24 preschoolers	I Love Math Robot	Pre/Post Tests
Alam (2022)	India	Conceptual Review	N/A	Various Robots	Synthesis of Research
Di Lieto et al. (2017)	Italy	Pilot Study	12 children	Bee-Bot	Neuropsychological Tests
Berciano-Alcaraz et al. (2022)	Spain	Case Study	8 children (3 years)	Unspecified Robot	Task Observation, Argumentation
Haas et al. (2022)	Luxembourg	Design-based	12 children, parents	CAD + Robot	Chats, Messages, Logs
Hu et al. (2024)	China's Taiwan region	Experimental	25 students	IoT Robot + Toy	Tests, Questionnaire
Heikkilä (2020)	Finland	Qualitative	Preschoolers	Social Robots	Observation, Interview
Isnaini et al. (2019)	Indonesia	Mixed Methods	Preschool Class	MatataBot	Pre/Post Test, Observation
Manera (2020)	Italy	Case Study	Preschool Group	LEGO Robots	Activity Logs, Reflection
Sala-Sebastià et al. (2025)	Spain	Survey-based	Teachers	Various ER Tools	Survey
Gerosa et al. (2022)	Brazil	Quasi-experimental	Children (N/A)	ER in CT Activities	Video, Audio Analysis
Fridin (2016)	Israel	Experimental	Kindergarten Class	Humanoid Robot	Performance, Observation
Papadakis et al. (2021)	Greece	Comparative Study	Children Aged 4–6	Bee-Bot vs. Tablet	Pre/Post Measures
Papadakis et al. (2023)	Greece	Review	N/A	Educational Robots	Content Analysis
Özdemir et al. (2020)	Turkey	Quasi-experimental	Preschool Children	Bee-Bot	Pre/Post Testing
Zarzycka-Piskorz et al. (2020)	Poland	Exploratory	Preschool Groups	Dash & Dot	Task-Based Evaluation
Lin et al. (2021)	China's Taiwan region	Experimental	Children Aged 5–6	AI Storytelling Robot	Engagement Scale, Interviews
Alves et al. (2019)	Portugal	Pilot Study	20 children	Thymio Robot	Field Notes, Audio
Alimisis (2022)	Multiple (EU)	Policy Review	N/A	General Educational Robotics	Policy and Curriculum Documents

Table 1. Characteristics of the 28 selected articles

5. Limitations

This review synthesizes a diverse body of literature but is constrained by several factors. Many studies rely on small sample sizes, limiting generalizability. The lack of longitudinal and experimental designs hinders the understanding of long-term impact. Additionally, few studies isolate the effects of AI-specific features versus traditional programming. The focus on Western contexts may also underrepresent experiences in low-income or non-English-speaking regions [37]. Finally, research remains disproportionately centered on early-level skills like sequencing or directionality, with fewer investigations into higher-order reasoning or conceptual math development [38].

6. Future Research Directions

To advance the field, future research should: Conduct longitudinal studies that trace the developmental trajectory of math skills with robotics support. Disentangle the differential effects of AI-enabled robots (e.g., adaptive feedback, natural language) from simpler programmable toys. Develop inclusive robotics tools that are culturally relevant, gender-sensitive, and accessible across socioeconomic contexts [39]. Expand assessments to include metacognitive strategies, abstract reasoning, and error correction processes. Explore how teacher professional development can integrate robotics into formal curricula, supported by co-design with educators. Investigate hybrid learning models that combine robotics with home learning and parental engagement [40].

7. Conclusion

Educational robotics, particularly those powered by AI or embedded in STEAM-based frameworks, is reshaping the landscape of early childhood mathematics education. The reviewed studies provide robust evidence of their effectiveness in promoting spatial thinking, sequencing, problem-solving, and motivation. Moreover, integrating robotics into project-based and inquiry-driven activities aligns with developmental needs and fosters deeper learning. Yet, realizing the full potential of these technologies depends on addressing systemic inequities, enhancing educator preparedness, and developing adaptable, user-friendly platforms. The future of early mathematics education lies in intentional, inclusive, and evidence-based implementation of intelligent educational robots.

Reference

[1] Emen-Parlatan, M., & Aslan, D. (2023). Technology and early mathematics skills: Effectiveness of I Love Math with Robots. Journal of Educational Research, 116(2), 90–99. https://doi.org/10.1080/00220671.2023.2203092

[2] Zhang, S.-H. (2022). Applying Artificial Intelligence into Early Childhood Math Education: Lesson Design and Course Effect. International Conference on Teaching, Assessment, and Learning for Engineering, 635–638. https://doi.org/10.1109/TALE54877.2022.00109

[3] Hijón-Neira, R., Pizarro, C., Borrás-Gené, O., & Cavero, S. (2024). AI-Generated Context for Teaching Robotics to Improve Computational Thinking in Early Childhood Education. Education Sciences, 14(12), 1401. https://doi.org/10.3390/educsci14121401

[4] Su, J., Yang, W., Yim, I. H. Y., Li, H., & Hu, X. (2024). Early artificial intelligence education: Effects of cooperative play and direct instruction on kindergarteners' computational thinking, sequencing, self-regulation and theory of mind skills. Journal of Computer Assisted Learning. https://doi.org/10.1111/jcal.13040

[5] Review on Artificial Intelligence and Robots in STEAM Education for Early Childhood Development. (2022). Advances in Early Childhood and K-12 Education, 468–498. https://doi.org/10.4018/978-1-7998-8649-5.ch019

[6] Macrides, E., Miliou, O., & Angeli, C. (2022). Programming in early childhood education: A systematic review. International Journal of Child-Computer Interaction, 32, 100396.

[7] Chaldi, D., & Mantzanidou, G. (2021). Educational robotics and STEAM in early childhood education. Advances in Mobile Learning Educational Research, 1(2), 72-81.

[8] 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.

[9] Alam, A. (2022, March). Educational robotics and computer programming in early childhood education: a conceptual framework for assessing elementary school students' computational thinking for designing powerful educational scenarios. In 2022 International Conference on Smart Technologies and Systems for Next Generation Computing (ICSTSN) (pp. 1-7). IEEE.

[10] Haas, B., Lavicza, Z., Houghton, T., & Kreis, Y. (2022, June). Evaluating technology-enhanced, STEAM-based remote teaching with parental support in Luxembourgish early childhood education. In Frontiers in Education (Vol. 7, p. 872479). Frontiers Media SA.

[11] Okur, E., Sahay, S., Alba, R. F., & Nachman, L. (2022). End-to-end evaluation of a spoken dialogue system for learning basic mathematics. arXiv preprint arXiv:2211.03511.

[12] Ani-Rus, A., Catalano, C., Mestic, G., & Catalano, H. (2023). A Study Regarding Early Teachers' Perception Toward the Introduction of Artificial Intelligence Applications and the Use of Educational Robots in the Teaching Process. Educatia 21, (25), 336-346.

[13] David, K. H., Peawat, D. Z., & Ladan, N. J. (2023). The Future of Science Teaching: Pre-Primary Teachers' Knowledge of Educational Robotics in STEM Learning in Plateau State. International Journal of Research and Innovation in Social Science, 7(5), 1278-1283.

[14] Berrezueta-Guzman, S., Dolón-Poza, M., & Wagner, S. (2025). Supporting Preschool Emotional Development with AI-Powered Robot. In Proceedings of the 24th Interaction Design and Children (pp. 1134-1139).

[15] Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. International Journal of Social Research Methodology, 8(1), 19-32. https://doi.org/10.1080/1364557032000119616

[16] Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., ... & Moher, D. (2018). A scoping review on the conduct and reporting of scoping reviews. BMC Medical Research Methodology, 18(1), 1-10. https://doi.org/10.1186/s12874-018-0611-x

[17] Alam, A. (2022). Educational robotics and computer programming in early childhood education: A conceptual framework for assessing elementary school students' computational thinking for designing powerful educational scenarios. In the 2022 International Conference on Smart Technologies and Systems for Next Generation Computing (ICSTSN).https://doi.org/10.1109/ICSTSN53084.2022.9761354

[18] Dinler, H. (2024). Intelligent educational robots in early childhood education: Building the future. In Intelligent Educational Robots Toward Personalized Learning Environments (pp. 169–197).

[19] Palmér, H. (2017). Programming in preschool—with a focus on learning mathematics. International Research in Early Childhood Education, 8(1), 75–87.

[20] Kim, H. J., & Song, M. S. (2017). Development of a teaching model for STEAM using R- learning educational robot to promote young children's creative problem- solving ability. Advanced Science Letters, 23(10), 10445–10450. https://doi.org/10.1166/asl.2017.10471

[21] Mariappan, M., Sing, J. C., & Wee, C. C. (2017). Early childhood educational robotic system (C-Block): A design methodology. Advanced Science Letters, 23(11), 11206–11210. https://doi.org/10.1166/asl.2017.10252

[22] Karachristos, C., Nakos, K., Komis, V., & Misirli, A. (2018). e ProBotLab: Design and evaluation of an open educational robotics platform. In Research on E Learning and ICT in Education: Technological, Pedagogical and Instructional Perspectives (pp. 339–365).2017

[23] Chin, C. (2025). Raising young coders: A parent's guide to teaching programming at home (pp. 1–150).

[24] Alam, A. (2022, September). Educational robotics and computer programming in early childhood education: A conceptual framework for assessing elementary school students' computational thinking for designing powerful educational scenarios. In Proceedings of the 2022 IEEE International Conference on Smart Technologies and Systems for Next Generation Computing (ICSTSN) (pp. [page numbers, if known]). IEEE.

[25] Di Lieto, M. C., Inguaggiato, E., Castro, E., Cecchi, F., Cioni, G., Dell'Omo, M., Laschi, C., Pecini, C., Santerini, G., Sgandurra, G., & Dario, P. (2017). Educational robotics intervention on executive functions in preschool children: A pilot study. Computers in Human Behavior, 71, 16–23. https://doi.org/10.1016/j.chb.2017.01.018

[26] Hu, C. C., Yang, Y. F., & Chen, N. S. (2024). Integrating educational robots and low-cost self-made toys to enhance STEM learning performance for primary school students. Behaviour & Information Technology, 43(8), 1614–1635..https://doi.org/10.1080/0144929X.2023.2222308

[27] Nebot, P. D. D., Vera, D. A., & Somoza, J. A. G. C. (2018). Problem-solving elements in early childhood education with Bee-bot. EDMA 0–6: Educación Matemática en la Infancia, 7(1), 12–41.

[28] Kim, H. J., & Song, M. S. (2017). Development of a teaching model for STEAM using R learning educational robot to promote young children's creative problem solving ability. Advanced Science Letters, 23(10), 10447–10452. https://doi.org/10.1166/asl.2017.10471

[29] Haas, B., Lavicza, Z., Houghton, T., & Kreis, Y. (2022). Evaluating technology-enhanced, STEAM-based remote teaching with parental support in Luxembourgish early childhood education. Frontiers in Education, 7, Article 872479..https://doi.org/10.3389/feduc.2022.872479

[30] Berciano-Alcaraz, A., Salgado-Somoza, M., & Jiménez-Gestal, C. (2022). Computer literacy in early childhood education: Difficulties and benefits in a 3-year-old classroom. Revista Electronica Educare, 26(2).https://doi.org/10.15359/ree.26-2.15

[31] Su, J., Yang, W., Yim, I. H. Y., Li, H., & Hu, X. (2024). Early artificial intelligence education: Effects of cooperative play and direct instruction on kindergarteners' computational thinking, sequencing, self-regulation, and theory of mind skills. Journal of Computer Assisted Learning, 40(6), 2917-2925.

[32] Sala-Sebastià, G., Breda, A., & Font, V. (2025). Characterising computational and geometric thinking in pre-service early childhood education teachers by playing with MATLAB. Education and Information Technologies..https://doi.org/10.1007/s10639-025-13589-3

[33] Tarrés-Puertas, M. I., Costa, V., & Dorado, A. D. (2023). Child-robot interactions using educational robots: An ethical and inclusive perspective. Sensors, 23(3).10.3390/s23031675

[34] Isnaini, R., Budiyanto, C., & Widiastuti, I. (2019). Robotics-based learning to support computational thinking skills in early childhood. In the 2nd International Conference on Science, Mathematics, Environment, and Education (ICoSMEE 2019).https://doi.org/10.1007/s10639-023-11843-0

[35] Manera, L. (2020). STEAM and educational robotics: Interdisciplinary approaches to robotics in early childhood and primary education. In 12th International Workshop on Human-Friendly Robotics (HFR 2019) (pp. 103–109).

[36] 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

[37] Gerosa, A., Koleszar, V., Tejera, G., Gómez- Sena, L., & Carboni, A. (2022). Educational robotics intervention to foster computational thinking in preschoolers: Effects of children's task engagement. Frontiers in Psychology, 13, Article 904761. https://doi.org/10.3389/fpsyg.2022.904761

[38] Welch, L. E., Shumway, J. F., Clarke-Midura, J., & Lee, V. R. (2022). Exploring measurement through coding: Children's conceptions of a dynamic linear unit with robot coding toys. Education Sciences, 12(2), Article 143. https://doi.org/10.3390/educsci12020143

[39] Kyprianou, G., Karousou, A., Makris, N., Sarafis, I., Amanatiadis, A., & Chatzichristofis, S. A. (2023). Engaging learners in educational robotics: Uncovering students' expectations for an ideal robotic platform. Electronics, 12(13), 2865. https://doi.org/10.3390/electronics12132865

[40] Heikkilä, M. (2020). What happens when the robot gets eyelashes? Gender perspective on programming in preschool. In STEM Education Across the Learning Continuum: Early Childhood to Senior Secondary (pp. 29–44).