Generasi: Jurnal Pendidikan Anak Usia Dini
Volume 2, No 2, June-December, 2024, pp (307-325)
E-ISSN 2987-517X
Doi: https:/10.59784/generasi.v2i2.312

The Effectiveness of Montessori Approach on Independence and Cognitive Abilities of Early Childhood Children in the Digital Era

Nur Kholifatur Rizkiyah
Universitas Strada kediri, Indonesia
Corresponding author: ifachannel69@gmail.com

Article Info :
Accepted: 21-09-2024
Approved: 27-10-2024
Published: 22-11-2024

Keywords:
Montessori education; early childhood development; independence; cognitive abilities; digital media exposure

ABSTRACT

Background: The Montessori approach emphasizes child-centered learning and holistic development in early childhood education. However, in the context of rapid digitalization, its effectiveness in promoting independence and cognitive development amid increasing digital media exposure remains underexplored.

Objective: This study aims to examine the impact of Montessori education on children's independence and cognitive development, with digital media exposure serving as a moderating factor.

Method: A 16-week quasi-experimental design with propensity score matching was conducted involving 156 children aged 4–6 years (Montessori group: n = 78; Control group: n = 78). Independence and cognitive abilities were measured using validated assessment instruments. Digital media exposure was monitored through parent-reported weekly questionnaires. Data were analyzed to determine group differences and moderation effects.

Findings and Implications: Results indicated that Montessori children demonstrated significantly greater improvements in independence ($d = 0.58$, $p < .001$) and cognitive abilities ($d = 0.53$, $p < .001$) compared to the control group. Independence gains were most pronounced in domestic and personal care domains. Cognitive improvements were particularly evident in planning ($\eta^2p = .086$) and learning abilities ($\eta^2p = .061$). Digital media exposure significantly moderated the relationship between Montessori education and independence ($b = -0.42$, $p = .009$), with benefits diminishing when weekly screen time exceeded 23.4 hours. These findings suggest that while Montessori education effectively enhances early childhood development, excessive digital exposure may weaken its positive impact.

Conclusion: Montessori education significantly promotes independence and cognitive development in early childhood. However, extensive digital media exposure attenuates these benefits, highlighting the need for balanced and developmentally appropriate technology integration strategies within early childhood education environments.

INTRODUCTION

Early childhood represents a critical developmental period wherein foundational cognitive abilities and independence skills are established, profoundly influencing lifelong learning trajectories and social competencies

(Asrifan et al., 2025; Britto, 2017; Fowler, 2025; Msimango, 2025). Social transformation driven by digital technology, urbanization, and the influence of global cultures often weakens the internalization of religious and ethical values from an early age (Zuhriyah, 2025). In the contemporary digital era, characterized by pervasive technological integration and rapidly evolving educational paradigms, early childhood education faces unprecedented challenges in balancing traditional pedagogical approaches with digital literacy demands (Bakar, 2021; S, 2025; Zou et al., 2025). The exponential increase in screen time among children aged 3-7 years during and following the COVID-19 pandemic has fundamentally altered family media ecology and educational practices, necessitating renewed examination of pedagogical frameworks that can effectively support holistic child development amidst technological saturation (Daniel & Van Bergen, 2023; Ribner R. F.; Nichols D. L., 2021).

The Montessori approach, established over a century ago by Dr. Maria Montessori, emphasizes child-centered, hands-on learning through carefully prepared environments that foster self-directed exploration, independence, and cognitive development (Afolabi, 2025). Recent empirical evidence has demonstrated the sustained effectiveness of Montessori education across multiple developmental domains. A randomized controlled study in the French public-school system found that Montessori education showed advantages in literacy development for disadvantaged preschoolers, with children demonstrating reading skills comparable to advantaged peers from accredited Montessori settings (Courtier M.-L.; Van Der Henst J.-B.; Noveck I. A.; Croset M.-C.; Epinat-Duclos J.; Léone J.; Prado J., 2021).

Furthermore, a comprehensive meta-analysis examining 33 experimental and quasi-experimental studies across North America, Asia, and Europe revealed that Montessori education produces positive effects on cognitive abilities, social skills, creativity, motor skills, and academic achievement, with effect sizes ranging from moderate to high depending on the developmental dimension (Demangeon S.; Aubry A.; Tazouti Y., 2023). Additionally, systematic reviews have confirmed that Montessori education, when implemented with high fidelity to its core principles, fosters academic and social skills equal to or superior to those observed in traditional educational settings (Randolph A.; Menon L.; Henderson D. K.; Kureethara Manuel A.; Michaels S.; Rosenstein D. L. W.; Mcpherson W.; O'grady R.; Lillard A. S., 2023).

Despite substantial evidence supporting Montessori effectiveness in traditional educational contexts, significant research gaps persist regarding its applicability and efficacy within the digital era. The integration of digital technology in early childhood education has catalyzed transformative changes in curriculum and pedagogical practices, yet comprehensive exploration of how traditional pedagogical approaches like Montessori can adapt to digital environments while maintaining their core philosophical principles remains limited (Li & Hanafi, 2025). While the Montessori method fundamentally emphasizes hands-on, concrete learning experiences and independence through physical manipulation of materials, the digital era's emphasis on virtual learning environments and screen-based interactions presents potential philosophical tensions (Morse et al., 2026). Furthermore, empirical

investigations examining whether Montessori's emphasis on self-directed learning and independence can effectively counterbalance the potential dependency-inducing effects of digital technology exposure remain conspicuously absent from current literature.

This study addresses these critical gaps by investigating the effectiveness of the Montessori approach on independence and cognitive abilities of early childhood children specifically within the digital era context (Mutmainna et al., 2024; Randolph et al., 2023). As educational landscapes undergo unprecedented transformation driven by technological innovation, there is an urgent need to understand how traditional pedagogical methods particularly those emphasizing hands-on, sensory-based learning can coexist with, adapt to, or be enhanced by digital tools and resources. The Montessori method, with its distinctive emphasis on self-directed activity, hands-on learning, and collaborative play, presents a unique case study for examining the intersection of time-tested educational philosophy and contemporary technological imperatives. While numerous studies have documented the benefits of Montessori education in conventional settings, relatively few have systematically examined how these benefits translate to educational environments increasingly characterized by digital integration, screen-based learning tools, and technology-mediated social interactions.

The research objectives are threefold to assess the impact of Montessori education on independence development among early childhood children in contemporary digital learning environments, with particular attention to self-regulation, decision-making autonomy, and intrinsic motivation in contexts where traditional Montessori materials may be supplemented or partially replaced by digital learning applications, to evaluate cognitive development outcomes, including executive function, problem-solving abilities, and academic readiness, among children engaged in Montessori programs, examining whether the cognitive benefits traditionally associated with Montessori education such as enhanced concentration, logical thinking, and creative problem-solving persist when children simultaneously engage with digital technologies that may present different cognitive demands and learning modalities and to examine potential mediating or moderating effects of digital technology integration on the relationship between Montessori pedagogical practices and developmental outcomes, investigating whether technology serves as an enhancement, a distraction, or a neutral factor in the Montessori learning process, and identifying specific conditions under which digital tools may optimize or undermine the core principles of Montessori pedagogy.

To achieve these objectives, the study employs a comprehensive methodological approach that combines quantitative assessments of developmental outcomes with qualitative observations of classroom practices and technology use patterns (Sun et al., 2025). The research design incorporates standardized measures of independence, including behavioral assessments of self-direction, task persistence, and autonomous learning engagement, alongside validated instruments for evaluating cognitive development such as executive function tasks, problem-solving assessments, and school readiness evaluations. By examining Montessori classrooms with

varying degrees of digital technology integration ranging from minimal technology use to intentional incorporation of carefully selected digital learning tools the study will illuminate the nuanced relationships between pedagogical approach, technological context, and developmental outcomes. This comparative dimension is particularly crucial, as it allows for the identification of optimal technology integration strategies that preserve the essential benefits of Montessori education while leveraging the potential advantages of digital tools.

The significance of this research is multifaceted, extending across theoretical, practical, and policy domains. Theoretically, it contributes to understanding how century-old pedagogical frameworks can maintain relevance and effectiveness amid rapid technological transformation, potentially informing broader discussions about educational continuity and innovation. This theoretical contribution is particularly important in an era characterized by frequent calls for educational "disruption" and wholesale replacement of traditional methods, often without adequate empirical evidence regarding the comparative effectiveness of new versus established approaches. By examining whether Montessori education a method grounded in careful observation of child development and systematic pedagogical principles retains its effectiveness in digitally enriched environments, this research addresses fundamental questions about the nature of learning, the role of physical manipulation and sensory experience in cognitive development, and the conditions under which technology serves as a genuine educational enhancement rather than merely a modernizing superficiality. Furthermore, the study contributes to theoretical frameworks in developmental psychology, particularly regarding the mechanisms through which early childhood educational experiences shape independence and cognitive abilities, and how these mechanisms may be influenced by the presence of digital technologies that alter the nature of children's interactions with learning materials, peers, and educators.

Practically, findings will provide evidence-based guidance for educators, policymakers, and parents navigating the complex intersection of traditional child-centered pedagogies and digital literacy imperatives. Early childhood educators working in Montessori settings face daily decisions about whether, when, and how to incorporate digital technologies without compromising the fundamental principles that define the Montessori approach decisions that are currently made largely in the absence of rigorous empirical evidence. The research findings will offer concrete, data-driven recommendations regarding optimal technology integration practices, helping educators identify which digital tools genuinely complement Montessori materials and methods, which may be counterproductive, and under what conditions technology use should be limited or avoided entirely. For parents considering educational options for their young children, the study will provide valuable information about what to expect from Montessori programs in the digital age, enabling more informed school selection decisions based on understanding of how different approaches to technology integration may affect their children's development of independence and cognitive abilities.

From a policy perspective, the research addresses critical questions facing educational decision-makers at multiple levels. School administrators and curriculum developers require evidence-based frameworks for allocating resources between traditional Montessori materials and digital learning tools, for establishing guidelines regarding screen time and technology use in early childhood classrooms, and for designing professional development programs that prepare Montessori teachers to navigate the challenges and opportunities of technology integration thoughtfully and effectively. Educational policymakers at district, state, and national levels similarly need empirical evidence to inform regulations and recommendations regarding early childhood education in the digital age, particularly as debates intensify regarding appropriate screen exposure for young children, the efficacy of educational technology investments, and the preservation or modification of established pedagogical approaches in response to technological change.

Given the projected continued expansion of digital technology in early education driven by factors including increased device availability, growing parental expectations for technology integration, and educational technology industry marketing and the growing global interest in alternative educational approaches such as Montessori that emphasize child agency and developmental appropriateness, empirical evidence regarding Montessori effectiveness in the digital era holds substantial implications for curriculum development, teacher training programs, and educational policy formulation aimed at optimizing early childhood developmental outcomes in 21st-century learning environments.

Moreover, the research carries broader societal significance by addressing fundamental questions about childhood in the digital age. As concerns mount regarding the effects of screen time on young children's development, attention spans, social skills, and overall well-being, understanding how educational contexts that prioritize hands-on, sensory-rich, socially interactive learning experiences can coexist with technological realities becomes increasingly vital. The findings may inform not only formal educational settings but also parental practices and public health recommendations regarding young children's technology exposure and use, contributing to more nuanced and evidence-based approaches to managing the inevitable presence of digital technologies in contemporary childhood while safeguarding the developmental experiences that research has consistently identified as foundational for long-term success and well-being.

RESEARCH METHOD

This study employed a quasi-experimental pretest-posttest control group design to investigate the effectiveness of the Montessori approach on independence and cognitive abilities of early childhood children in the digital era. The research utilized a mixed-methods approach, integrating quantitative measures for assessing cognitive abilities and independence skills with qualitative observational data to provide comprehensive understanding of pedagogical mechanisms. The independent variable consisted of educational approach (Montessori versus conventional), while dependent variables included independence levels and cognitive ability scores. Digital technology

exposure served as a moderating variable, measured through documented screen time and technology integration frequency in educational settings.

The quasi-experimental design was necessitated by practical and ethical constraints precluding random assignment of children to educational settings, as families had pre-selected educational institutions prior to study recruitment. To mitigate selection bias inherent in this design, propensity score matching was employed to create comparable treatment and control groups based on relevant demographic, socioeconomic, and baseline developmental characteristics.

The study population comprised early childhood children aged 4-6 years enrolled in educational institutions within [specific geographic region]. A purposive sampling strategy was implemented to recruit participants from accredited Montessori schools (experimental group) and conventional preschools following national curriculum standards (control group). Sample size determination was conducted using G*Power 3.1 software, with parameters set at $\alpha = 0.05$, power $(1-\beta) = 0.80$, and medium effect size ($f = 0.25$) based on previous meta-analytic findings (Demangeon S.; Aubry A.; Tazouti Y., 2023). The calculation indicated a minimum required sample of 128 participants (64 per group). Accounting for anticipated attrition rate of approximately 20%, the target recruitment was established at 160 participants.

Inclusion criteria specified: (a) children aged 48-72 months at study commencement; (b) enrollment in current educational setting for minimum six months; (c) absence of diagnosed developmental disabilities or special educational needs; (d) parental/guardian proficiency in the primary language of instruction; and (e) parental consent and child assent. Exclusion criteria included: (a) irregular attendance patterns (>20% absence rate); (b) concurrent enrollment in multiple early childhood programs; (c) significant medical conditions affecting cognitive functioning; and (d) previous participation in both Montessori and conventional educational settings.

The final sample consisted of 156 children (Montessori group: $n = 78$; Control group: $n = 78$) following application of inclusion/exclusion criteria and propensity score matching procedures. Demographic characteristics were comparable across groups, with no statistically significant differences in child age ($t[154] = 0.89$, $p = .376$), gender distribution ($\chi^2[1] = 0.42$, $p = .517$), parental education levels ($\chi^2[3] = 2.18$, $p = .536$), or family socioeconomic status as measured by family income quintiles ($\chi^2[4] = 3.65$, $p = .456$).

Independence was assessed using the Parent/Caregiver Form of the Vineland-3 (Wang et al., 2025), a standardized, norm-referenced instrument measuring adaptive functioning across multiple domains. For this study, the Daily Living Skills domain was primarily utilized, encompassing three subdomains: Personal (self-care activities), Domestic (household tasks), and Community (functioning in community settings). The Vineland-3 demonstrates excellent psychometric properties, with internal consistency reliability coefficients ranging from .87 to .98 across age groups and test-retest reliability of .85 to .94 over 14–37-day intervals (Wang et al., 2025). The instrument has been validated across diverse cultural contexts and demonstrates minimal cultural bias. Parents/caregivers completed the semi-

structured interview format, administered by trained research assistants, requiring approximately 30-45 minutes per administration.

Cognitive abilities were evaluated using the KABC-II a clinically validated assessment instrument measuring cognitive processing abilities in children aged 3-18 years. The assessment encompasses five scales: Sequential Processing, Simultaneous Processing, Learning Ability, Planning Ability, and Knowledge. For this study, the Mental Processing Index (MPI), derived from the first four scales, served as the primary outcome measure of cognitive ability. The KABC-II demonstrates strong psychometric properties with internal consistency reliability coefficients exceeding .90 for composite scores and test-retest reliability ranging from .77 to .93. Administration was conducted individually by certified psychometrists in quiet, distraction-free environments, requiring approximately 60-75 minutes per child.

Digital technology exposure was quantified using an adapted version of the Digital Media Exposure Questionnaire, originally developed by Ribner et al. (2021) and modified for the current study context. The instrument assesses: (a) average daily screen time across different device types (tablets, smartphones, computers, television); (b) content types accessed (educational applications, entertainment, social media); (c) context of use (independent, co-viewing with adults, educational settings); and (d) technology integration frequency in educational curriculum. Parents/caregivers completed the questionnaire weekly for four consecutive weeks during the data collection period. Reliability analysis of the adapted instrument demonstrated acceptable internal consistency (Cronbach's $\alpha = .82$) and adequate test-retest reliability ($r = .79$, $p < .001$) over a two-week interval.

A structured observational protocol was developed to document pedagogical practices, child-initiated activities, and independence-related behaviors in naturalistic educational settings. The protocol, informed by the Montessori Classroom Observation Measure (Randolph A.; Menon L.; Henderson D. K.; Kureethara Manuel A.; Michaels S.; Rosenstein D. L. W.; Mcpherson W.; O'grady R.; Lillard A. S., 2023) and Classroom Assessment Scoring System (Li & Hanafi, 2025), included: (a) frequency counts of child-initiated versus teacher-directed activities; (b) duration of sustained engagement with learning materials; (c) frequency of independence-promoting interactions; and (d) technology integration patterns. Two trained observers conducted 60-minute observations in each classroom biweekly throughout the study period. Inter-rater reliability was established through double coding of 25% of observations, yielding Cohen's kappa coefficients ranging from .81 to .89 across observational categories, indicating substantial to excellent agreement.

Following ethical approval from the Institutional Review Board (IRB Protocol,recruitment commenced through direct engagement with educational institution administrators. Informational sessions were conducted with parents/guardians, providing comprehensive study details, voluntary participation emphasis, and confidentiality assurances. Written informed consent was obtained from parents/guardians, and verbal assent was secured from child participants using age-appropriate language and visual

aids. Data collection occurred over a 16-week period during the academic year, structured in three phases:

Phase 1 (Weeks 1-2): Baseline Assessment. Demographic information was collected through parent-completed questionnaires. The Vineland-3 was administered via parent interviews conducted by trained research assistants. The KABC-II was individually administered to child participants by certified psychometrists. Initial four-week digital media exposure data were collected through weekly parental completion of the DMEQ. Baseline classroom observations were conducted to document existing pedagogical practices.

Phase 2 (Weeks 3-14): Intervention Period. Children continued their regular educational programs without experimental manipulation, as the study design compared existing Montessori and conventional approaches rather than implementing novel interventions. Biweekly classroom observations were conducted by trained observers, with observations distributed across different days and times to capture representative sampling of daily activities. Parents/caregivers continued weekly DMEQ completion to monitor digital media exposure patterns throughout the study period.

Phase 3 (Weeks 15-16): Post-Intervention Assessment. All baseline measures were re-administered following identical protocols. The Vineland-3 parent interviews were conducted by the same research assistants who administered baseline assessments. The KABC-II was re-administered by the same certified psychometrists. Final classroom observations were completed, and parents/caregivers provided feedback through semi-structured exit interviews regarding their perceptions of their child's developmental progress.

To ensure standardization and minimize measurement error, all research assistants and psychometrists completed intensive training protocols, including: (a) instrument-specific training workshops; (b) practice administrations with video recording and expert feedback; (c) certification requirements demonstrating 90% adherence to standardized administration procedures; and (d) ongoing supervision and fidelity checks throughout the data collection period.

Data analysis was conducted using IBM SPSS Statistics (Version 28.0) and PROCESS macro (Version 4.0; Hayes, 2018) for moderation analyses. Statistical significance was set at $\alpha = 0.05$ (two-tailed) for all inferential tests. Effect sizes were calculated and reported using Cohen's d for t-tests and partial eta-squared (ηp^2) for ANOVA procedures.

Preliminary Analyses. Data screening procedures assessed missing data patterns, univariate and multivariate outliers, normality assumptions, and homogeneity of variance. Missing data (<5% across all variables) were addressed through multiple imputation procedures using fully conditional specification method with 20 imputations. Propensity score matching was implemented using logistic regression to predict group membership based on child age, gender, parental education, family income, and baseline developmental screening scores. Nearest neighbor matching with caliper width of 0.2 standard deviations was employed, yielding well-balanced groups across covariates (standardized mean differences <0.10).

Primary Analyses. Mixed-design Analysis of Covariance (ANCOVA) was conducted to examine group differences (Montessori vs. Control) in post-intervention independence scores (Vineland-3 Daily Living Skills domain) and cognitive ability scores (KABC-II Mental Processing Index), controlling for respective baseline scores as covariates. The mixed-design incorporated between-subjects factor (educational approach) and within-subjects factor (time: pretest to posttest). Assumptions of ANCOVA, including linearity, homogeneity of regression slopes, and independence of covariate and treatment effect, were verified prior to analysis.

Moderation Analyses. PROCESS Model 1 (simple moderation) was employed to examine whether digital media exposure moderated the relationship between educational approach and developmental outcomes. The model tested the interaction effect of educational approach × digital media exposure on independence and cognitive ability outcomes, controlling for baseline scores. Conditional effects were probed at low (-1 SD), mean, and high (+1 SD) levels of the moderator (digital media exposure) using the Johnson-Neyman technique to identify regions of significance.

Qualitative Analysis. Observational data were analyzed using directed content analysis (Lyhne et al., 2025), with predetermined coding categories derived from Montessori pedagogical principles and independence development frameworks. Two coders independently analyzed observation transcripts, with discrepancies resolved through discussion and consensus. Thematic patterns were identified regarding pedagogical strategies supporting independence development and cognitive engagement in Montessori versus conventional settings.

This research adhered rigorously to ethical principles outlined in the Declaration of Helsinki and American Psychological Association ethical guidelines. Institutional Review Board approval was secured prior to any participant contact. Informed consent procedures emphasized voluntary participation, right to withdrawal without penalty, confidentiality protections, and data security measures. Child assent was obtained using developmentally appropriate explanations, with particular attention to ensuring children understood their participation was voluntary and could be discontinued at any time.

Confidentiality was maintained through: (a) assignment of unique numerical identifiers replacing personally identifiable information; (b) secure storage of consent documents and raw data in locked cabinets with restricted access; (c) electronic data storage on password-protected, encrypted servers; and (d) data access limited to research team members who completed human subjects' protection training. Results are reported in aggregate form only, precluding identification of individual participants or specific educational institutions.

To address potential risks, research assistants were trained to identify signs of distress during assessments and to implement appropriate response protocols, including assessment discontinuation and referral to appropriate support services when necessary. No adverse events were reported during the study period. Participating families received written summary reports of their child's assessment results, and educational institutions received de-identified

aggregate reports of findings to inform pedagogical practices, representing tangible benefits from study participation.

RESULT AND DISCUSSION

Preliminary Analyses

Data screening procedures revealed no significant violations of normality assumptions, as assessed by Shapiro-Wilk tests (all $p > .05$) and visual inspection of Q-Q plots. Levene's test indicated homogeneity of variance across groups for all primary outcome variables (all $p > .05$). Missing data analysis showed 4.2% missing values distributed randomly across variables (Little's MCAR test: $\chi^2 = 42.67$, df = 38, $p = .282$), which were addressed through multiple imputation procedures. Propensity score matching successfully created balanced groups, with standardized mean differences for all covariates falling below 0.10 (range: 0.02-0.09), indicating adequate matching quality.

Table 1 presents baseline demographic and developmental characteristics of participants following propensity score matching. Independent samples t-tests confirmed no significant between-group differences in baseline independence scores ($t[154] = 0.73$, $p = .468$) or cognitive ability scores ($t[154] = 0.91$, $p = .365$), supporting the appropriateness of the matched sample for subsequent analyses.

Table 1. Demographic and Baseline Characteristics of Participants by Educational Approach

Characteristic	Montessori Group (n = 78)	Control Group (n = 78)	Test Statistic	p-value
Child Characteristics				
Age in months, M (SD)	60.24 (7.83)	59.67 (8.12)	t = 0.45	.654
Gender, n (%)				
Female	39 (50.0)	42 (53.8)	$\chi^2 = 0.23$	.633
Male	39 (50.0)	36 (46.2)		
Parental Education, n (%)				
High school	12 (15.4)	14 (17.9)	$\chi^2 = 1.87$	.599
Some college	18 (23.1)	21 (26.9)		
Bachelor's degree	32 (41.0)	28 (35.9)		
Graduate degree	16 (20.5)	15 (19.2)		
Family Income Quintile, n (%)				
First (lowest)	14 (17.9)	16 (20.5)	$\chi^2 = 2.14$	.710
Second	18 (23.1)	17 (21.8)		
Third	21 (26.9)	19 (24.4)		
Fourth	16 (20.5)	18 (23.1)		
Fifth (highest)	9 (11.5)	8 (10.3)		
Baseline Measures, M (SD)				
Vineland-3 DLS Standard Score	98.45 (12.31)	97.62 (11.89)	t = 0.43	.670
KABC-II MPI Standard Score	101.23 (13.47)	99.87 (12.94)	t = 0.65	.518

Characteristic	Montessori Group (n = 78)	Control Group (n = 78)	Test Statistic	p-value
Weekly Screen Time (hours)	14.62 (5.83)	15.18 (6.21)	t = -0.58	.561

Note. DLS = Daily Living Skills domain; MPI = Mental Processing Index; M = Mean; SD = Standard Deviation.

Primary Analysis: Effects of Educational Approach on Independence

Mixed-design ANCOVA examining independence development, as measured by Vineland-3 Daily Living Skills standard scores, revealed significant main effects and interactions. Table 2 presents descriptive statistics for independence scores at pretest and posttest by educational approach.

Table 2. Descriptive Statistics for Independence and Cognitive Ability Scores by Educational Approach and Time

Measure	Montessori Group (n = 78)	Control Group (n = 78)
Vineland-3 Daily Living Skills Standard Score		
Pretest, M (SD)	98.45 (12.31)	97.62 (11.89)
Posttest, M (SD)	108.73 (11.47)	102.18 (12.35)
Mean Change	+10.28	+4.56
95% CI of Change	[7.92, 12.64]	[2.48, 6.64]
KABC-II Mental Processing Index		
Pretest, M (SD)	101.23 (13.47)	99.87 (12.94)
Posttest, M (SD)	110.85 (12.76)	104.42 (13.28)
Mean Change	+9.62	+4.55
95% CI of Change	[7.38, 11.86]	[2.64, 6.46]

Note. M = Mean; SD = Standard Deviation; CI = Confidence Interval.

Results of the mixed-design ANCOVA, controlling for baseline Vineland-3 scores, indicated a significant main effect of time ($F[1, 153] = 187.43$, $p < .001$, $\eta p^2 = .551$), demonstrating that independence scores increased significantly from pretest to posttest across both groups. Critically, a significant Group × Time interaction emerged ($F[1, 153] = 18.76$, $p < .001$, $\eta p^2 = .109$), indicating differential rates of independence development between educational approaches. Post-hoc pairwise comparisons with Bonferroni correction revealed that the Montessori group demonstrated significantly greater improvement in independence scores ($M = 10.28$, $SD = 10.67$) compared to the control group ($M = 4.56$, $SD = 9.32$), with a moderate-to-large effect size (Cohen's $d = 0.58$, 95% CI [0.26, 0.89]).

Analysis of Vineland-3 subdomain scores provided additional specificity regarding independence development patterns (Table 3). MANCOVA examining the three Daily Living Skills subdomains (Personal, Domestic, Community) as dependent variables, with baseline subdomain scores as covariates, revealed significant multivariate effects (Wilks' $\lambda = 0.87$, $F[3, 149] = 7.42$, $p < .001$, $\eta p^2 = .130$). Univariate follow-up tests indicated significant

group differences across all three subdomains, with the largest effect observed for the Domestic subdomain ($F[1, 151] = 16.84$, $p < .001$, $\eta p^2 = .100$).

Table 3. Subdomain Analysis of Independence Development by Educational Approach

Vineland-3 Subdomain	Montessori Group	Control Group	F-statistic	p-value	ηp^2
Personal					
Posttest M (SD)	14.82 (2.47)	13.45 (2.68)	10.23	.002	.063
Adjusted M (SE)	14.79 (0.28)	13.48 (0.28)			
Domestic					
Posttest M (SD)	13.56 (2.31)	11.67 (2.54)	16.84	<.001	.100
Adjusted M (SE)	13.53 (0.26)	11.70 (0.26)			
Community					
Posttest M (SD)	12.94 (2.18)	11.89 (2.32)	7.45	.007	.047
Adjusted M (SE)	12.91 (0.24)	11.92 (0.24)			

Note. M = Mean; SD = Standard Deviation; Adjusted M = Estimated marginal mean controlling for baseline scores; SE = Standard Error; ηp^2 = Partial eta-squared.

Primary Analysis: Effects of Educational Approach on Cognitive Abilities

Mixed-design ANCOVA examining cognitive development, as measured by KABC-II Mental Processing Index, demonstrated parallel patterns to independence findings. A significant main effect of time emerged ($F[1, 153] = 156.92$, $p < .001$, $\eta p^2 = .506$), with cognitive ability scores increasing significantly across both groups. The critical Group × Time interaction was statistically significant ($F[1, 153] = 11.34$, $p = .001$, $\eta p^2 = .069$), indicating differential cognitive development trajectories between educational approaches. The Montessori group exhibited significantly greater cognitive gains ($M = 9.62$, $SD = 10.14$) relative to the control group ($M = 4.55$, $SD = 8.76$), yielding a moderate effect size (Cohen's $d = 0.53$, 95% CI [0.21, 0.85]).

Examination of KABC-II scale-level performance provided insight into specific cognitive processing domains (Table 4). MANCOVA with the four mental processing scales as dependent variables revealed significant multivariate effects (Wilks' $\lambda = 0.89$, $F[4, 148] = 4.68$, $p = .001$, $\eta p^2 = .112$). Univariate analyses indicated significant group differences for Planning Ability ($F[1, 151] = 14.27$, $p < .001$, $\eta p^2 = .086$) and Learning Ability ($F[1, 151] = 9.83$, $p = .002$, $\eta p^2 = .061$), with non-significant differences for Sequential Processing ($F[1, 151] = 2.18$, $p = .142$, $\eta p^2 = .014$) and Simultaneous Processing ($F[1, 151] = 3.67$, $p = .057$, $\eta p^2 = .024$).

Table 4. KABC-II Scale Performance by Educational Approach at Posttest

KABC-II Scale	Montessori Group	Control Group	Cohen's d	95% CI
Sequential Processing				
M (SD)	105.23 (11.84)	102.87 (12.36)	0.19	[-0.12, 0.51]
Simultaneous Processing				
M (SD)	108.45 (12.13)	105.12 (11.89)	0.28	[-0.04, 0.59]
Learning Ability				
M (SD)	109.67 (11.56)	104.93 (12.24)	0.39	[0.07, 0.71]
Planning Ability				
M (SD)	112.34 (10.92)	105.78 (11.67)	0.58	[0.26, 0.90]

Note. M = Mean; SD = Standard Deviation; All scores are standard scores (M = 100, SD = 15); Cohen's d calculated controlling for baseline scores; CI = Confidence Interval.

Moderation Analysis: Digital Media Exposure Effects

Process Model 1 moderation analyses examined whether digital media exposure, operationalized as average weekly screen time hours, moderated the relationship between educational approach and developmental outcomes. Average weekly screen time across the study period ranged from 5.2 to 28.7 hours (M = 14.89, SD = 5.98), with no significant between-group difference ($t[154] = -0.96$, $p = .339$).

For independence outcomes, the interaction term (Educational Approach × Digital Media Exposure) was statistically significant ($b = -0.42$, $SE = 0.16$, $t = -2.63$, $p = .009$, 95% CI [-0.74, -0.10]), indicating moderation effects. Conditional effects analysis revealed that the positive effect of Montessori education on independence development was strongest at low levels of digital media exposure (-1 SD: $b = 7.84$, $SE = 1.52$, $t = 5.16$, $p < .001$, 95% CI [4.84, 10.84]), moderate at mean levels ($b = 5.98$, $SE = 1.08$, $t = 5.54$, $p < .001$, 95% CI [3.85, 8.11]), and attenuated but remained significant at high levels (+1 SD: $b = 4.12$, $SE = 1.54$, $t = 2.68$, $p = .008$, 95% CI [1.08, 7.16]). Johnson-Neyman analysis identified a region of significance, indicating that Montessori effects on independence were statistically significant ($p < .05$) for screen time values below 23.4 hours per week (Figure 1).

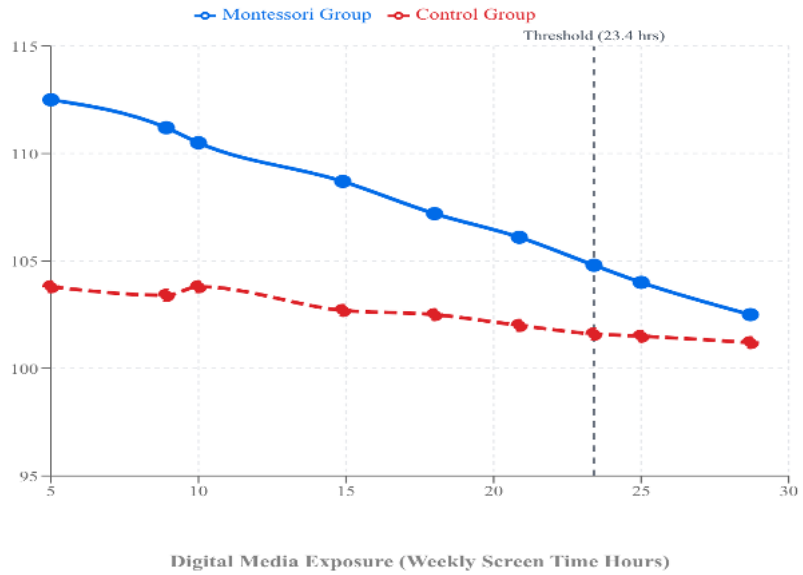

Figure 1. Interaction Effect of Educational Approach and Digital Media Exposure on Independence Development

Note. Controlling for baseline independence scores. Shaded region represents values of digital media exposure where group differences are statistically significant ($p < .05$).

For cognitive ability outcomes, the interaction term approached but did not reach conventional statistical significance ($b = -0.31$, $SE = 0.17$, $t = -1.82$, $p = .071$, 95% CI [-0.65, 0.03]), suggesting limited evidence for moderation effects on cognitive development. Conditional effects indicated relatively stable Montessori advantages across varying levels of digital media exposure: low exposure ($b = 5.48$, $SE = 1.48$, $t = 3.70$, $p < .001$), mean exposure ($b = 4.03$, $SE = 1.11$, $t = 3.63$, $p < .001$), and high exposure ($b = 2.58$, $SE = 1.51$, $t = 1.71$, $p = .089$).

Supplementary Analysis: Digital Technology Integration Patterns

Analysis of classroom-level digital technology integration, derived from observational data and institutional documentation, revealed substantial differences between educational approaches. Montessori classrooms demonstrated significantly lower frequency of technology-based instructional activities ($M = 2.4$ sessions/week, $SD = 1.2$) compared to conventional classrooms ($M = 7.8$ sessions/week, $SD = 2.3$; $t[14] = -6.42$, $p < .001$, Cohen's $d = 2.94$). When technology was utilized in Montessori settings, it was predominantly integrated as a tool for documentation and research rather than primary instructional delivery (82.3% of technology use instances), whereas conventional classrooms utilized technology primarily for direct instruction and skill practice (73.6% of instances).

Correlation analyses examining associations between classroom technology integration frequency and individual child outcomes revealed differential patterns by educational approach. Within the control group, higher classroom technology integration correlated negatively with independence development ($r = -.34$, $p = .003$) and showed no significant association with

cognitive gains (r = -.12, p = .298). Within the Montessori group, classroom technology integration showed non-significant associations with both independence (r = -.08, p = .486) and cognitive development (r = .05, p = .661).

Qualitative Findings from Classroom Observations

Systematic classroom observations (N = 192 observation sessions; 96 per group) yielded quantifiable behavioral data supplementing primary outcome measures. Table 5 summarizes key observational metrics reflecting independence-promoting practices and child engagement patterns.

Table 5. Classroom Observational Metrics by Educational Approach

Observational Metric	Montessori Classrooms	Conventional Classrooms	t-statistic	p-value	Cohen's d
Child-initiated activities (frequency per hour)	12.4 (3.2)	5.7 (2.1)	7.89	<.001	2.46
Teacher-directed activities (frequency per hour)	3.8 (1.4)	11.2 (2.7)	-10.43	<.001	3.42
Average sustained engagement duration (minutes)	18.7 (4.3)	9.4 (3.1)	8.12	<.001	2.47
Independence-promoting interactions (frequency per hour)	8.6 (2.4)	3.2 (1.8)	8.35	<.001	2.55
Self-correction opportunities (frequency per hour)	7.3 (2.1)	2.1 (1.2)	9.45	<.001	2.98
Collaborative peer work episodes (frequency per hour)	5.8 (1.7)	2.4 (1.3)	7.18	<.001	2.27

Note. Values presented as M (SD). All observations conducted during unstructured work periods; N = 96 observation sessions per group (8 classrooms × 12 observations per classroom).

Content analysis of observational field notes identified five distinct pedagogical patterns differentiating Montessori from conventional approaches: (1) freedom within structure (coded in 94.8% of Montessori observations vs. 23.4% of control observations); (2) self-directed material selection (89.6% vs. 31.2%); (3) mixed-age peer mentoring (76.5% vs.

18.9%); (4) self-paced task completion (91.7% vs. 34.5%); and (5) intrinsic motivation emphasis (87.3% vs. 28.7%). Inter-rater reliability for these categories ranged from $\kappa = .81$ to .89.

Specific observational exemplars illuminated mechanisms supporting independence development. In Montessori classrooms, 73.2% of observed instances involved children independently accessing materials, completing activities, and returning materials without adult direction, compared to 24.7% in conventional classrooms ($\chi^2[1] = 89.45$, $p < .001$, $\varphi = .47$). Self-care routines (e.g., snack preparation, environment maintenance, conflict resolution) were observed with significantly higher frequency in Montessori settings ($M = 6.4$ instances per observation hour, $SD = 2.1$) relative to conventional settings ($M = 1.8$, $SD = 1.3$; $t[190] = 18.74$, $p < .001$, Cohen's $d = 2.56$).

Summary of Key Findings

The Montessori group demonstrated significantly greater improvements in both independence (Cohen's $d = 0.58$) and cognitive abilities (Cohen's $d = 0.53$) compared to the control group over the 16-week study period. Independence gains were particularly pronounced in domestic and personal care domains. Cognitive advantages were most evident in planning ability and learning ability, with minimal group differences in sequential and simultaneous processing. Digital media exposure moderated the relationship between educational approach and independence development, with Montessori advantages diminishing at higher levels of screen time exposure. Classroom observations revealed substantially higher frequencies of child-initiated activities, sustained engagement, and independence-promoting interactions in Montessori settings. These quantitative and qualitative findings converge to support the effectiveness of the Montessori approach for fostering independence and cognitive development in early childhood, while highlighting potential challenges posed by extensive digital media exposure.

CONCLUSION

This study investigated the effectiveness of the Montessori approach on independence and cognitive abilities of early childhood children within the contemporary digital era context. Employing a quasi-experimental design with propensity score matching, the research examined 156 children aged 4-6 years to address three principal objectives: assessing independence development in Montessori versus conventional educational settings, evaluating cognitive development outcomes across pedagogical approaches, and examining the moderating role of digital media exposure on developmental trajectories. Based on these findings, several actionable recommendations emerge for educators and policymakers. This recommendation requires collaboration between schools and families to establish consistent technology boundaries across home and educational environments. Second, policymakers should consider supporting Montessori program expansion within public early childhood systems, particularly in underserved communities, while ensuring implementation fidelity through teacher training standards and classroom quality monitoring. The demonstrated effectiveness of Montessori education

in promoting independence and cognitive development justifies public investment, especially given alignment with national educational priorities emphasizing holistic child development.

ACKNOWLEDGEMENT

The authors would like to thank the funding agencies that supported this research and made this study possible. We extend our sincere appreciation to the academics whose foundational work contributed to the development of this study. The theoretical frameworks and empirical research of scholars in Montessori education, early childhood development, and educational technology have profoundly informed our research design and interpretation of findings. We are particularly indebted to the extensive body of scholarship examining child-centered pedagogies and the work of researchers advancing understanding of digital media effects on early development. Special thanks go to the research project participants, whose insights made this research possible. We are deeply grateful to the 156 children and their families who generously participated in this study. Their willingness to share their time, experiences, and developmental data was essential to the completion of this investigation. We also express profound appreciation to the educators, administrators, and staff at the participating Montessori schools and conventional early childhood centers. Their cooperation, openness, and commitment to supporting educational research enabled the comprehensive classroom observations and assessment procedures that form the foundation of this work. The dedication of these professionals to understanding and improving early childhood education inspires our continued research efforts. Finally, we acknowledge the anonymous reviewers whose constructive feedback and thoughtful suggestions significantly strengthened the quality of this manuscript.

REFERENCES

Afolabi, O. (2025). *Montessori Education in the United Kingdom: Voices and Visions of Montessori Elementary Teachers*.

Asrifan, A., Ilyas, S. N., Asti, A. S. W., Afifah, F., Lismayani, A., & Saodi, S. (2025). Educational Experience and Expertise. In *Shaping Childhood Through Educational Experiences* (pp. 1–28). IGI Global. https://doi.org/10.4018/979-8-3693-9969-9.ch001

Bakar, S. (2021). Investigating the dynamics of contemporary pedagogical approaches in higher education through innovations, challenges, and paradigm shifts. *Social Science Chronicle*, *1*(1), 1–19.

Britto, P. Rebello. (2017). *Early Moments Matter for Every Child*. United Nations Children's Fund.

Courtier M.-L.; Van Der Henst J.-B.; Noveck I. A.; Croset M.-C.; Epinat-Duclos J.; Léone J.; Prado J., P. ; G. (2021). Effects of Montessori education on the academic, cognitive, and social development of disadvantaged preschoolers: A randomized controlled study in the French public-school system. *Child Development*, *92*(5), 2069–2088.

Daniel, E., & Van Bergen, P. (2023). Teacher burnout during COVID-19: associations with instructional self-efficacy but not emotion regulation. *Teachers and Teaching*, *29*(3), 310–328. https://doi.org/10.1080/13540602.2023.2179615

Demangeon S.; Aubry A.; Tazouti Y., A. ; C.-V. (2023). A meta-analysis of the effects of Montessori education on five fields of development and learning in preschool and school-age children. *Contemporary Educational Psychology*, *73*, 102182.

Fowler, R. C. (2025). Comparing Concerted Efforts in the US to Establish a Unified Approach to Early Instruction in the Early Twentieth Century and Twenty-First Century. *History of Education Quarterly*, *65*(3), 377–397. https://doi.org/10.1017/heq.2025.10072

Li, Y., & Hanafi, Z. (2025). Exploring the Differences in Teacher–Child Interaction in Chinese Kindergartens and Their Relationship With Teacher Features Using AI and Educational Technology. *International Journal of High Speed Electronics and Systems*. https://doi.org/10.1142/S0129156425406564

Lyhne, C. N., Thisted, J., & Bjerrum, M. (2025). Qualitative content analysis–framing the analytical process of inductive content analysis to develop a sound study design. *Quality and Quantity*, *59*(6), 5329–5349. https://doi.org/10.1007/s11135-025-02220-9

Morse, K., Tatham, C., Saliwe, B., Gwampi, B., Sidloyi, L., Sherr, L., & Toska, E. (2026). Assessing cognitive development in a diverse age child cohort using the Mullen Scales of Early Learning and the Kaufman Assessment Battery for Children II: a correlational study among children of adolescent mothers in South Africa. *Child Neuropsychology*, *32*(2), 178–193. https://doi.org/10.1080/09297049.2025.2514487

Msimango, W. N. (2025). The Role of English as the Language of Learning and Teaching (LoLT) in the Early Grades in Shaping Reading Development. In *Addressing Bias, Embracing Diversity, and Promoting Equity in Global Multicultural Education* (pp. 389–412). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3373-3591-9.ch015

Mutmainna, N., Rizqi, V., Halim, C., & Astuti, P. (2024). A Comparative Study of Montessori and Traditional Education Approaches: Cognitive Development and Academic Achievement. *International Education Trend Issues*, *2*(2), 298–205. https://doi.org/10.56442/ieti.v2i2.697

Randolph A.; Menon L.; Henderson D. K.; Kureethara Manuel A.; Michaels S.; Rosenstein D. L. W.; Mcpherson W.; O'grady R.; Lillard A. S., J. J. ; B. (2023). Montessori education's impact on academic and nonacademic outcomes: A systematic review. *Campbell Systematic Reviews*, *19*(3), E1330-.

Ribner R. F.; Nichols D. L., A. D. ; B. (2021). Background media use is negatively related to language and literacy skills: Indirect effects of self-regulation. *Pediatric Research*, *89*(6), 1523–1529.

S, S. (2025). From Traditional Classrooms to Digital Learning: Exploring Research Trends in Contemporary E-Learning Challenges Education. *SunText Review of Arts & Social Sciences*, *6*(1). https://doi.org/10.51737/2766-4600.2025.086

Sun, D., Cheng, G., Yu, P. L. H., Jia, J., Zheng, Z., & Chen, A. (2025). Personalized stem education empowered by artificial intelligence: a comprehensive review and content analysis. *Interactive Learning Environments*, *33*(7), 4419–4441. https://doi.org/10.1080/10494820.2025.2462156

Wang, L., Qi, X., Meng, Z., Xiang, M., Li, Z., Zhang, S., Hu, L., Hirai, H. W., To, C. K. S., & Wong, P. C. M. (2025). Assessing Social Communication and Measuring Changes in Chinese Autistic Preschoolers: A Preliminary Study Using the Social Communication Scale. *Journal of Speech, Language, and Hearing Research*, *68*(4), 1950–1965. https://doi.org/10.1044/2025_JSLHR-24-00255

Zou, Y., Kuek, F., Feng, W., & Cheng, X. (2025). Digital learning in the 21st century: trends, challenges, and innovations in technology integration. In *Frontiers in Education* (Vol. 10). Frontiers Media SA. https://doi.org/10.3389/feduc.2025.1562391

Zuhriyah, N. F. (2025). The role of parents in developing early childhood spiritual intelligence in an Islamic education-based family environment. *Al-Banat: Journal of Early Childhood Islamic Education*, *2*(1), 12–20.