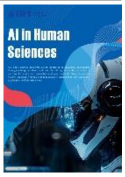
AI in Human Sciences

https://polaris-aihs.com/journal/index.php/aihs/index



Are Home Educational Robots Really Effective? Insights from Systematic Review

Yan Yang[1] *

[1]Research Institute of Higher Education, Yunnan University, Kunming, China

Article history:

Received May 18, 2025

Revised June 3, 2025

Accepted June 20, 2025

***Corresponding Author:**

Yan Yang

E-mail:

YYLZPL@126.com

Abstract: This study reviews recent scientific literature on the use of robots as educational tools in home settings, aiming to evaluate their effectiveness and identify future research directions. Following a systematic search and screening process, 12 relevant studies were included. For each study, we analyzed the research purpose, the role and type of robot, methodological approach, and sample characteristics (size and age), along with the reported outcomes. Findings suggest that home educational robots, through companion-based learning, help transform learning into social interaction, thereby enhancing children's motivation, engagement and social skills. Notably, robots have shown strong potential in supporting social skill interventions for children with special needs in home environments. However, some studies reported no significant improvement in cognitive learning under certain conditions, with outcomes influenced by individual characteristics, family background, and robot design. Based on these insights, we propose future research directions focused on multi-agent interaction, unstructured educational content, and physical design of robots, offering valuable guidance for researchers and parents.

Keywords: home education, human-robot interaction, cognitive learning, social skills, companion-based learning, systematic review

1. INTRODUCTION

Are educational robots truly high-tech tools that promote child development, or are they merely educational illusions wrapped in technology? In recent years, an increasing number of robots have entered home education settings, emerging as novel support tools for children's learning. Compared to traditional screen-based media, robots offer interactive feedback, emotional companionship, and personalized services, demonstrating the dual potential of "companionship and education" within the home context. This technology is expected to help address common challenges in family education, such as insufficient emotional engagement and interaction due to parents' time poverty and cognitive overload, as well as lack of academic guidance and pedagogical knowledge. Consequently, the effectiveness and potential of home educational robots have garnered unprecedented attention: Can robots truly provide effective support for child development?

Assessing the effectiveness of home educational robots should be grounded in the core goals of child development and family education. Vygotsky's sociocultural theory of development posits that children's cognitive growth relies on social interaction, and that learning itself occurs through engagement with others (Vygotsky, 1978). Hoover-Dempsey and Sandler's parental involvement model emphasizes that the primary function of family education lies in enhancing children's learning motivation, academic achievement, and social adaptation through parent-child interaction (Hoover-Dempsey & Sandler, 1997). However, in practice, family education often suffers from an imbalance—emphasizing knowledge input while neglecting social experience (Lareau, 2003). Based on both theoretical and practical considerations, the evaluation of educational robots should focus on whether they effectively support children's cognitive learning and social skill development within real home environments.

Previous research has provided preliminary evidence regarding the effectiveness of home educational robots in supporting children's cognitive learning and social skill development. Studies have shown that robots can interactively influence children's learning and social behaviors. Children often perceive robots as "learning partners" or "social companions," and during these interactions, they tend to demonstrate greater motivation and more expressive social behavior, which in turn enhances learning outcomes (Haber & Corriveau, 2023). For example, in robot-assisted guided reading activities, children transformed reading into a social experience, which promoted both motivation and comprehension (Michaelis & Mutlu, 2018; Salma et al., 2025). Comparative studies have also found that, compared to traditional media or web-based instruction (WBI), home educational robots are more effective in improving students' attention, learning interest, and academic performance (Han et al., 2008).

These findings suggested that home educational robots may serve as effective support tools. However, this assertion requires further confirmation through systematic empirical evidence. Most existing studies adopt narrow perspectives, involve small sample sizes, and cover short intervention periods—limitations that make it difficult to assess the broader impact of robots on children's learning and social development. Furthermore, current systematic reviews tend to focus on formal educational settings, such as schools (Wang et al., 2023; Sapounidis et al., 2024), and there remains a lack of comprehensive synthesis and review of their use in home education contexts.

To address this gap, this study systematically reviewed the literature from the past two decades on the use of robots in home education, with particular attention to their effects on children's cognitive learning and social skills. The central research question is: Can the integration of robots into home education effectively promote children's development, particularly in cognitive learning and social skills? The specific research questions are as follows:

RQ1. What roles do home robots play in children's cognitive learning and social skills?

RQ2. How are the effects of robots evaluated?

RQ3.What are the overall effects and influencing factors of robots?

2. METHOD

A systematic review is a method for evaluating and interpreting all available research relevant to a specific research question (Kitchenham, 2004). First, we identified the necessity of this study by conducting a preliminary search to determine whether systematic reviews in the field of home educational robots already existed. Two directly relevant reviews were identified: Yi et al. (2024) used bibliometric methods to explore the current state and trends of artificial intelligence and robotics in early childhood education; Cagiltay and Mutlu (2024) constructed a family-centered human-robot interaction framework using a deductive approach, focusing on broader aspects of family life. In addition, several reviews focused on social robots for children with autism (Bartl-Pokorny et al., 2021; Kouroupa et al., 2022; Islam et al., 2023), but these studies covered a wide range of settings—including schools, hospitals, and homes—without specifically targeting the home context. Given the limited number of existing reviews and the absence of a focused synthesis on the two critical dimensions of child development—learning and social skills—within the home environment, there is a clear need for a systematic review that centers on these aspects. Such a review can better inform the practical effectiveness and potential of educational robots in family settings.

2.1 Literature Search

This study followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Page et al., 2021) to identify and screen relevant articles (see Figure 1). A systematic search was conducted in March and April 2025 across the following databases: (a) Web of Science (WOS), (b) IEEE, and (c) ACM. Eligible sources included peer-reviewed journal articles and international conference papers, written in English, published between January 2005 and April 2025, and available in full text.

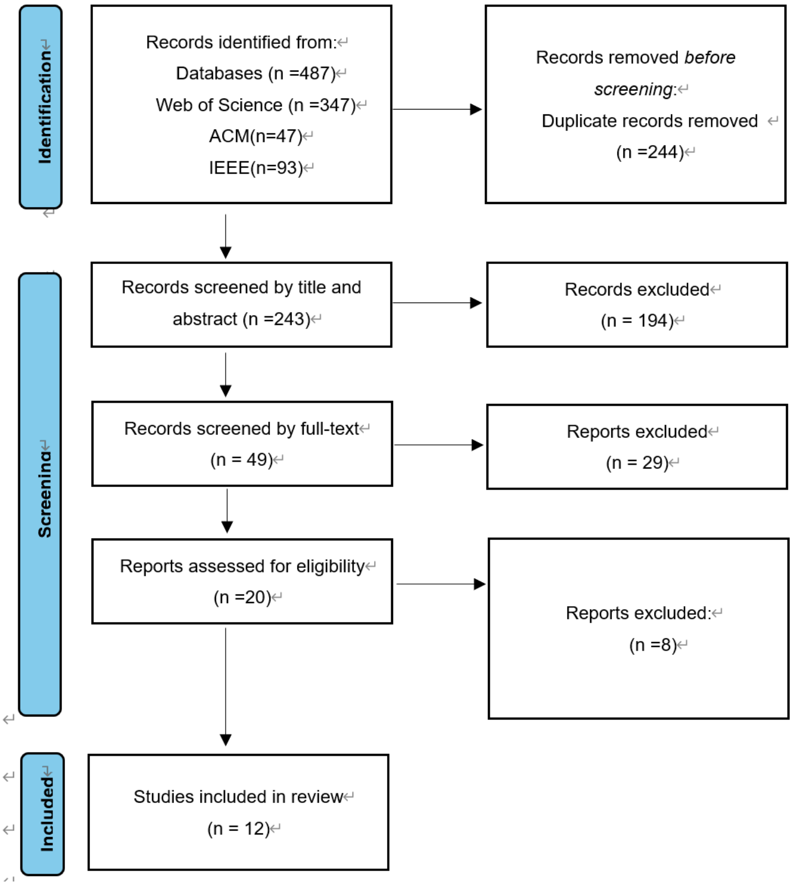


Figure1. Flowchart of study selection process

Three categories of search terms and their variations were used, including robots (robot, human-robot interaction), children (child, toddler, infant), and home context (home, domestic, parent-child, parent-toddler). The Boolean search strategy applied was: (robot OR human-robot interaction) AND (child OR young children OR toddler OR infant) AND (home OR parent-child OR parent-toddler). This initial search yielded a total of 487 articles.

2.2 Study Selection

Articles retrieved from the initial search underwent title and abstract screening, followed by full-text review to determine eligibility for inclusion in the systematic review. Studies were first required to focus on the use of robots to support children's cognitive learning or social skills specifically within home settings. Subsequently, each article was evaluated against predefined inclusion and exclusion criteria (see Table 1).

These criteria were established through consensus and applied by two independent reviewers. In cases where a study received conflicting decisions or the reviewers cited different exclusion reasons, final inclusion was determined through discussion with a third author to reach consensus.

Table 1. Inclusion and exclusion criteria for study selection

Inclusion Criteria	Exclusion Criteria
Robots used as educational tools	Robots used for household chores, caregiving, or other service tasks
Children and adolescents under 18 and their caregivers	only adults aged 18 and above
Application setting is the home	Schools, hospitals, or other institutional environments
The study examines the effects or impact of robots on learning or social outcomes	The study does not assess the effects of robot
Robots are physical entities that directly interact with children	Robots are used only as learning materials without direct interaction
The study focuses on educational or social applications of robots	The study focuses on technical aspects of robots or user preferences/attitudes
Only peer-reviewed journal and international conference papers	Theses, dissertations, or research proposals
Published between January 2005 and June 2025	Written in languages other than English

2.3 Quality Assessment

All articles retained after full-text screening were subjected to a quality assessment using the Mixed Methods Appraisal Tool (MMAT). This standardized tool has demonstrated strong validity and reliability across diverse research designs, including randomized controlled trials and non-randomized or observational studies (Pluye & Hong, 2013). Two reviewers independently conducted a double-blind quality evaluation of each study based on the five core MMAT criteria, applying tailored standards according to the specific study type (e.g., RCTs vs. non-randomized quantitative studies). Following the developer's guidelines, we avoided using an overall numerical score to prevent oversimplification of research quality’s multidimensional nature. Instead, we adopted a criterion-based coding approach, recording each item as "Yes", Can't tell", or "No" "Yes" responses indicated methodological rigor and were determined through a consensus process after back-to-back independent assessments. This dimension-based evaluation strategy allowed us to more precisely identify the methodological strengths and potential limitations of each study, rather than relying on a reductive grading scale.

3. RESULT

3.1 Study Selection and Characteristics

A total of 487 articles were initially retrieved for title and abstract screening, followed by full-text assessment. After a rigorous selection process, 12 articles were ultimately included in the review (Figure 1). The selected articles were categorized as either non-experimental or quasi-/experimental designs. Table 2 provided a summary of these studies: Column 1 listed the authors and publication year; Column 2 outlined the research objectives; and Column 3 indicated the study type. This categorization reflected commonly used research designs in educational evaluation, as Trochim & Donnelly (2006) suggested.

Table 2. Articles and study type

Article	Article description	Study type
Chen et al. (2025)	Exploring the potential of social robots as conversational catalysts in parent-child interaction.	R O X1 O R O X2 O R O O
Michaelis and Mutlu (2018)	A learning companion robot was designed to enhance guided reading activities and to examine its impact on the home reading experience.	R O X O R O O
Lym et al. (2024)	Developed home robot-based activity services to promote children's social-emotional development and evaluated their effectiveness.	N X O
Gvirsman et al. (2020)	Designed the robot platform Patricc for toddler–parent–robot triadic interaction and evaluated its design features and interaction dynamics.	R X1 O X2 O

Abe et al. (2018)	Developed a telepresence robot named ChiCaRo to facilitate remote interaction between infants and toddlers (0–3 years) and their grandparents, and explored its social acceptance and parenting support effectiveness in home settings.	R X1 O X2 O N X O
Chen et al.（2022）	Designed a social robot to promote high-quality parent–child–robot triadic interaction.	N X1 O N X2 O N O
Michaelis and Mutlu（2017）	Explored how children engage in social interaction with robots and how such interaction influences the development of reading interest.	N X O
Han et al. (2008)	Examined the effects of children's interaction with a home robot on their interest in learning English, attention, and academic performance, and compared these effects with those of other instructional media.	R X1 O R X2 O R X3 O
Scassellati et al. (2018)	Evaluated the long-term intervention effects of an autonomous social robot on the social communication skills of children with autism spectrum disorder (ASD) in a home environment.	N A (O) → B (X O) → A (O)
Berrezueta-Guzman et al. (2021)	Evaluated the therapeutic support effects of the robotic assistant (Atent@) in helping children with ADHD complete homework tasks.	N O X O
Javed and Park（2022）	Promoted physical activity and social engagement in children with autism through robot-assisted dance interaction.	O1 X O2
Clabaugh et al. (2019)	Designed and evaluated a reinforcement learning–based personalized socially assistive robot framework to provide long-term in-home learning support for children with autism.	N O1 X O2

Table 3 presented the main content and findings of the included articles. For each article, Table 4 displayed the following attributes:(a) Column 1: Authors;(b) Column 2: Age of participants;(c) Column 3: Topics, indicating the content the robot was responsible for or taught;(d) Column 4: Robot type, describing the type of robot used in the study;(e) Column 5: Sample, showing the sample size;(f) Column 6: Study details, outlining the data collection and analysis methods;(g) Column 7: Major findings, summarizing the key results of each study, including both proved and non-proved results.

Table 3. Context of the articles and major findings

Article	Age	Topics	Robot type	Sample	Detail study type	Major findings	
						Proved results	**Non-proved results**
Chen et al. (2025)	3-7 years old	Guided parent-child reading to improve dialogue quality and long-term interaction	Jibo	71 families	Quantitative method. Compared parent-child interaction data (dialogue quality and reading characteristics) under different conditions.	Active robot participation significantly improved dialogue quality. The dialogic reading program overall enhanced parent-child interaction. Parental English proficiency significantly moderated the effect of robot involvement.	No significant differences were found across conditions (robot vs. no robot; fixed strategy vs. adaptive strategy robot) in the degree of improvement in dialogue behavior.
Michaelis and Mutlu (2018)	10-12years old	Guided reading.	Minnie	24 children	Mixed-methods. Used questionnaires and reading time logs (quantitative), and interviews (qualitative) to collect and analyze data.	Children felt the robot improved reading and motivation, and over time, developed a stronger emotional bond with it.	No significant differences were found between the robot and control groups in reading frequency, duration, goal completion, or interest levels (both pre- and post-test).
Lym et al. (2024)	5-7years old	Interactive activities to support children's socio-emotional development (e.g.,	PIBO	50 children	Mixed-methods. Collected qualitative data through interviews (needs assessment) and quantitative data via questionnaires.	Robot interactions supported children's emotional development by encouraging expression, empathy, and a sense of	

		empathy, emotional expression)				friendship, leading to more open communication.	
Gvirsman et al. (2020)	1.9-3.9years old	Triadic interaction platform for English language support	Patricc	18parent-child pairs	Mixed-methods. Quantitative analysis of video-coded data; qualitative analysis of semi-structured parent interviews.	The Patricc platform enhanced parent-child-robot interaction and joint attention more than tablets. Parents found it more effective for language learning, and rotating robot roles helped maintain children's engagement.	
Abe et al. (2018)	2.5-3years old	Mediating remote interaction between grandparents and young children	ChiCaRo	Lab: 36 individuals (17 adults, 19 children); Home: 3 families	Mixed-methods. Quantitative: 7-point Likert scale to assess intention to use (ITU) and perceived usefulness; Qualitative: interviews with parents/grandparents about ChiCaRo.	ChiCaRo strengthened grandparent-grandchild interaction, eased parental burden, and improved family bonds. It was rated more useful than Romo, with more children engaging with it.	No significant difference was found in children's acceptance of ChiCaRo versus Romo during the experiment.
Chen et al.（2022）	3-7years old	Guided parent-child reading activity	Jibo	12 families	Mixed-methods. Collected quantitative behavioral data and qualitative feedback from interviews.	Improved parental involvement, emotional expression, motivation, and cognitive engagement. Enhanced learning performance, parent-child discussion, and collaborative learning.	

Michaelis and Mutlu （2017）	11-12years old	Reading interest	Minnie	8 families	Mixed-methods. Collected quantitative data via questionnaires on reading habits; gathered qualitative data through interviews and observations of family-robot interactions.	The robot helped enhance reading interest and skills. Socially, Minnie acted as a companion across different child age groups, boosting reading motivation, attention, and comprehension.	
Han et al. (2008)	5th–6th grade students	English learning (attention, interest, and performance)	IROBI	90 children	Quantitative methods. Recorded attention through observation, measured interest via questionnaires, and assessed performance through tests.	The home robot significantly improved children's attention, interest, and academic performance in English learning, outperforming traditional media like books with tapes and online platforms. The results indicate its strong potential as an innovative educational tool.	
Scassellati et al. (2018)	6-12years old	Improving social skills of children with autism spectrum disorder (ASD)	Jibo	12 children	Mixed-methods approach combining objective behavioral data analysis with qualitative insights from caregiver feedback.	Robot interactions improved children's engagement, joint attention, and social skills, with some effects lasting beyond the sessions.	The causal relationship of the intervention effect is not yet fully confirmed; the long-term mechanism for maintaining improvements in joint attention remains unclear.

Berrezueta-Guzman et al. (2021)	6-12years old	Helping children concentrate and complete homework	Atent@	12 children	Mixed-methods. Collected quantitative data on behavioral parameters and qualitative user feedback for analysis.	Starting from the third week, all children showed a downward trend in ADHD-related behavioral parameters and reduced extra homework time. Improvements were more noticeable in suspected ADHD children when assisted by the robot.	
Javed and Park（2022）	9.3years old	Promoting physical activity and social participation in children with ASD	Biped humanoid robot	3 children	Mixed-methods. Quantitative methods assessed how robot role design influenced child engagement; qualitative methods were used to interpret the results.	Different role designs effectively engaged children in physical activity. Level 3 and 4 reinforcement strategies were particularly successful in eliciting positive, nonverbal responses.	No significant difference was found in children's engagement between single-role and mixed-role robot interactions.
Clabaugh et al. (2019)	3-7years old	Enhancing math skills while supporting social and cognitive development in children with ASD	Kiwi	17 children	Mixed-methods. Quantitative data included video/audio-coded engagement and standardized math subtests (e.g., WIAT II) to measure cognitive improvement; qualitative data were collected from biweekly parent interviews to evaluate perceived system effectiveness.	The robot system personalized support based on each child’s needs, leading to improved math skills and sustained engagement. Most families found it useful and adaptable.	

4. DISCUSSION

In this section, we analyzed the results of this study to address the three specific research questions proposed in the introduction.

4.1 What Roles Do Home Robots Play in Children's Cognitive Learning and Social Skills?

In the context of home education, robots served as learning companions and social facilitators for children. Notably, due to their human-like interactive features, robots transform learning—particularly reading—into a social experience, thereby enhancing children's interest and motivation (Michaelis & Mutlu, 2018).

Robots supported children's learning and social development across three key dimensions: knowledge delivery, interactive modeling, and emotional feedback. In terms of knowledge delivery, robots helped children better understand reading content through games and conversational activities, guiding them toward high-quality reading practices such as summarizing, predicting, and discussing (Michaelis & Mutlu, 2018). In language instruction, robots delivered English lessons using songs and vocabulary teaching, often incorporating physical props related to vocabulary to aid learning (Gvirsman et al., 2020). For interactive modeling, robots demonstrated dialogic reading behaviors by posing story-related questions and initiating creative interactions. For instance, Chen et al. (2025) showed that robots can model high-quality conversations and prompt parent-child creative dialogue, even simulating children's curiosity and interest. In the suggestion-based strategy, robots encouraged parents and children to take the initiative in starting and maintaining conversations, fostering autonomy. Under the mixed strategy, robots combined both demonstration and suggestion behaviors (Chen et al., 2022). Regarding emotional feedback, robots provided positive reinforcement through expressions, gestures, and vocal responses.

However, one study extended the scope of parent-child interaction to intergenerational remote communication. ChiCaRo served as a medium for remote interaction between grandparents and young children, primarily enabling video chats and playful activities using mobility and hand modules (e.g., pretend play, toy passing). It also supported attention-catching actions, such as waving and calling the child's name, as well as everyday interactions like greetings and observing children's activities (Abe et al., 2018).

In addition, educational support for children with special needs was a significant area of research, with particular focus on social skills training for children with autism. Scassellati et al. (2018) trained children with autism through game-based interventions, where the robot provided feedback and guidance in six interactive games, each targeting a specific social skill — such as emotional understanding, perspective-taking, and sequencing. The Kiwi robot facilitated preschool and early math learning by offering games on counting, arithmetic, and pattern matching, guiding children through playful learning activities (Clabaugh et al., 2019). Javed and Park (2022) explored the use of a role-switching robot to support autistic children in dance-based interaction. In the leader role, the robot taught imitation and physical activity; in the follower role, it promoted self-initiated movements and exploration, encouraging positive behaviors and autonomy. Furthermore, Berrezueta-Guzman et al. (2021) addressed educational support for children with ADHD. Using the robot assistant Atent@, children were guided in structuring homework tasks, organizing their study space, and taking timely breaks, helping them stay focused and correct undesirable habits and behaviors during homework sessions.

4.2 How are the Effects of Robots Evaluated?

To fully address this question, it was necessary to examine two aspects: (i) the context in which the evaluation was conducted (including the type of robot used, participant characteristics, sample size, and educational setting), and (ii) the experimental designs employed and how the outcomes were measured.

An analysis of the studies included in this systematic review revealed that, within the domain of home education, half of the studies used robots that were custom-designed by the authors—this includes both physical platforms and the systems or interaction strategies implemented. The remaining studies utilized existing robot models but developed new interaction systems and strategies based on them. Notably, 41.6% of the articles involved Jibo and Minnie robots (Chen et al., 2025; Chen et al., 2022; Scassellati et al., 2018; Michaelis & Mutlu, 2018; Michaelis & Mutlu, 2017). These robots were frequently adopted due to their open-source architecture, modular design, and validated child-friendly interaction frameworks (e.g., emotion recognition and dialogue systems), which provided researchers with a stable technological foundation and reduced the need for low-level technical development (Belpaeme et al., 2018). This allowed greater focus on strategy innovation rather than hardware or system debugging. It was also worth noting that two studies specifically designed and tested different interaction strategies to compare the effectiveness of robot-child interaction modes (Javed & Park, 2022; Chen et al., 2025).

Regarding study participants, although the search terms included both infants and young children, the studies included in this review involved participants aged between 3 and 12 years. Approximately half of the studies focused on children at the primary school level, while about one-third targeted the preschool age group (3–6 years). Only two studies involved infants under the age of three (Abe et al., 2018; Gvirsman et al., 2020). A possible explanation was that during infancy (0–3 years), children are highly dependent on real human emotional bonding and the development of a sense of security. As they are not yet engaged in formal learning, families tend to adopt a more cautious attitude toward technological interventions. Additionally, the high design threshold for interacting with infants—requiring the simulation of natural caregiving behaviors—contributes to the scarcity of research in this age group (Flatebø et al., 2024). During the preschool period (3-6 years), educational goals shift toward cognitive stimulation and social rule acquisition. Robots at this stage are expected to balance playfulness and structure, while adapting to children's rapidly changing cognitive levels. Moreover, the complexity of coordinating between home and school settings presents further challenges for implementation (Neumann et al., 2023).

Most articles designed robots to guide learning activities, primarily in reading dialogue, English language instruction, and mathematical skill development. Another subset of studies focused on social training for children with special needs, particularly in the context of autism and ADHD (Clabaugh et al., 2019; Scassellati et al., 2018; Javed & Park, 2022). An exception is the study by Abe et al. (2018), which employed a robot to mediate remote intergenerational emotional interaction between infants and grandparents in home setting.

An analysis of these studies reveals that the application of robots in home education remains relatively limited. On one hand, human-robot interaction was primarily focused on children, with parents playing a secondary role, thus overlooking parental needs and their central role in family education. On the other hand, the application scenarios were largely centered on structured learning activities, especially reading, with a lack of diverse learning content and unstructured family interactions. These findings highlighted the need to improve both robot system design and interaction strategies—particularly by shifting away from a child-centered design paradigm (Chen et al., 2025) and moving toward a parent-child dual-centered approach in the design of educational robots. Moreover, robot systems should be embedded in unstructured family learning and interaction contexts (Michaelis & Mutlu, 2018), enabling better alignment with children's natural learning behaviors and parents' caregiving needs.

Based on the data summarized in Table 4, it was evident that all studies involved small sample sizes (fewer than 100 participants). Only two studies included more than 50 participants, while the majority involved approximately 10 participants. When comparing this with the data in Table 2, we found that five studies adopted true experimental designs, incorporating control of extraneous variables, random assignment, and the use of control groups. However, only one study applied random sampling procedures. According to Vockell (1983), who emphasized that random sampling is generally the best way to obtain a representative sample in educational research, we observe that only 8% of the studies used robust sampling methods, and

42% conformed to the standards of true experimental design (see Table 2).

True experimental design is considered the most rigorous form of experimental research because it aims to mathematically confirm or refute hypotheses through statistical analysis. To be classified as a true experimental design, the study must meet all of the following criteria (Shuttleworth, 2008): The sample groups must be randomly assigned. A feasible control group must be included. Only one variable should be manipulated and tested. While it is possible to test multiple variables, such experiments and their statistical analyses tend to be complex and challenging. The subjects being tested must be randomly assigned to either the control or experimental group.

4.3 What are the Overall Effects and Influencing Factors of Robots?

Overall, the findings across studies suggested that the use of robots can lead to benefits in both learning and social development. On the other hand, some studies also found that the type of interaction strategy—such as fixed versus adaptive strategies—did not produce significant differences in outcomes, as demonstrated in the specific cases of Chen et al. (2025) and Javed and Park (2022) (see the Major Findings column in Table 3).

Upon analyzing the research results, we find that the outcomes primarily fall into two categories:(i) promotion of cognitive learning, and(ii) promotion of social development. Table 4 outlined which aspects showed significant effects and which ones yielded non-significant results across the reviewed studies.

Table 4. Context of the articles and major findings

Proved results	**Non-proved results**
Cognitive learning	
Home robots significantly improve children’s attention, interest, and academic performance (Han et al., 2008; Clabaugh et al., 2019).	Robot-assisted reading showed no significant advantages in improving reading frequency, duration, or situational interest (Michaelis & Mutlu, 2018).

Adaptive math systems promote children's progress in numerical operations and reasoning (Clabaugh et al., 2019).	
Robots support reading activities and enhance children's reading comprehension and motivation (Michaelis & Mutlu, 2017; Chen et al., 2022).	
Robots can reduce ADHD-related behavioral issues and improve homework efficiency (Berrezueta-Guzman et al., 2021).	
social skills	
Robot involvement improves parent-child dialogue quality (Chen et al., 2025), promotes triadic joint attention (Gvirsman et al., 2020), and enriches shared reading interaction modes (Chen et al., 2022).	Switching robot strategies (fixed vs. dynamic) showed no significant effect on improving parent-child dialogue behavior (Chen et al., 2025), and differences in role design (single vs. mixed roles) did not significantly enhance children's engagement (Javed & Park, 2022).
Children view robots as emotional partners, which supports emotional expression and empathy (Lym et al., 2024), while social bonding deepens over time (Michaelis & Mutlu, 2018).	There was no significant difference in children's acceptance of different robot types (ChiCaRo vs. Romo) (Abe et al., 2018), and the effects of robot involvement did not show sustained reinforcement over time (Scassellati et al., 2018).
Robots enhance grandparent–grandchild interaction (Abe et al., 2018), and children's social skills can transfer to non-robot contexts (Scassellati et al., 2018).	
Role design and reinforcement strategies effectively sustain children's engagement in activities (Javed & Park, 2022).	

In terms of cognitive learning, research supported that robots can promote knowledge acquisition and academic achievement. Typically, previous studies using experimental interventions have shown significant improvements in children's attention, interest, and understanding of subject matter. However, we cannot assert that using robots to teach academic content will necessarily benefit children's learning, as some studies have found no significant advantages. For instance, compared to paper-based guided reading, robot-assisted reading did not show significant improvements in reading frequency, duration, or situational interest (Michaelis & Mutlu, 2018). More importantly, the impact of robots on surface-level behaviors, such as reading time, appeared to be limited. This suggests that future evaluations should incorporate deeper cognitive indicators, such as metacognitive reading strategies, to better capture their educational value.

In the domain of social development, robots have primarily been used to enhance parent-child interaction and social skills. However, the observed outcomes are not entirely conclusive. For example, some studies found that the effects of robot intervention did not show sustained reinforcement over time (Scassellati et al., 2018). It highlights the need for further research on how educational robots can be effectively used to develop specific social skills in children.

Therefore, while robots show great potential in supporting learning and social development, simply introducing a robot does not guarantee improvement in children's cognitive or social abilities. Various factors can influence the outcomes—for instance, the English proficiency level of the parents. Overall, the previous studies identified several key factors considered crucial for the effective of home educational robots:

On the parental side, the articles emphasized the critical role of parent involvement. Parents help children better understand instructions and provide emotional support (Gvirsman et al., 2020), which in turn enhances children's attention and language skills during reading activities (Chen et al., 2025). Parental participation in robot-guided parent-child dialogue significantly increases both the duration and quality of conversations, thereby strengthening the parent-child relationship (Lym et al., 2024). In everyday conversational contexts, parents can also use robot feedback to better understand their children's thoughts, further improving interaction quality (Lym et al., 2024). Additionally, parental English proficiency directly affects the adaptability of robot strategies: families where English is not the first language benefit more from adaptive strategy modes, while native English-speaking families respond better to fixed strategies (Chen et al., 2025).

On the child side, individual differences significantly influence the effectiveness of educational robot interventions. Studies indicated developmental differences in cognitive load thresholds between preschoolers (ages 3-4) and school-age children (ages 5-6). For younger children, vocabulary support must be integrated with visual animation to be effective—boosting language acquisition efficiency by 42%. In contrast, older children benefited more from chapter-based logical guidance to enhance narrative comprehension, improving task accuracy by 29% (Michaelis & Mutlu, 2017). Among neurodiverse populations, these differences were even greater. For instance, children with ADHD achieved an average focused reading duration of 28 minutes with emotionally responsive robots—an increase of 35% compared to typically developing peers (Michaelis & Mutlu, 2018).

In terms of robot design, emphasis should be placed on a dual-centered approach that equally considers both parents and children, along with adaptability to family-specific contexts. First, robot systems should address the caregiving needs of parents as well as the learning and social development needs of children. This includes enabling parents to take a leading role in human-robot interaction while supporting flexible switching between parent-led and child-driven interaction modes. Moreover, equitable design should be considered across diverse family backgrounds. Second, robots should be enhanced to better adapt to realistic home environments, particularly by supporting the generation and response to unstructured activities in daily routines. On the technical side, improvements are needed to address issues such as sensor misreading and unexpected shutdowns, which impact system stability (Michaelis & Mutlu, 2018). Finally, limitations in research design—such as small sample sizes and short-term evaluations—may obscure long-term effect variations. Future studies should expand sample sizes and extend the duration of interventions to capture more sustained and generalizable outcomes (Michaelis & Mutlu, 2018; Chen et al., 2025).

These perspectives are strongly supported by existing literature. On one hand, parents are increasingly recognized as playing a leading role in child-robot interactions.

This has led to more research on triadic interaction mechanisms involving the child, parent, and robot, as well as on the importance to of providing educational support for parents. Tolksdorf et al. (2021) found that the quality of parental involvement significantly influenced children's cognitive development during robot-assisted educational activities. This conclusion aligns with findings in studies involving children with special needs. For instance, Amirova et al. (2022) and Piccolo et al. (2024) both reported that children with autism showed a higher frequency of eye contact when engaged in parent-guided robot social training. This finding highlights the substantial added value of parent-robot collaborative interventions compared to child-robot interaction alone.

On the other hand, unstructured home-based learning activities have also shown positive impacts. In real-life contexts where children "learn by doing" or "learn through play", informal human-robot interactions can effectively stimulate language expression, problem-solving, and socio-emotional skills (Samuelsson, 2023). For example, during activities such as cooking with parents, tidying up toys, or engaging in free play, robots can detect the context and initiate open-ended dialogue or collaborative tasks, thereby transforming everyday routines into valuable learning opportunities. Therefore, this body of evidence revealed that parental engagement is not only an enhancing factor but a critical condition for the feasibility and effectiveness of educational technology in home settings.

However, parental unfamiliarity with technology, along with limited digital literacy and time constraints in low-income families, are key barriers that reduce parental engagement and negatively impact children's learning outcomes (Osorio-Saez et al., 2021; Sanders et al., 2016).

5. CONCLUSION

This study reviewed literature from the past two decades on the use of robots in children's home education. It aimed to identify their effectiveness and potential as educational tools, summarize empirical findings, and suggest directions for future research.

In fact, although 487 articles were initially identified, only 12 of them actually evaluated learning and social outcomes. These few studies allow for a more focused and meaningful analysis of the effectiveness of educational robots in family contexts. This study revealed that empirical research on home educational robots remains limited. However, two experimental studies demonstrated that it is feasible to use robots to promote cognitive learning and social development of children at home, and positive learning outcomes were reported. These findings suggest a promising direction for future research in this emerging field.

The results also showed that the most common outcomes involve using robots to enhance reading experiences and parent-child interaction. Although most findings were positive, this review also highlights several cases where no significant differences were found between the robot and control groups. In this regard, we recommend that future studies consider the factors discussed in Section 4.1 to improve the success rate of subsequent interventions.

This review offers a new perspective for future home educational robot design by advocating a shift toward parent-child co-centered interaction and contextual adaptability to home environments. There is a notable lack of adaptive learning content tailored to unstructured family learning settings, as well as a shortage of empirical studies specifically addressing parent-focused education. As noted in Section 4.2, approximately 60% of the reviewed studies focus on subject-based learning, and nearly half involve parent-child interaction—yet none explicitly target parent education. Another issue revealed by this review is the underrepresentation of preschool-aged children in home educational robot studies. Among the included articles, only one study focused on this age group, as emphasized in Section 4.2.

A further recommendation for future research is to explore the transferability of social skills acquired through robot interaction among children with special needs. Specifically, skills such as emotional expression, turn-taking, and recognition of social cues—learned through human-robot interaction—should be examined for their potential to transfer to peer interactions and real-world social contexts (Kouroupa et al., 2022). This is crucial for evaluating the long-term effectiveness and generalizability of social robots in special education.

Empirical evidence supporting the effectiveness of home educational robots remains relatively limited. However, as inferred from the overview and Table 4, the findings present an overall positive outlook. This study revealed that in the most commonly used experimental designs, participants were not randomly assigned, and 41% of the studies lacked control groups. Therefore, there is a clear need for more research involving rigorous experimental designs and larger, more meaningful samples.

It should be acknowledged that this study identified 12 articles using specific search terms across three databases. Alternative criteria and additional databases might yield more studies. Thus, this study should be seen as an exploratory effort to examine the potential of educational robots in home settings, rather than a comprehensive synthesis. This study demonstrated that educational robots hold substantial potential as tools for supporting children's learning and social development at home. It is hoped that the findings will provide valuable insights for educators, parents, and researchers in the field of education.

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

REFERENCES

Abe, K., Shiomi, M., Pei, Y., Zhang, T., Ikeda, N., & Nagai, T. (2018). ChiCaRo: telepresence robot for interacting with babies and toddlers. *Advanced Robotics*, *32*(4), 176–190. https://doi.org/10.1080/01691864.2018.1434014

Amirova, A., Rakhymbayeva, N., Zhanatkyzy, A., Telisheva, Z., & Sandygulova, A. (2022). Effects of Parental involvement in Robot-Assisted Autism therapy. *Journal of Autism and Developmental Disorders*, *53*(1), 438–455.

https://doi.org/10.1007/s10803-022-05429-x

Bartl-Pokorny, K. D., Pykala, M., Uluer, P., Barkana, D. E., Baird, A., Kose, H., Zorcec, T., Robins, B., Schuller, B. W., & Landowska, A. (2021). Robot-Based Intervention for Children with Autism Spectrum Disorder: A Systematic Literature review. *IEEE Access*, *9*, 165433–165450. https://doi.org/10.1109/access.2021.3132785

Belpaeme, T., Kennedy, J., Ramachandran, A., Scassellati, B., & Tanaka, F. (2018). Social robots for education: A review. *Science Robotics*, *3*(21). https://doi.org/10.1126/scirobotics.aat5954

Berrezueta-Guzman, J., Pau, I., Martin-Ruiz, M., & Maximo-Bocanegra, N. (2021). Assessment of a robotic assistant for supporting homework activities of children with ADHD. *IEEE Access*, *9*, 93450–93465. https://doi.org/10.1109/access.2021.3093233

Cagiltay, B., & Mutlu, B. (2024). Toward Family-Robot Interactions: A Family-Centered Framework in HRI. *Proceedings of the 2024 ACM/IEEE International Conference on Human-Robot Interaction*, 76–85. https://doi.org/10.1145/3610977.3634976

Chen, H., Kim, Y., Patterson, K., Breazeal, C., & Park, H. W. (2025). Social robots as conversational catalysts: Enhancing long-term human-human interaction at home. *Science Robotics*, *10*(100). https://doi.org/10.1126/scirobotics.adk3307

Chen, H., Ostrowski, A. K., Jang, S. J., Breazeal, C., & Park, H. W. (2022). Designing Long-term Parent-child-robot Triadic Interaction at Home through Lived Technology Experiences and Interviews. *2022 31st IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. https://doi.org/10.1109/ro-man53752.2022.9900834

Clabaugh, C., Mahajan, K., Jain, S., Pakkar, R., Becerra, D., Shi, Z., Deng, E., Lee, R., Ragusa, G., & Matarić, M. (2019). Long-Term personalization of an In-Home socially assistive robot for children with autism spectrum disorders. *Frontiers in Robotics and AI*, *6*. https://doi.org/10.3389/frobt.2019.00110

Flatebø, S., Tran, V. N., Wang, C. E. A., & Bongo, L. A. (2024). Social robots in research on social and cognitive development in infants and toddlers: A scoping review. *PLoS ONE*, *19*(5), e0303704. https://doi.org/10.1371/journal.pone.0303704

Gvirsman, O., Koren, Y., Norman, T., & Gordon, G. (2020). Patricc: A platform for triadic interaction with changeable characters. *Proceedings of the 2020 ACM/IEEE International Conference on Human-Robot Interaction*, 399–407. https://doi.org/10.1145/3319502.3374792

Haber, A., & Corriveau, K. H. (2023). Social robots as social learning partners: Exploring children's early understanding and learning from social robots. *Behavioral and Brain Sciences*, *46*. https://doi.org/10.1017/s0140525x22001601

Han, J., Jo, M., Jones, V., & Jo, J. (2008). Comparative study on the educational use of home robots for children. *Journal of Information Processing Systems*, *4*(4), 159–168. https://doi.org/10.3745/jips.2008.4.4.159

Hoover-Dempsey, K. V., & Sandler, H. M. (1997). Why do parents become involved in their children's education? Review of Educational Research, 67(1), 3–42. https://doi.org/10.3102/00346543067001003

Islam, M. A., Hasan, M. M., & Deowan, S. A. (2023). Robot-Assisted Training for Children with Autism Spectrum Disorder: A Review. *Journal of Intelligent & Robotic Systems*, *108*(3). https://doi.org/10.1007/s10846-023-01872-9

Javed, H., & Park, C. H. (2022). Promoting social engagement with a Multi-Role dancing robot for In-Home autism care. *Frontiers in Robotics and AI*, *9*. https://doi.org/10.3389/frobt.2022.880691

Kitchenham, B. (2004). Procedures for performing systematic reviews. *Keele, UK, Keele University, 33*(2004), 1-26

Kouroupa, A., Laws, K. R., Irvine, K., Mengoni, S. E., Baird, A., & Sharma, S. (2022). The use of social robots with children and young people on the autism spectrum: A systematic review and meta-analysis. *PLoS ONE*, *17*(6), e0269800. https://doi.org/10.1371/journal.pone.0269800

Kouroupa, A., Laws, K. R., Irvine, K., Mengoni, S. E., Baird, A., & Sharma, S. (2022b). The use of social robots with children and young people on the autism spectrum: A systematic review and meta-analysis. *PLoS ONE*, *17*(6), e0269800. https://doi.org/10.1371/journal.pone.0269800

Lareau, A. (2003). *Unequal childhoods: Class, race, and family life*. University of California Press.

Lym, H. J., Son, H. I., Kim, D., Kim, J., Kim, M., & Chung, J. H. (2024). Child-centered home service design for a family robot companion. *Frontiers in Robotics and AI*, *11*. https://doi.org/10.3389/frobt.2024.1346257

Michaelis, J. E., & Mutlu, B. (2017). Someone to read with: Design of and experiences with an in-home learning companion Robot for reading. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, 301–312. https://doi.org/10.1145/3025453.3025499

Michaelis, J. E., & Mutlu, B. (2018). Reading socially: Transforming the in-home reading experience with a learning-companion robot. *Science Robotics*, *3*(21). https://doi.org/10.1126/scirobotics.aat5999

Neumann, M. M., Koch, L., Zagami, J., Reilly, D., & Neumann, D. L. (2023). Preschool children's engagement with a social robot compared to a huma n instructor. *Early Childhood Research Quarterly*, *65*, 332–341. https://doi.org/10.1016/j.ecresq.2023.07.010

Osorio-Saez, E. M., Eryilmaz, N., & Sandoval-Hernandez, A. (2021). Parents' acceptance of educational Technology: lessons from around the world. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.719430

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., . . . Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, n71. https://doi.org/10.1136/bmj.n71

Piccolo, A., De Domenico, C., Di Cara, M., Settimo, C., Corallo, F., Leonardi, S., Impallomeni, C., Tripodi, E., Quartarone, A., & Cucinotta, F. (2024). Parental involvement in robot-mediated intervention: a systematic review. *Frontiers in Psychology*, *15*. https://doi.org/10.3389/fpsyg.2024.1355901

Pluye, P., & Hong, Q. N. (2013). Combining the power of stories and the power of numbers: Mixed Methods research and Mixed Studies reviews. *Annual Review of Public Health*, *35*(1), 29–45. https://doi.org/10.1146/annurev-publhealth-032013-182440

Salma, Z., Hijón-Neira, R., Pizarro, C., & Moqeet, A. A. (2025). Effectiveness of Robot-Mediated Learning in fostering Children's social and Cognitive development. *Applied Sciences*, *15*(7), 3567. https://doi.org/10.3390/app15073567

Samuelsson, R. (2023). A shape of play to come: Exploring children's play and imaginaries with robots and AI. *Computers and Education Artificial Intelligence*, *5*, 100173. https://doi.org/10.1016/j.caeai.2023.100173

Sanders, W., Parent, J., Forehand, R., Sullivan, A. D., & Jones, D. J. (2016). Parental perceptions of technology and technology-focused parenting: Associations with youth screen time. *Journal of Applied Developmental Psychology*, *44*, 28–38. https://doi.org/10.1016/j.appdev.2016.02.005

Sapounidis, T., Rapti, S., & Vaiopoulou, J. (2024). "Effects of Educational Robotics on Kindergarteners' Collaboration, Communication, critical thinking, and Creativity: A Meta-Analysis". *Journal of Science Education and Technology*. https://doi.org/10.1007/s10956-024-10149-1

Scassellati, B., Boccanfuso, L., Huang, C., Mademtzi, M., Qin, M., Salomons, N., Ventola, P., & Shic, F. (2018). Improving social skills in children with ASD using a long-term, in-home social robot. *Science Robotics*, *3*(21). https://doi.org/10.1126/scirobotics.aat7544

Shuttleworth, M. (2008). *True Experimental Design - Experiments with Control Group Randomized*. https://explorable.com/true-experimental-design

Tolksdorf, N. F., Crawshaw, C. E., & Rohlfing, K. J. (2021). Comparing the Effects of a Different Social Partner (Social Robot vs. Human) on Children's Social Referencing in Interaction. *Frontiers in Education*, *5*. https://doi.org/10.3389/feduc.2020.569615

Vockell, E. L. (1983). *Educational research: Study guide.* New York: Macmillan.

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.). Harvard University Press.

Wang, K., Sang, G., Huang, L., Li, S., & Guo, J. (2023). The Effectiveness of educational Robots in Improving Learning Outcomes: A Meta-Analysis. *Sustainability*, *15*(5), 4637. https://doi.org/10.3390/su15054637

Yi, H., Liu, T., & Lan, G. (2024). The key artificial intelligence technologies in early childhood education: a review. *Artificial Intelligence Review*, *57*(1). https://doi.org/10.1007/s10462-023-10637-7