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Article

The Effects of a Classroom-Based AI Robot-Assisted Teaching Intervention on Preschool Children's Behavior and Emotions: A Quasi-Experimental Study

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Abstract

The purpose of this study is to investigate how preschoolers' behavioral and emotional development is affected by artificial intelligence (AI) robot-assisted instruction. Children from a middle-class kindergarten in Zhengzhou, Henan Province, China, participated in the study. A non-equivalent pre-test-post-test Class A was used in a quasi-experimental approach. While the Class A received traditional teacher-led training, the Class B received a three-week interactive teaching intervention utilizing the AI robot "Beiya." Children's abilities in four areas-emotional regulation, school preparedness, social confidence, and family involvement-were assessed using the Preschool Behavioral and Emotional Rating Scale (PreBERS). According to the findings, the Class B outperformed the Class A in every category following the intervention, with improvements in social confidence and emotional control being especially noteworthy. According to these results, AI robots may help foster prosocial behavior and emotional growth in preschoolers. The study offers factual evidence in favor of using AI in early childhood education.

Keywords

Artificial intelligence, Robot-assisted teaching, Preschool children, Behavioral development, Emotional regulation

Article History

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1. Introduction

1.1 Social-Emotional Development as the Developmental Goal

The emotional development of preschool children has long been an important topic in early childhood research [1]. Positive social-emotional development is closely related to children's overall well-being [2], and their ability to follow social and behavioral norms is connected with emotional intelligence and self-control [3]. In daily interaction, children gradually build emotional experience and form patterns of behavior [4]. Emotional knowledge includes perceiving, understanding, and regulating emotions, as well as knowing what may affect emotional states [5]. Previous studies have found positive links among emotional competence, social competence, and emotional self-regulation [6]. Around the age of four, children become better able to recognize and manage emotions [7]. This is also consistent with Erikson's stage of initiative versus guilt, in which self-directed regulation and behavioral control become more visible [8]. During this period, children begin to show clearer abilities in handling simple conflicts, staying on task, and expressing emotions in social situations [9,10]. Social-emotional learning (SEL) can further support emotional regulation and help children develop empathy, care, and other prosocial behaviors [11-13].

At the same time, not all children develop these abilities smoothly. Excessive digital media exposure may reduce opportunities for direct social interaction and may affect self-regulation and emotional expression [14,15]. Children's social-emotional development is also influenced by factors such as gender, family structure, and access to educational resources [16,17]. Because of these challenges, different programs have been introduced to support young children's social development [18,19]. Against this background, AI-assisted teaching and social robots have become a possible support tool in early childhood education. Compared with traditional digital media, social robots can provide interaction, feedback, and guided practice, so they may be more suitable for supporting children's social-emotional learning. Therefore, this study takes social-emotional learning as the main goal of the intervention and uses AI robots to support children's development in important social-emotional and behavioral domains.

1.2 Robot-Assisted Learning as an Interactive Support for SEL

In recent years, educational and social robots have received more attention in learning research. Studies show that robots can act as assistants, peers, or guides in educational settings and may help improve children's participation and interest. However, most studies still focus on cognitive learning, language tasks, or short-term classroom performance. Research in real classroom settings is still limited. As [20] noted, intelligent technologies in early childhood education are gaining attention, but their educational value has not been fully explored.

Preschool is a key stage for children's social-emotional and behavioral development. During this period, children gradually learn to understand emotions, express feelings, control impulses, and build social relationships. These abilities develop through daily interaction and guided practice [21]. At the same time, family support and peer interaction also play an important role in children's emotional growth [22].

For this reason, robot-assisted learning may be useful in early childhood education. Social robots can provide interaction, feedback, and repeated practice. Still, the robot itself does not directly cause developmental change. Its value depends on how it is used in classroom activities and guided by teachers. Therefore, in this study, robot-assisted learning is treated as a support tool within a teacher-guided social-emotional learning process.

1.3 CTML as an Explanation of the Learning Process

In early childhood education, teachers often use picture books, themed activities, teacher demonstration, and hands-on practice to support learning [23,24]. Today, children also meet more technology in daily life, including AI [25]. Technology is already part of informal learning [26], although some studies also warn that too much early exposure may bring negative effects [27]. Even so, recent research shows that media and technology can still support interaction and learning when they are used properly [28].

Mayer's Cognitive Theory of Multimedia Learning (CTML) helps explain this point [29]. It suggests that children can learn better when information is presented in different ways, such as words, pictures, sound, and action. Some studies also show that technology can help children's learning, motivation, communication, and social development [30-33]. In recent years, AI educational robots have received more attention in early childhood education. These robots can interact with children through speech, visual cues, and feedback, and they may help with language, self-regulation, emotional expression, and social behavior [34,35].

Based on this idea, this study uses CTML as the theoretical support for AI robot-assisted activities. The robot is not treated as something that changes children by itself. Its role is to support teacher-guided learning. Therefore, this study uses the AI robot Beiya and a quasi-experimental design to examine whether robot-assisted classroom activities can support preschool children's emotional and behavioral development. PreBERS is used as the main measurement tool because it has good reliability and validity and covers emotional regulation, social confidence, school readiness, and family involvement [36].

1.4 Integrated Conceptual Framework

Based on recent studies, this research uses an integrated framework to explain how AI robot-assisted activities may support preschool children's socio-emotional development. Social-emotional learning is important in early childhood because children are still learning how to regulate emotions, interact with others, and control their behavior. Preschool SEL programs have been shown to improve children's social, emotional, and behavioral outcomes [37,38]. Teacher emotion coaching and co-regulation are also important for children's self-regulation in the classroom [39].

In this study, the AI robot is not treated as the final goal, but as a classroom support tool. Recent studies show that AI in early childhood education is receiving more attention, but stronger evidence is still needed [40]. Some studies also found that robots do not always lead to better engagement than human teaching [41]. Here, CTML helps explain how the robot may work. When spoken language, gestures, visual cues, and feedback are combined, children may understand emotional and social information more easily [42]. With teacher guidance, they can then practice skills such as emotion recognition, cooperation, and self-regulation. This idea is also supported by research on human-robot collaborative teaching [43].

1.5 Research Questions

The purpose of this study is to determine whether various teaching strategies result in appreciable variations in preschoolers' social and emotional growth. The following particular research goals were developed to accomplish this goal:

(1) After receiving AI robot-assisted teaching, does the Class B perform better than the Class A in emotional regulation?

(2) After receiving AI robot-assisted teaching, does the Class B perform better than the Class A in social confidence?

(3) After receiving AI robot-assisted teaching, does the Class B perform better than the Class A in school readiness?

(4) After receiving AI robot-assisted teaching, does the Class B perform better than the Class A in family involvement?

2. Method

2.1 Research Design

Criterion sampling, a form of purposive selection, was used in this study's quasi-experimental design to choose the study group and participants. Children have to be in the same age range (5-6 years) and have never received robot-assisted instruction before in order to be eligible. This selection approach guarantees congruence with the research objectives, according to Creswell [44]. These criteria were found to be suitable for participant selection given the practical nature of the intervention.

This study employed a quasi-experimental pre- and post-test control design to explore the impact of AI-assisted classroom teaching intervention on the behavior and emotions of preschool children. A quasi-experimental design was used because participants came from a full kindergarten class, making individual randomization difficult in a natural educational environment. Before the intervention, both groups of children completed a pre-test assessment. Subsequently, the Class B received the AI-assisted teaching intervention, while the Class A continued with regular classroom activities/traditional teaching. After the intervention, both groups completed a post-test assessment using the same tools.

A Class A and an Class B were formed from the participants. While the Class A received conventional training from the same teacher, the Class B received instruction assisted by an AI robot. The PreBERS scale was used to evaluate both groups both before and after the intervention.

The AI robot "Beiya" was utilized in the Class B to support instructional activities centered around social and emotional issues. Over the course of three weeks, the intervention duration appears inconsistent throughout the manuscript. In the abstract, the intervention is described as lasting four weeks, while the methods section indicates a three-week intervention. Please clarify. The intervention was carried out twice a week for 25 minutes each. The same subjects were taught to the Class A using conventional teaching techniques.

The social education component of the conventional five-domain preschool curriculum served as the foundation for the AI robot-assisted curriculum in the Class B. It was created to find integration points where the robot could be used in class activities in a meaningful way. The experimental curriculum added interaction elements between the children and the robot while maintaining the typical structure, in contrast to the Class A's conventional approach (As shown in Figure 1).

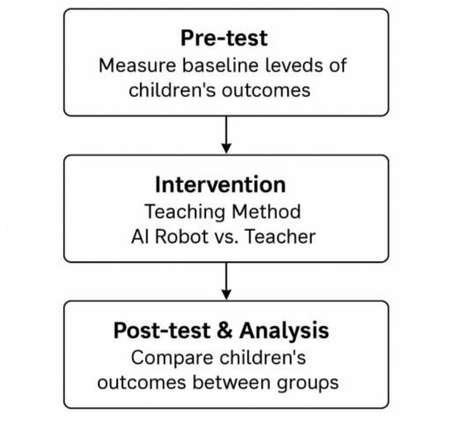

Figure 1. Variable Path Diagram.

This study's independent variable was the form of instruction, which was split into two groups: the Class A received traditional teacher-led training, and the Class B received AI robot-assisted instruction utilizing the "Beiya" robot. The PreBERS scale was used to measure children's behavioral and emotional development along four dimensions: emotional control, school readiness, social confidence, and family participation.

This study used a quasi-experimental design in which participants were recruited from intact preschool classrooms rather than randomly assigned at the individual level. One class served as the Class B and the other served as the Class A. Therefore, the study had a cluster-based structure at the classroom level. Because children were nested within existing classes, the assumption of fully independent observations may have been weakened. This feature should be considered when interpreting the results.

2.2 Participants

Sixty preschoolers, ages five to six, from two middle-level classrooms at a kindergarten in Zhengzhou, China, made up the sample. Gender and overall ability were distributed equally among the participants. Participants were divided into an Class B and a Class A, each comprising 30 kids, using class-based categorization. There were 14 girls and 16 boys in the Class B and 17 girls and 13 boys in the Class A.

This specific kindergarten was chosen because it offers equal learning opportunities, a balanced setting for developmental comparison, and serves children from similar cultural and socioeconomic origins. The school also had the required technical infrastructure, including classrooms for AI-assisted learning activities.

Participants in this study were selected from full-fledged preschool classrooms using convenience sampling. Because participants were drawn from existing classrooms and not randomly assigned at the individual level, this study can be described as a cluster quasi-experiment. The experimental and Class As were divided based on classroom groupings within a real-world educational environment.

2.3 Intervention Procedure

The intervention in this study was conducted in a regular kindergarten classroom, primarily through teacher-led AI robot-assisted activities. Throughout the intervention, the teacher did not simply observe but actively participated. The teacher first introduced the activity content, maintained classroom order, and encouraged children to speak and participate. If some children did not understand, the teacher provided timely explanations and helped them connect the activity content with their emotional expressions and social behaviors in daily life.

During the activity, the AI robot primarily serves to assist in teaching and guide interaction. It provides simple verbal prompts to the children, presents small scenarios related to emotions or behaviors, and asks simple questions. After the children answer, the robot provides feedback. Sometimes, the robot also uses actions, gestures, facial expressions, or visual cues to attract the children's attention, making it easier for them to understand the socio-emotional content of the activity.

Each intervention activity followed a fairly fixed process. At the beginning, the teacher first gave a simple introduction of the topic, so the children could know what this class activity was about. Then, the robot started to present the related content, such as an emotional expression, a social situation, or a simple behavior task. After that, the children responded according to the robot’s prompts. Sometimes they answered one by one, and sometimes they responded together. If some children had difficulties during this process, the teacher would give reminders and guidance. After that, the children did some repeated practice, such as identifying emotions, expressing their own feelings, taking turns to answer, or reacting to a certain social situation. At the end of the activity, the teacher made a simple summary and again stressed the socio-emotional skills that the children were expected to learn in this activity.

For example, in some activities, the robot will first present an emotional or social situation, then ask the children to judge what emotions the people in the situation are experiencing, or to think about how they should respond appropriately. After answering, the children will imitate the relevant expressions or actions and engage in a simple discussion led by the teacher. The teacher will help the children further understand their answers, correct any inappropriate responses, and encourage them to make more appropriate socio-emotional responses. Such activities will be repeated in different courses, mainly to help children gradually improve their abilities in emotion recognition, emotion expression, cooperation, taking turns, and self-regulation through continuous practice and teacher guidance.

2.4 Data Collection Process

Data collection was conducted in three phases: pre-test, intervention, and post-test. Before the intervention, parents completed the PreBERS scale as a pre-test. The intervention lasted three weeks, twice a week, for 20 to 30 minutes each time. After the intervention, parents completed the scale again as a post-test. This procedure allowed the study to compare changes in children's behavior and emotional expression before and after the intervention.

This study received ethical approval from the ethics committee before it began. All participating children's parents or legal guardians signed informed consent forms. Study participants were recruited from a private kindergarten in Zhengzhou, Henan Province, on a voluntary basis. Parents were informed of the research purpose and procedures before participation, and only children with parental consent were included in the study. All research procedures complied with ethical requirements for research involving young children.

2.5 Instruments and Reliability

2.5.1 Instrument

This study used the Chinese version of the Preschool Behavioral and Emotional Rating Scale (PreBERS) as the primary research tool. The original PreBERS was developed by Epstein and Synhorst in 2009, aiming to assess the emotional and behavioral strengths of preschool children from a strengths perspective. The Chinese version was revised in 2011 by Zhou Renlai and Hua Mizhi based on translation, back-translation, and expert discussions. During the revision process, items unsuitable for Chinese preschool children were removed, resulting in the final Chinese version of the scale.

The scale comprises four subscales: Emotional Regulation (ER), School Readiness (SR), Social Confidence (SC), and Family Involvement (FI). Emotional Regulation measures a child's ability to control emotions and behavior in social situations; School Readiness assesses a child's skills required for school entry, such as attention, language comprehension, and the ability to complete tasks independently; Social Confidence measures a child's ability to establish and maintain positive interactive relationships with peers and adults; and Family Involvement reflects the degree to which a child integrates into family life and their relationships with family members. In this study, parents who have frequent daily contact with their children completed the scale assessments based on their children's performance in daily life.

All items were rated on a four-point Likert scale from 0 to 3, where 0 indicates "completely inconsistent with the child," 1 indicates "somewhat inconsistent with the child," 2 indicates "somewhat consistent with the child," and 3 indicates "very consistent with the child." Higher scores indicate stronger emotional and behavioral dominance in the child. Previous research has shown that the Chinese version of PreBERS has good psychometric properties. Exploratory factor analysis supports its consistent four-factor structure with item factor loadings ranging from 0.540 to 0.936, explaining 61.440% of the total variance. Furthermore, the Chinese version of PreBERS also demonstrates good criterion-related validity and high internal consistency, with Cronbach's alpha coefficients for each subscale ranging from 0.885 to 0.932. In this study, the overall Cronbach's alpha coefficient of the scale was 0.89, indicating good reliability.

2.5.2 Use of the AI Robot

In this study, the AI robot "Beiya" was chosen as the teaching tool for AI-assisted instruction (As shown in Figure 2). Beiya is specifically made for the child companionship and education market, in contrast to other commercially accessible robots. It is ideal for usage in preschool environments because of its sophisticated human-robot interaction qualities, which include fluid communication and captivating reactivity. The robot fosters the development of several competencies and is aimed at children between the ages of 3 and 8, particularly those in middle and upper kindergarten. These include language use, social interaction, behavioral patterns, emotional expression, and fundamental everyday living abilities. For example, Beiya may teach kids how to recognize and communicate emotions like joy, rage, and sadness, comprehend taking turns and cooperating in social settings, and pick up skills like washing their hands, saying hello to others, and supporting their classmates.

The Cognitive Theory of Multimedia Learning (CTML), which stresses the integration of visual, aural, and semantic elements to facilitate meaningful learning, serves as the foundation for Beiya's instructional design. The robot uses age-appropriate story scenarios, voice interaction, and animated facial expressions to convey content. Beiya allows kids to learn via play in an immersive setting by mimicking real-life conversation and giving prompt feedback. This method successfully promotes social-emotional development in early childhood education while also raising engagement.

Additionally, Beiya Robotics has developed scientifically created cognitive models for kids at various stages to address preschoolers' developmental needs in five domains: science, art, language, society, and health. Based on the assessment, the big data analysis platform will create and distribute specific smart audio albums. results of each child, achieving the goal of teaching students in accordance with their aptitude.

Figure 2. Beiya Robot.

The following table outlines the six-week AI robot-assisted teaching intervention using the BeiYa robot. Each theme is aligned with socio-emotional learning objectives and the corresponding dimensions of the PreBERS scale (As shown in Table 1).

Table 1. Teaching themes of BeiYa robot-assisted instruction.

Week	**Teaching theme**	**Content summary**	**Socio-emotional learning objectives**	**PreBERS dimension**
1	Emotion Detective	Recognize and name basic emotions (e.g., happiness, anger, sadness) through games and role-playing.	Identify and express one's own emotions appropriately; understand others' emotions.	Emotional Regulation
2	My Good Friend	Learn friendship skills like listening, turn-taking, and mutual respect via stories and dialogue.	Build positive peer relationships and initiate social interactions.	Social Confidence
3	I Can Help	Simulate life scenes (e.g., tidying up, setting the table) to encourage responsibility and helping behavior.	Develop a sense of belonging in the family and willingness to help.	Family Involvement
4	Good Habits	Demonstrate rule-following behavior (e.g., queuing, finishing tasks) and conduct robot-guided discussions.	Foster habits of task completion and rule compliance.	School Readiness
5	I Can Control Myself	Identify impulsive behaviors and learn self-regulation strategies through animated scenarios.	Manage frustration and regulate emotions during challenges or conflict.	Emotional Regulation
6	Happy Family	Role-play family interactions to enhance understanding of family roles and emotional expression.	Strengthen family bonding, emotional expression, and communication.	Family Involvement

2.6 Data Analysis Methods

This study used SPSS 26.0 statistical software for data entry and analysis, and mainly used the following statistical methods to test the intervention effect and the moderating effect of gender variables:

(1) Intergroup homogeneity test

To ensure the validity and comparability of the research results, an intergroup homogeneity analysis was conducted before the formal data analysis to test whether the Class B and the Class A were statistically equivalent in the pre-test stage. The study used an independent samples t-test to compare the differences between the two groups in the PreBERS total score and the scores of the four subscales to determine whether there were significant differences between the two groups before the intervention. If the results showed no statistically significant difference ($p > 0.05$), it indicated that the two groups had good homogeneity, thus laying the foundation for subsequent analysis of the intervention effect..

(2) Pre-intervention baseline consistency test

To further verify baseline equivalence, the study used an independent samples t-test to compare whether there were significant differences in the total PreBERS score and scores in the four dimensions between the Class B and the Class A before the intervention. If the differences were not significant, it indicated that the two groups were comparable before the intervention.

(3) Analysis of differences between groups after intervention After confirming the homogeneity between groups, a further analysis of differences after intervention was conducted. The study used an independent samples t-test to compare the differences between the Class B and the Class A in the total PreBERS score and four dimensions-emotional regulation, school readiness, social confidence, and family involvement-after intervention. If the Class B scored significantly higher than the Class A in the post-test ($p < 0.05$), it indicates that AI robot-assisted teaching has a positive promoting effect on the behavioral and emotional development of preschool children. This analysis not only helps to verify the effectiveness of AI-supported teaching models in early childhood education but also provides empirical support for their wider application in early childhood education.

Although the statistical analysis was conducted at the individual level, the participants were all from complete classes. Therefore, the results should be interpreted with caution, as class-level clustering effects may affect statistical independence.

3. Research Results

3.1 Homogeneity Analysis of the Class B, Class A

In quasi-experimental research, a pretest is required to evaluate the disparity between the groups, according to Kuo, S.Y [45]. The degree of inequality between the two groups should be as low as feasible to reduce the elements that could compromise the internal validity. In order to determine whether the children's "emotions and behaviors" varied significantly depending on the designated "group," an independent sample T-test was used. The analysis showed that there was no significant difference in "emotional and behavioral performance" between the two groups before the test ($p>0.05$). This demonstrates that the children's emotions and actions were similar in the Class B and the Class A before the introduction of various instructional strategies (Table 2 and Table 3).

Table 2. Group statistics.

Group statistics of pre-test variables	What class is your child in?	N	Mean	Std. deviation	Std. error mean
Pre-test emotion regulation	Class A	30	1.9879	.55516	.10136
	Class B	30	1.8545	.44766	.08173
Pre-test for school admission preparation	Class A	30	2.1394	.67514	.12326
	Class B	30	1.7091	.44241	.08077
pretest confidence	Class A	30	1.9333	.55294	.10095
	Class B	30	1.7778	.46182	.08432
Pre-test family integration	Class A	30	1.9222	.61547	.11237
	Class B	30	1.7389	.45208	.08254

Table 3. Independent samples test.

Independent samples t-test of Pre-test variables		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference	
									Lower	Upper
Pre-test emotion regulation	Equal variances assumed	3.159	.081	1.024	58	.310	.13333	.13020	-.12730	.39397
	Equal variances not assumed			1.024	55.506	.310	.13333	.13020	-.12755	.39422
Pre-test for school admission preparation	Equal variances assumed	8.435	.005	2.920	58	.005	.43030	.14737	.13531	.72530
	Equal variances not assumed			2.920	50.028	.005	.43030	.14737	.13430	.72630
pretest confidence	Equal variances assumed	.340	.562	1.183	58	.242	.15556	.13153	-.10774	.41885
	Equal variances not assumed			1.183	56.216	.242	.15556	.13153	-.10791	.41903
Pre-test family integration	Equal variances assumed	1.221	.274	1.315	58	.194	.18333	.13942	-.09575	.46242
	Equal variances not assumed			1.315	53.237	.194	.18333	.13942	-.09629	.46295

To ensure the comparability of the experimental and Class As before the intervention, a homogeneity test was conducted on children’s scores across the four dimensions using independent-samples t-tests.

To examine the comparability of the experimental and Class As before the intervention, this study conducted independent samples t-tests on the children's pre-test scores on the four dimensions of the PreBERS. The results showed that there was no significant difference between the experimental and Class As on the emotion regulation dimension ($t(58) = 1.024$, $p = 0.310 > 0.05$); similarly, there was no significant difference between the two groups on the self-confidence dimension ($t(58) = 1.183$, $p = 0.242 > 0.05$); and no significant difference was also found on the family integration dimension ($t(58) = 1.315$, $p = 0.194 > 0.05$). These results indicate that the pre-test levels of the experimental and Class As on these three dimensions were relatively similar, demonstrating good baseline consistency.

However, on the school readiness dimension, the pretest difference between the two groups reached a statistically significant level. Since the homogeneity of variance test result was significant (Levene's test: $F = 8.435$, $p = 0.005 < 0.05$), the test result without assuming homogeneity of variance was used. The results showed that the Class B's pretest score on the school readiness dimension was significantly higher than that of the Class A, $t(50.028) = 2.920$, $p = 0.005 < 0.05$. This indicates that the baselines of the two groups on this dimension were not completely consistent.

Overall, the experimental and Class As showed good homogeneity across most dimensions during the pretest phase, but a significant difference existed on the school readiness dimension. Therefore, the results on this dimension should be interpreted cautiously in subsequent analyses of intervention effects.

3.2 The Analysis of Posttest Analysis

To examine the differences between the experimental and Class As on the four dimensions of PreBERS after the intervention, this study conducted an independent samples t-test on the post-test scores. The results showed that, on the emotion dimension, the difference between the two groups was statistically significant ($t(58) = -4.559$, $p < 0.001$), with Class B scoring significantly higher than Class A; on the school readiness dimension, the difference was also statistically significant ($t(58) = -4.123$, $p < 0.001$), with Class B scoring significantly higher than Class A; on the self-confidence dimension, the difference was statistically significant ($t(58) = -4.273$, $p < 0.001$), with Class B scoring significantly higher than Class A; and on the family integration dimension, the difference was also statistically significant ($t(58) = -4.361$, $p < 0.001$), with Class B scoring significantly higher than Class A.

Overall, the post-test results indicated that Class B performed significantly better than Class A on all four dimensions of PreBERS, demonstrating a clear difference between the two groups after the intervention (Table 4 and Table 5).

Table 4. Group statistics.

PreBERs post-test scores by dimension	What class is your child in?	N	Mean	Std. deviation	Std. error mean
Post-test emotion regulation	Class A	30	2.1182	.85984	.15698
	Class B	30	3.0333	.68509	.12508
Post-test for school admission preparation	Class A	30	2.1545	.88564	.16169
	Class B	30	3.0273	.74819	.13660
Post-test confidence	Class A	30	2.1222	.70972	.12958
	Class B	30	2.9278	.75007	.13694
Post-test family integration	Class A	30	2.1222	.81289	.14841
	Class B	30	3.0056	.75491	.13783

Table 5. Independent samples test.

Outcome variables		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Post-test emotion regulation	Equal variances assumed	2.425	.125	-4.559	58	.000	-.91515	.20072	-1.31694	-.51336
	Equal variances not assumed			-4.559	55.244	.000	-.91515	.20072	-1.31737	-.51294
Post-test for school admission preparation	Equal variances assumed	1.023	.316	-4.123	58	.000	-.87273	.21167	-1.29643	-.44902
	Equal variances not assumed			-4.123	56.425	.000	-.87273	.21167	-1.29669	-.44877
Post-test confidence	Equal variances assumed	.164	.687	-4.273	58	.000	-.80556	.18853	-1.18294	-.42817
	Equal variances not assumed			-4.273	57.824	.000	-.80556	.18853	-1.18297	-.42815
Post-test family integration	Equal variances assumed	1.054	.309	-4.361	58	.000	-.88333	.20254	-1.28876	-.47790
	Equal variances not assumed			-4.361	57.685	.000	-.88333	.20254	-1.28881	-.47786

As shown in Table 6, the effect size analysis for the post-test indicated large practical effects across all four dimensions. Specifically, Cohen's d values were -1.177 for emotional regulation, -1.065 for school readiness, -1.103 for confidence, and -1.126 for family involvement. The negative signs reflect the direction of the comparison (Class A minus Class B), and, when interpreted together with the post-test means, indicate that the Class B outperformed the Class A across all four dimensions. In terms of magnitude, the absolute values of all effect sizes exceeded 0.80, suggesting that the post-intervention differences were not only statistically significant but also practically meaningful. In addition, none of the 95% confidence intervals included zero, indicating that the effect size estimates were stable and reliable.

Table 6. Independent Samples Effect Sizes.

Dependent variables		Standardizera	Point estimate	95% confidence interval Lower	Upper
Post-test emotion regulation	Cohen's d	.77739	-1.177	-1.722	-.624
	Hedges' correction	.78763	-1.162	-1.700	-.615
	Glass's delta	.68509	-1.336	-1.939	-.717
Post-test for school admission preparation	Cohen's d	.81980	-1.065	-1.602	-.519
	Hedges' correction	.83059	-1.051	-1.581	-.512
	Glass's delta	.74819	-1.166	-1.747	-.571
Post-test confidence	Cohen's d	.73018	-1.103	-1.643	-.555
	Hedges' correction	.73979	-1.089	-1.622	-.548
	Glass's delta	.75007	-1.074	-1.643	-.491
Post-test family integration	Cohen's d	.78444	-1.126	-1.668	-.576
	Hedges' correction	.79477	-1.111	-1.646	-.569
	Glass's delta	.75491	-1.170	-1.751	-.574

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the Class A.

As shown in Table 7, to further examine the magnitude of changes in the two groups of children before and after the intervention, this study calculated the incremental scores for each dimension by subtracting the pre-test scores from the post-test scores and conducted descriptive comparisons. The results showed that the Class A showed only slight improvements in all four dimensions, while the Class B showed more significant increases in all four dimensions.

Specifically, in the emotion regulation dimension, the increase in the Class A was 0.1303, while the increase in the Class B was 1.1788; in the school readiness dimension, the increase in the Class A was 0.0151, while the increase in the Class B was 1.3182; in the self-confidence dimension, the increase in the Class A was 0.1889, while the increase in the Class B was 1.1500; and in the family integration dimension, the increase in the Class A was 0.2000, while the increase in the Class B was 1.2667. Overall, the Class B showed significantly greater improvements in all four dimensions than the Class A, exceeding them by 1.0485, 1.3031, 0.9611, and 1.0667, respectively.

The analysis of pre-test, post-test, and incremental score results shows that although there were significant differences between the two groups in the pre-test scores on the school readiness dimension, after the intervention, the Class B not only scored significantly higher than the Class A in all four dimensions in the post-test, but also showed significantly greater increases in all four dimensions. This indicates that AI robot-assisted teaching intervention may have a positive impact on preschool children's emotional regulation, school readiness, self-confidence, and family integration. However, since there were already significant baseline differences in the school readiness dimension pre-test, the interpretation of the intervention effect in this dimension still needs to be approached with caution.

Table 7. Comparison of pre- and post-test means and incremental scores in each dimension of PreBERS between class B and class A.

Dimension	Class A pre-test	Class A post-test	Class A gain	Class B pre-test	Class B post-test	Class B gain	Additional improvement of Class B over Class A
Emotional Regulation	1.9879	2.1182	0.1303	1.8545	3.0333	1.1788	1.0485
School Readiness	2.1394	2.1545	0.0151	1.7091	3.0273	1.3182	1.3031
Confidence	1.9333	2.1222	0.1889	1.7778	2.9278	1.1500	0.9611
Family Involvement	1.9222	2.1222	0.2000	1.7389	3.0056	1.2667	1.0667

The combined results of pre-test, post-test, effect size, and incremental score analysis show that after the AI robot-assisted teaching intervention, the Class B outperformed the Class A in all four dimensions: emotion regulation, school readiness, self-confidence, and family integration. These differences were statistically significant and demonstrated substantial practical effects. Furthermore, the Class B showed significantly greater improvements across all four dimensions than the Class A, indicating that the intervention has a positive promoting effect on the behavioral and emotional development of preschool children. However, since a significant baseline difference existed in the school readiness dimension during the pre-test phase, the interpretation of the results for this dimension should be approached with caution.

3.3 Results of ANCOVA

An analysis of covariance (ANCOVA) was conducted to examine the effect of group on post-test scores while controlling for pre-test performance. The results indicated that the covariate, pre-test score, was significantly associated with post-test performance, $F(1, 57) = 8.170$, $p = .006$, partial $\eta^2 = .125$. After adjusting for pre-test differences, a significant main effect of group was observed on post-test scores, $F(1, 57) = 6.108$, $p = .016$, partial $\eta^2 = .097$. In addition, the overall model was statistically significant, $F(2, 57) = 7.140$, $p = .002$, accounting for 20.0% of the variance in post-test scores (As shown in Table 8).

Table 8. Results of ANCOVA (Dependent variable: Post-test).

Source	SS	df	MS	F	p	Partial η^2
Pre-test	6.111	1	6.111	8.170	.006	.125
Group	4.569	1	4.569	6.108	.016	.097
Error	42.651	57	0.748			
Model	10.680	2	5.340	7.140	.002	.200

Note. Post-test scores were entered as the dependent variable, pre-test scores as the covariate, and group as the fixed factor. The model explained 20.0% of the variance in post-test scores ($R^2 = .200$, adjusted $R^2 = .172$).

4. Discussion

The results of this study indicate that AI robot-assisted teaching has a certain promoting effect on the social and emotional development of young children. Compared with the Class A, the Class B performed better in multiple dimensions. This result is basically consistent with existing research on the application of teaching robots in early childhood education [34,35], and also provides new supplements to related research in Chinese kindergartens. Overall, the findings of this study suggest that integrating AI robots into daily classroom activities under the guidance of teachers may help promote the emotional and behavioral development of young children.

The discussion of this study can be mainly carried out from three aspects. First, the results of this study are consistent with existing research on robot-assisted learning. Previous studies have pointed out that, if used properly, robots can improve children's participation, engagement and learning interest in the classroom to a certain extent [34,35]. The better performance of the Class B after the intervention in this study also supports this point to some extent. Second, the results of this study are also related to research on social-emotional learning intervention. Previous studies have shown that structured activities and repeated guided practice help promote early emotional and social development in young children. The better performance of the Class B in this study may also be related to this structured support. Third, this study further enriches the research on the application of technology in early childhood education. Unlike many studies that mainly focus on cognitive, language or academic skills, this study focuses more on behavioral and emotional development, and therefore has a certain supplementary significance in terms of research perspective.

4.1 Key Findings and Theoretical Implications

Theoretically, the improvement in social confidence and emotion regulation observed in this study corresponds to Mayer's cognitive load multimedia learning theory to some extent [29]. AI robots in the classroom do not simply provide information, but work together through language, actions, visual presentations and instant feedback to make it easier for young children to notice information related to emotions and social behavior and to form a more intuitive understanding of this content. In other words, the reason why AI robot-assisted activities may be effective is not only because it is a new technology, but more likely because it provides clearer multimodal input and creates more opportunities for participation and practice.

Meanwhile, this study suggests that this positive effect may also be related to the guided interactive process in the classroom. During the intervention, children were not passively receiving content, but rather responding, imitating, and repeating exercises with the robot under the support of the teacher. This type of activity helps improve children's classroom engagement and may also help them better understand emotional expression, social cues, and appropriate behavioral responses. Compared to simple verbal explanations from teachers, the robot's more stable, timely, and non-judgmental feedback may, to some extent, provide a more engaging learning environment for children, which may be one of the reasons for the significant improvement in emotion regulation.

4.2 Practical Applications

From a practical perspective, this study offers at least three insights. First, thematic and contextualized activity design may be more suitable for young children's socio-emotional development. For example, activities centered around specific themes and involving repeated participation through contextualized practice may be more effective than simple lecturing. Second, robots are better suited as teacher aids rather than replacements. In this study, teachers still played a role in organizing, explaining, reminding, and guiding, while robots primarily assisted teachers in providing interactive prompts and practice support; therefore, they are better understood as a "collaborative teaching" tool. Third, in areas with relatively scarce teacher resources, AI robots may, to some extent, help maintain consistency in the implementation of structured socio-emotional learning projects, thus providing supplementary support to kindergarten classrooms.

4.3 Limitations and Future Directions

Of course, this study still has some limitations, and the results need to be viewed with caution. First, the intervention period was only three weeks, so it is currently difficult to determine the long-term effects of AI robot-assisted teaching. Although the Class B showed a post-test advantage in all four PreBERS dimensions, whether this effect can be sustained requires further follow-up research. Second, this study mainly relies on parent-reported data, which may be affected by subjective judgment and response bias. In particular, since the intervention itself takes place in a classroom environment, parents cannot directly observe immediate changes in the classroom, so the relevant results may not fully reflect the children's actual performance in the classroom. Future research could combine teacher evaluations, behavioral observations, and other multimodal measurement methods to improve measurement validity. Third, this study used a single-site quasi-experimental design, with the sample coming from only one kindergarten, and the pre-tests between groups were not completely equivalent. In particular, there were significant pre-test differences in the school readiness dimension, so the results in this dimension need to be interpreted more carefully.

Furthermore, the participants in this study came from entire classes, meaning the study itself has a certain clustering structure, while the current analysis is primarily conducted at the individual level. Therefore, there are certain limitations in statistical inference. Future research could expand the sample size to include more classes and samples from different regions, and try using methods more suitable for handling clustered data to improve the robustness of the research conclusions. Simultaneously, future research could extend the intervention period to examine the differences in effects across different intervention durations, and further analyze the potential differences in children's interactions with robots across different cultural backgrounds. Including longitudinal tracking would also help determine whether the positive effects observed in this study can be maintained long-term.

4.4 Technological Aspects

This study also suggests some directions for further improvement. First, the visibility of robots in group teaching can affect children's participation; therefore, larger displays, projection methods, or other presentation formats more suitable for group activities could be considered in the future. Second, robots with a higher level of personalized adaptability may be better suited to match the learning pace and comprehension level of different children. Third, considering children's strong tactile and exploratory tendencies, the robot's appearance design and safety of use also need careful consideration. Overall, this study demonstrates that AI systems, when appropriately designed and used under teacher guidance, can not only support the development of children's academic skills but also have a positive impact on their socio-emotional and behavioral development.

5. Conclusion

This study examined the effects of robot-assisted teaching on preschool children’s behavioral and emotional development through a quasi-experimental design. The findings suggest that the “BeiYa” robot intervention may be helpful for children’s emotional regulation, confidence, school readiness, and family involvement. Compared with the Class A, the Class B obtained higher post-test scores and showed greater improvement across all four dimensions of the PreBERS.

At the same time, these findings should be interpreted with caution. The sample size was relatively small, the intervention lasted only three weeks, and the study was conducted in a single setting. In addition, there was already a difference between the two groups in school readiness before the intervention. For this reason, the present study can only provide preliminary support for the use of robot-assisted teaching in early childhood education, rather than firm evidence. Future studies should include larger samples, longer intervention periods, and more rigorous research designs to further test these findings and explore more effective forms of human-robot collaboration.

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