Fostering Holistic Development through Educational Robotics: A Two-Year Evaluation of the 'Robotics in Kindergartens' Program*

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Abstract

This study evaluates the impact of the Robotics in Kindergartens program on the emotional, social, and cognitive development of children across five public kindergartens over two consecutive academic years (N=281). Using a pre–post repeated-measures design, educators completed a validated 19-item questionnaire assessing developmental change across the three domains. Results from Year 1 (N=129) showed statistically significant improvements in all domains, with medium to large effect sizes. Detailed item-level analyses indicated notable gains in interest in technology, problem-solving, curiosity, social interaction, perseverance, and coping with frustration. Year 2 (N=152) demonstrated stable pre–post trends with higher initial baseline scores and smaller, non-significant domain-level changes, reflecting program maturation and contextual variation. Across both years, no significant differences were observed by gender or immigrant background, indicating equitable program impact. Findings support the role of early-childhood robotics as a holistic developmental tool that strengthens cognitive engagement, social collaboration, and emotional resilience within authentic educational settings.

Keywords

Educational Robotics, Early Childhood Education, Computational Thinking, Inclusive Learning

1. Introduction

Despite increasing global recognition of the importance of early exposure to STEM and digital skills, many young children, especially those in underserved communities and from immigrant backgrounds, continue to experience limited access to structured technological learning opportunities that also nurture emotional and social development [1,2]. Traditional early childhood education settings often lack developmentally appropriate tools that combine hands-on exploration, computational thinking, and collaborative problem-solving. Educational robotics, and particularly systems such as LEGO Education WeDo 2.0 and its successor LEGO Education SPIKE Essential, offers a promising response to this gap by integrating physical construction with visual programming. This multimodal approach has been shown to support engagement, creativity, perseverance, communication, and foundational problem-solving skills in young learners [3–5].

The pedagogical rationale for robotics in early childhood is grounded in constructionist learning theory, which argues that meaningful learning emerges when children actively create, play, explore, and reflect on tangible artifacts [6]. This theoretical foundation is reinforced by recent research demonstrating that social and educational robots can serve as mediators for curiosity, collaboration, and social-emotional learning, thereby amplifying the developmental impact of early STEM activities [7,8]. Such findings highlight the potential of robotics not only as a technology introduction tool, but also as a holistic developmental platform.

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This study presents findings from a two-year empirical evaluation of the Robotics in Kindergartens program in public kindergartens in a northern low-medium socioeconomic municipality. The program sought to promote emotional resilience, social competence, and cognitive curiosity through structured, developmentally appropriate robotics activities delivered to a diverse population of 281 children from both veteran and immigrant families. Central to the implementation were teacher training and ongoing professional support, designed to ensure pedagogical alignment and consistent instructional quality.

To evaluate the program's impact, educators completed a 19-item Likert-scale questionnaire at two time points (pre and post intervention), assessing children's emotional, social, and cognitive development. The instrument demonstrated strong internal reliability (Cronbach's α = .91–.94). The present paper focuses on evaluating the program's effectiveness and situating its outcomes within the broader literature on early childhood robotics, constructionist learning, and inclusive STEM education.

2. Literature Review

Educational robotics is increasingly used in early childhood not only to introduce STEM concepts, but also to support broader developmental outcomes. Recent work suggests that robotics activities can simultaneously engage children in planning and problem-solving, collaboration and communication, and emotionally meaningful trial-and-error. This review summarizes the core theoretical grounding and the evidence base that supports viewing robotics as a holistic developmental learning context.

2.1. Constructionism and PTD

Early-childhood robotics is strongly aligned with constructionism, which argues that children learn best when they actively create meaningful artifacts that make their ideas visible, shareable, and open to refinement [1]. Robotics naturally supports this cycle because children can quickly test an idea, observe what the robot does, and iteratively redesign or reprogram.

Bers' Positive Technological Development (PTD) framework extends this view by emphasizing that technology-rich activities in early childhood can foster developmental competencies beyond cognition, including communication, collaboration, creativity, community building, content creation, and ethical conduct [2,3]. In practice, robotics sessions often require shared materials, negotiated roles, joint decision-making, and responsibility for group outcomes, features that position robotics as a social and developmental platform rather than a narrow "coding lesson".

2.1.1. Cognitive and inquiry-based learning

A central rationale for robotics in early childhood is its potential to cultivate cognitive processes associated with computational thinking (CT), including sequencing, decomposition, pattern recognition, abstraction, and debugging [6]. Robotics operationalizes these processes in an accessible way: children plan step-by-step actions, anticipate outcomes, and revise instructions when the robot behaves unexpectedly.

Across studies, robotics-based activities have been associated with gains in early reasoning and problem-solving skills, including logical and sequential thinking, spatial reasoning, early mathematics, and inquiry-oriented habits such as predicting and observing [7–10]. Robotics can also place demands on executive functions such as working memory and cognitive flexibility, as children hold multi-step sequences in mind while coordinating physical construction and symbolic commands [11]. Importantly, robotics may elicit metacognitive talk as children explain outcomes, identify causes of errors, and justify their revisions [12]. Together, these findings support the view that robotics contributes to foundational thinking skills that extend beyond "learning to code".

2.1.2. Social–emotional learning

Robotics activities are typically collaborative, creating repeated opportunities for children to communicate, negotiate, and coordinate shared goals. The literature reports improvements in cooperation, turn-taking, communication, and emerging leadership behaviors in robotics contexts, including benefits for children who may struggle with social participation [23–28]. Because robots provide a shared, tangible focus, they may also function as social mediators that support joint attention and joint problem-solving, particularly in diverse classrooms.

Robotics also embeds trial-and-error as a normal part of learning. Debugging and redesign can normalize mistakes and create a structured context for practicing perseverance, coping with frustration, and sustained motivation [18–22]. These emotional-regulation experiences are closely tied to learning processes: persistence and flexible coping are often necessary to complete iterative design tasks. For this reason, social and emotional outcomes are increasingly treated as integral—not incidental—to early-childhood robotics.

2.1.3. Inclusion and equity in early-childhood robotics

A growing body of research highlights robotics as a promising context for inclusive participation. Early exposure may support long-term equity by reducing later gender gaps, particularly when activities emphasize creativity, collaboration, and storytelling rather than narrowly technical performance [29]. Robotics may also support immigrant and multilingual children by enabling participation through action, building, and demonstration, reducing reliance on verbal fluency while still allowing meaningful contribution [30–32]. These characteristics position robotics as a potentially equity-supportive pedagogy in heterogeneous kindergarten settings.

2.1.4. Robotics as a holistic developmental ecosystem

Taken together, theory and evidence increasingly suggest that robotics is best understood as an integrative learning ecosystem rather than a discrete STEM intervention. In a single activity, children may engage cognitive planning and debugging, social coordination, emotional coping with challenge, and creative expression, often within playful and embodied learning practices that are developmentally appropriate for early childhood [33–36]. This holistic framing is especially relevant when evaluating robotics programs intended to support broad competencies.

Building on this perspective, the present study provides multi-site, two-year evidence on how participation in the *Robotics in Kindergartens* program relates to children's cognitive, social, and emotional development in diverse kindergarten contexts.

3. Methodology

3.1. Research Design

This study employed a non-experimental pretest–posttest repeated-measures design to examine developmental change associated with participation in the Robotics in Kindergartens program. This design is widely used in authentic early-childhood educational settings where random assignment is neither feasible nor ethically appropriate, and where interventions are implemented at the classroom level rather than controlled laboratory environments [37].

Because all children enrolled in the participating kindergartens received the robotics program as part of their regular curriculum, no comparison or control group was available. Accordingly, the study focuses on within-child change over time, without making causal claims about the intervention's effects. Dimitrov and Rumrill emphasize that pretest–posttest repeated-measures designs are well-suited for evaluating developmental programs in naturalistic settings, particularly when the goal is to document growth rather than isolate treatment effects [38].

Repeated-measures approaches are especially valuable in early-childhood contexts, where substantial variability exists in initial skill levels and developmental rates. Measuring the same children over time increases statistical power and reduces error variance, thereby enabling more sensitive detection of meaningful developmental trends [38,39]. This approach also aligns with naturalistic robotics research, where pre–post educator ratings are commonly used to capture socio-emotional and behavioral competencies that unfold through everyday interactions [40].

3.2. Research Questions

This study investigates whether participation in the Robotics in Kindergartens program is associated with changes in children's development across cognitive, social, and emotional domains, and whether these patterns are consistent across groups and sites. The following research questions guide the analysis: **RQ1**: To what extent does participation in the program relate to changes in children's cognitive development indicators (e.g., curiosity, inquiry, problem-solving, interest in technology)?; **RQ2**: To what extent does participation in the program relate to changes in children's social development indicators (e.g., collaboration, communication, leadership, empathy)?; **RQ3**: To what extent does participation in the program relate to changes in children's emotional development indicators (e.g., perseverance, coping with frustration, motivation, anxiety expression)?; **RQ4**: Are outcomes consistent across gender and immigrant background groups and across kindergarten sites?

3.3. Participants and Setting

The study included 281 children aged 4.0 to 7.0 years enrolled in five public kindergartens and one first-grade classroom in a low-medium socio-economic northern municipality. The program was implemented across two consecutive academic years with two partially overlapping cohorts: (1) Year 1 (2021–2022): N = 129 children (mean age = 5.29 years, SD = 0.55); (2) Year 2 (2022–2023): N = 152 children (mean age = 5.59 years, SD = 0.52). In Year 2, approximately 75% of children were new to the program and 25% were returning for a second year. Within each year, the same children were rated pre and post (repeated measures). However, because the cohorts were not tracked longitudinally at the individual level across years, cross-year comparisons should be interpreted as between-cohort differences and prior exposure effects rather than within-child maturation. Classrooms served diverse communities including veteran families and immigrant families from multiple linguistic backgrounds. The program was delivered by trained kindergarten teachers with ongoing pedagogical support.

3.4. Procedure

The robotics program was implemented weekly throughout each academic year. Across the two-year period, the program used LEGO Education WeDo 2.0 and then transitioned to LEGO Education SPIKE Essential (transition implemented between the two academic years). Teachers participated in preparatory training sessions and received coaching during implementation.

Educators completed structured rating scales at two time points: (1) Pre-intervention (baseline): within the first two weeks of the school year; (2) post-intervention: immediately following the program's final session.

Teacher-completed questionnaires are a validated and widely adopted method in early-childhood developmental research, especially for assessing socio-emotional and behavioral outcomes that require extended observation across natural settings [39,40].

3.5. Measures

To assess developmental change, educators completed a 19-item Likert-scale questionnaire measuring three domains: Emotional development (5 items); Social development (6 items) and Cognitive development (8 items). Items were rated on a 1–5 scale (very low to very high). Previous research supports the reliability and validity of educator-report measures in early-childhood intervention studies, including robotics and STEM curricula [6–8]. In the present study, internal consistency was excellent across both years (Cronbach's α = .91–.94), exceeding the standard threshold for reliable behavioral scales.

Table 1
Questionnaire Items by Domain (19 Items Total) (Min = 1, Max = 5 Likert scale)

Domain	Description (brief)	Illustrative item example
Emotional (5 items)	Motivation, perseverance, coping with frustration, emotional regulation, and anxiety expression.	Perseverance when facing difficulty
Social (6 items)	Social skills, empathy, group work, communication, leadership.	Ability to work in a group
Cognitive (8 items)	Interest in technology, attention, curiosity/inquiry, creativity, problem-solving.	Interest in technology

3.6. Data Analysis

Data were analyzed at several levels: (1) Within-year pre–post change was assessed using paired-samples t-tests, appropriate for repeated-measures designs where the same individuals provide data at both time points [38]; (2) Cross-year differences in baseline and post-program scores were examined using independent-samples t-tests comparing the two independent cohorts (Year 1 vs. Year 2); and (3) Subgroup analyses explored differences across gender, immigrant background, and kindergarten sites.

Effect sizes (Cohen's d) were calculated to assess the magnitude of developmental change, following best practices for pre–post educational evaluations [39]. Statistical significance was set at α = .05.

3.7. Limitations

This study used a non-experimental pre–post design with no control group; therefore, findings should be interpreted as associations rather than causal effects. All outcomes were based on educator ratings, which may introduce rater bias or expectancy effects. Because the two academic years comprised independent cohorts, cross-year differences may reflect cohort/context differences and prior exposure rather than developmental maturation. Finally, the evaluation was conducted in a single municipality, which may limit generalizability.

4. Results

This section presents the quantitative findings from the two implementation years of the Robotics in Kindergartens program. Results are based on educator ratings collected at two time points (pre-program and post-program) using a 19-item questionnaire assessing emotional, social, and cognitive development. Internal reliability for each domain was high (Cronbach's α = .91–.94).

4.1. Year 1 Results (2023–2024; N = 129)

4.1.1. Cognitive Development

Educators evaluated eight cognitive indicators before and after participation in the robotics program. Five of the Eight indicators demonstrated statistically significant improvements, all with medium-to-large effect sizes (Table 2).

Table 2

Cognitive Development Year 1 (N = 129; Min = 1, Max = 5)

Cognitive Indicator	Pre M (SD)	Post M (SD)	t-value	Cohen's d	p
Interest in technology	3.52 (0.84)	3.82 (0.86)	−4.424	0.779	< .001
Anticipation for the robotics activity	3.71 (0.89)	3.77 (0.82)	n.s.	—	> .05
Problem-solving ability	3.26 (0.88)	3.50 (0.80)	−3.421	0.801	< .001
General interest and question-asking	3.17 (0.90)	3.49 (0.90)	−4.217	0.863	< .001
Concentration during robotics activity	3.53 (0.78)	3.65 (0.84)	n.s.	—	> .05
High cognitive ability	3.41 (0.81)	3.53 (0.84)	−2.130	0.664	= .035
Curiosity	3.39 (0.82)	3.63 (0.86)	−3.891	0.681	< .001
Creative ability	3.51 (0.89)	3.62 (0.88)	n.s.	—	> .05

Cognitively, the robotics program was associated with substantial gains in interest in technology, problem-solving, general curiosity and question-asking, and perceived cognitive ability. Effect sizes for these indicators were all in the medium-to-large range ($d \approx 0.66–0.86$). Concentration during the robotics activity, anticipation for the activity, and creative thinking were rated relatively high at baseline and did not change significantly.

4.1.2. Social Development

Educators reported significant gains in group work, social competence, communication, and leadership (Table 3). Effect sizes were consistently large ($d \approx 0.69–0.85$), indicating that children were perceived as substantially more capable of working in groups, initiating interactions, and taking leadership roles by the end of the program. Empathy ratings remained high but did not change significantly, suggesting that the robotics activities primarily strengthened collaborative and leadership behaviors rather than baseline empathic concern.

Table 3

Social Development Items Year 1 (N = 129; Min = 1, Max = 5)

Social Item	Pre M (SD)	Post M (SD)	t	Cohen's d	p
Ability to work in a group	3.66 (0.76)	3.79 (0.72)	−2.173	0.692	= .032

Social Item	Pre M (SD)	Post M (SD)	t	Cohen's d	p
Empathy toward others	3.59 (0.77)	3.68 (0.78)	n.s.	—	> .05
Social skills	3.54 (0.77)	3.80 (0.72)	−3.718	0.808	< .001
High social abilities	3.46 (0.76)	3.63 (0.80)	−2.544	0.764	= .012
Communication skills	3.36 (0.84)	3.59 (0.87)	−3.304	0.776	= .001
Leadership qualities	3.04 (0.90)	3.39 (0.89)	−4.694	0.847	< .001

4.1.3. Emotional Development

Across the year, educators reported marked gains in children's motivation and resilience (Table 4). Ratings of desire to learn new things, perseverance in the face of difficulty, and coping with failure all increased significantly, with Cohen's d values between 0.63 and 0.90, indicating medium-to-large practical effects. In parallel, self-esteem ratings showed a small, non-significant increase. Interestingly, ratings for "expresses anxieties and fears at a low frequency" decreased significantly ($t = 4.567$, $p < .001$, $d = 0.79$), meaning that by year's end teachers perceived children as showing somewhat more expressed fears. The original report interpreted this as a meaningful difference rather than a deterioration, suggesting that children may have felt safer to voice worries in the supportive robotics context.

Table 4

Emotional Development Items Year 1 (N = 129; Min = 1, Max = 5)

Emotional Item	Pre M (SD)	Post M (SD)	t	Cohen's d	p
Child expresses anxieties and fears at a low frequency	4.09 (0.88)	3.77 (0.93)	4.567	0.792	< .001
High self-esteem / belief in own abilities	3.65 (0.98)	3.75 (0.83)	n.s.	—	> .05
Desire to learn new things	3.35 (0.79)	3.70 (0.74)	−6.258	0.633	< .001
Perseverance when facing difficulty	3.21 (0.93)	3.58 (0.88)	−5.213	0.811	< .001
Coping with failure and non-success	3.03 (0.81)	3.49 (0.79)	−5.196	0.898	< .001

4.2. Year 2 Results (2024–2025; N = 152)

Year 2 analysis included six social indicators and eight cognitive indicators. Baseline means were higher than in Year 1, resulting in fewer statistically significant changes. Nonetheless, several cognitive indicators showed meaningful improvements.

4.2.1. Cognitive Development

As shown in Table 5, despite higher baseline scores, two indicators showed statistically significant improvement: problem-solving ability ($t = -3.083$, $p = .002$, $d = 0.71$) and question-asking ($t = -2.009$, $p = .046$, $d = 0.686$). Both demonstrated medium-to-large effect sizes, indicating meaningful advances in analytic thinking and inquiry.

Other indicators, concentration, creative thinking, general cognitive ability, technology interest, and anticipation, showed no significant change. Notably, technology interest slightly declined (d = 0.685), suggesting that children entered the year with very high enthusiasm that leveled over time.

Table 5
Cognitive Development Year 2 (N = 152; Min = 1, Max = 5)

Cognitive Indicator	Pre-Mean (SD)	Post Mean (SD)	t-value	Cohen's d	p
Interest in technology	4.02 (0.77)	3.88 (0.76)	2.812	0.685	= .006
Anticipation for robotics	3.97 (0.82)	3.90 (0.78)	n.s.	—	> .05
Concentration during robotics	3.93 (0.73)	3.83 (0.79)	n.s.	—	> .05
Curiosity	3.78 (0.81)	3.76 (0.83)	n.s.	—	> .05
Cognitive ability (general)	3.73 (0.82)	3.84 (0.88)	n.s.	—	> .05
Creative thinking	3.65 (0.85)	3.75 (0.84)	n.s.	—	> .05
Problem-solving ability	3.49 (1.00)	3.67 (0.86)	−3.083	0.710	= .002
Asking questions / curiosity	3.49 (0.99)	3.61 (0.94)	−2.009	0.686	= .046

4.2.2. Social Development (Year 2)

None of the six social indicators demonstrated statistically significant change. Baseline social ratings in Year 2 were high (M ≈ 3.7–3.8). Small, non-significant fluctuations were observed in both directions. The absence of significant gains suggests that social competencies may have stabilized, with most children already perceived as socially competent at the start of the year.

4.2.3. Emotional Development

Five emotional indicators were again assessed (Table 1). None of the items showed statistically significant pre–post differences. Educators' emotional ratings were already relatively high at the beginning of the year (especially for low levels of anxiety), and none of the items displayed statistically significant change. The pattern suggests a ceiling effect for emotional indicators in Year 2, likely reflecting the fact that the participating kindergartens had prior exposure to the program and entered the year with more positive emotional profiles.

4.3. Domain-Level Summary and subgroup analysis (year 1 and 2)

Domain-level indices were computed by averaging items within each domain (emotional, social, cognitive). For year 1, all three domains showed significant gains with medium effect sizes (Table 6).

Table 6
Domain Scores Year 1 and year 2 (N1 = 129; N2 = 152; Min = 1, Max = 5)

Domain	Year	Pre M (SD)	Post M (SD)	t	p	Cohen's d

Emotional	Year 1 (2023–2024)	3.47 (0.63)	3.69 (0.59)	-3.014	= .003	0.613
Social	Year 1 (2023–2024)	3.44 (0.62)	3.70 (0.77)	-3.140	= .002	0.710
Cognitive	Year 1 (2023–2024)	3.43 (0.70)	3.75 (0.72)	-3.637	= .001	0.716
Emotional	Year 2 (2024–2025)	3.64 (0.58)	3.64 (0.59)	—	> .05	—
Social	Year 2 (2024–2025)	3.64 (0.66)	3.66 (0.72)	—	> .05	—
Cognitive	Year 2 (2024–2025)	3.62 (0.75)	3.79 (0.78)	—	> .05	—

Comparisons between native children and children of immigrant families revealed *no significant domain-level differences*, although some item-level differences emerged (e.g., native children were rated higher on some curiosity and communication items, while immigrant children were rated higher on coping with failure). *No significant differences* were found between boys and girls on any domain or item. For year 2, domain-level comparisons alone did not show significant pre–post differences for emotional, social, or cognitive scores, consistent with the item-level findings.

Comparisons by parental origin (native vs. various immigrant groups) again showed *no significant domain-level differences,* although item-level patterns sometimes favored children of immigrants (e.g., lower observed anxiety, higher concentration, and stronger self-belief among children of Ethiopian origin). As in Year 1, there were no gender differences in social or cognitive domains, but in Year 2 girls were rated higher than boys on some emotional indicators (e.g., self-esteem, coping with failure and group work), with medium effect sizes.

5. Discussion

The present two-year evaluation provides empirical evidence that a structured, constructionist robotics curriculum can contribute meaningfully to children's emotional, social, and cognitive development in early childhood education. The significant Year 1 gains across all domains align closely with constructionist theory, which posits that deep learning emerges when children actively build and manipulate meaningful artifacts [1]. Bers' Positive Technological Development framework extends constructionism to early childhood, emphasizing the social, ethical, and collaborative dimensions of technological play [2]. The robust improvements documented in motivation, perseverance, social engagement, and curiosity reflect these theoretical premises.

The strong cognitive gains observed in Year 1, including increases in problem-solving, curiosity, and inquiry behavior, correspond with prior findings that robotics effectively supports early computational thinking, executive function, and STEM readiness [3–7]. Meta-analytic and scoping reviews similarly highlight that robotics-based tasks require decomposition, sequencing, hypothesis testing, and reflective iteration, all foundational cognitive processes that underpin later academic success [8,9]. The consistent improvements in question-asking echo findings that robotics contexts naturally elicit inquiry cycles, prediction, exploration, and debugging behaviors [10,11].

The emotional and social effects observed in Year 1 reinforce growing evidence that robotics supports SEL development. The safe, playful, trial-and-error context of robotics makes failure less threatening and encourages adaptive coping strategies, supporting children's resilience and emotional regulation [12]. Studies also show that robotics increases empathy, communication, and cooperative problem-solving, especially in diverse classrooms [13–15], aligning with the gains reported here. Improvements in perseverance and coping with frustration in the current study are consistent with literature indicating that robotics environments promote "productive failure," an emotional construct linked to deeper learning [16].

In Year 2, baseline scores were markedly higher across all domains, and domain-level differences were no longer statistically significant. This pattern suggests a maturation or ceiling effect, consistent with longitudinal robotics studies in which initial gains are strong but later cohorts, already familiar with the tools, begin at higher starting points and exhibit more modest changes [17]. Research similarly notes that robotics programs evolve from novelty-driven engagement in early stages to more stable, competency-driven development as they become integrated parts of the curriculum [18,19]. The continued improvement in specific cognitive indicators in Year 2, particularly problem-solving and inquiry, supports this interpretation; foundational novelty may fade, but cognitively substantive skills continue to grow with experience.

The decline in interest in technology in Year 2, although modest, aligns with research demonstrating that novelty effects diminish without increased challenge, creativity, or autonomy [20]. Constructionist principles emphasize "low floor, high ceiling, and wide walls," requiring that activities expand in complexity over time to sustain engagement [1]. The present findings suggest that while Year 1 activities were developmentally appropriate, Year 2 may benefit from more open-ended, project-based robotics challenges that provide broader expressive and collaborative opportunities.

The program's inclusive outcomes are noteworthy. Across both years, children from immigrant backgrounds performed at levels comparable to, or in some areas higher than, their native-born peers. These findings align with research showing that robotics can reduce linguistic and cultural barriers by relying on tangible, visual, and collaborative forms of learning [15,21]. Studies of multilingual early-childhood classrooms similarly report that robotics supports participation, turn-taking, and shared attention even among children with limited language proficiency [22]. The absence of gender differences in most domains also corresponds with evidence showing that early robotics activities help counteract gender stereotypes and provide equitable entry points into STEM [23].

Overall, the present study contributes to a growing body of longitudinal, classroom-based research showing that educational robotics functions not as a narrow technological enrichment, but as a holistic developmental ecosystem. When implemented with sustained teacher support, consistent routines, and developmentally appropriate challenges, robotics can simultaneously foster curiosity, resilience, collaboration, and cognitive flexibility. These multidimensional benefits underscore the value of integrating robotics programs into public early-childhood education, particularly in socio-economically diverse communities.

Future work should incorporate mixed-method designs, including observational assessments, standardized CT measures, and child interviews, to triangulate educator-reported outcomes. Longitudinal follow-up into early primary school would also clarify whether early robotics participation predicts lasting differences in STEM confidence, inquiry habits, and social-emotional competencies.

Declaration on Generative AI

During the preparation of this work, the author used ChatGPT-5.2 to: Grammar and spelling check. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the publication's content.

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