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Playful Smart Environments: Interactive Public Installations as Child-Centred Urban Learning Spaces

* [1] **Vigisha Gopalakrishnan**
Subject Lead for School of Design Innovation
[1] Senior Lecturer in Architecture, Faculty of Technology, Arts and Culture, De Montfort University, Dubai, UAE
[1] E-mail: vigisha.gopalakrishnan@dmu.ac.uk
[1] ORCID: https://orcid.org/0000-0001-9632-2124

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Abstract

This paper examines how interactive architectural installations can enhance children's engagement, learning, and social development in public space. The aim is to establish a design framework that integrates responsive technologies within child-centred urban environments. The study combines comparative case analysis, behavioural observation, and prototype-based spatial simulation to evaluate how sensor systems, adaptive lighting, and kinetic elements influence children's movement, collaboration, and creativity. Results show that spatial responsiveness increases physical activity, peer interaction, and exploratory behaviour when guided by safety, inclusivity, and developmental principles. The findings demonstrate that technology is most effective when embedded within clear architectural strategies rather than treated as add-on features. The study concludes that interactive installations can transform static playgrounds into adaptive learning landscapes. Its contribution lies in proposing a structured, research-based approach to designing developmentally supportive public architecture for children.
Keywords: Kids and Architecture; Interactive Design; Public Space; Child-Centred Environments; Urban Play.

1. Introduction

Urban public space constitutes one of the most consequential yet underexamined arenas for child development. Children experience cities not as commuters optimising routes or consumers navigating commercial space, but as embodied learners whose cognitive, social, and creative capacities are directly shaped by the spatial affordances of their immediate environment (Chawla, 2023). Yet the dominant paradigm of contemporary urban planning has systematically marginalised children's spatial needs: public space is designed primarily around adult mobility, commercial viability, and infrastructural efficiency, with child-specific provision typically confined to bounded playground zones that offer limited developmental stimulation beyond structured physical movement (Mouratidis, 2024).

The emergence of smart city technologies has, paradoxically, exacerbated this marginalisation. Whilst sensor networks, adaptive lighting systems, kinetic installations, and augmented reality overlays have transformed how adults navigate and experience urban environments, their application to child-centred public space design remains peripheral and unsystematic (Sharifi, 2023). The result is a developmental lacuna of significant consequence: children who constitute a substantial proportion of urban populations are experiencing public spaces that fail to engage them cognitively, socially, or creatively. Research consistently demonstrates that stimulating, responsive environments are not merely preferable but functionally necessary for child development: 68% of children's learning occurs through play (Pellegrini & Smith, 2022), whilst spatially responsive environments generate three times the social interaction of static equivalents (Chawla, 2023).

This paper addresses a precise and consequential research gap: the absence of any structured, evidence-based framework integrating responsive architectural technology with child developmental theory in the context of public urban installations. Whilst individual case studies of interactive installations exist, and whilst child-centred design has generated rich theoretical literature, no systematic methodology has yet emerged for combining these domains into a reproducible, evaluable design approach. The study operates at the productive intersection of three fields child-centred design, responsive architecture, and smart urbanism and its contribution lies in bridging theory to evidence-based practice through a novel tripartite research design and an original author-developed design framework.

1.1 Theoretical Context and Literature Review

Three theoretical pillars inform the analytical framework of this study, each addressing a distinct but interconnected dimension of the problem space.

1.1.1 Child-Centred Design Theory

The foundational premise that children's environments require qualitatively different design principles from adult spaces has been developed across several decades of scholarship. Chawla's (2023) comprehensive synthesis of research on childhood nature connection and developmental psychology establishes that children require psychologically rich, responsive environments for healthy cognitive and social development; spatial agency the capacity to affect, alter, and engage with one's surroundings is identified as foundational to this process. This finding resonates with Hart's (1979, revisited 2002) canonical ladder of children's participation, which positions genuine spatial agency at the apex of developmental quality and identifies environments offering only tokenistic engagement as developmentally inferior. Moss and Petrie (2019) extend this framework into service design, arguing that children's spaces should function as sites of exploration, discovery, and self-directed inquiry rather than passive consumption of pre-programmed stimuli. Katsavounidou (2023) situates this argument historically, showing that child-centred urbanism has periodically resurfaced across the twentieth century whenever cities have been redesigned around play rather than traffic, while Gill (2021) argues that child-friendly planning is best understood as a proxy indicator of overall city quality rather than a niche concern.

The physical learning space design literature reinforces these theoretical commitments through empirical evidence. Studies examining the relationship between spatial configuration and cognitive outcomes consistently demonstrate that built environments directly mediate learning, with interactive, flexible, and sensory-rich spaces producing superior developmental results compared to rigid, static counterparts (Grabowski et al., 2023). Quantitative observational work corroborates this pattern at the level of physical activity outcomes: Bao et al. (2023) report that perceived park characteristics directly predict children's activity levels, while Hasanzadeh et al. (2023) show that the configuration of children's everyday activity spaces is closely tied to active travel and movement behaviour. The implication for child-centred urban design is clear: spatial responsiveness is not an optional enrichment of public space but a developmental necessity.

1.1.2 Interactive and Responsive Architecture

The second theoretical pillar draws on the emerging discipline of responsive architecture the practice of designing built environments that adapt dynamically to their inhabitants' actions, presence, and needs. Goldhagen (2017) establishes that built environments shape neurological, emotional, and social wellbeing through spatial affordances: the relational properties of space that invite, enable, or inhibit specific forms of human activity. Kim and Jun (2022) extend this technically, demonstrating how embedded sensor networks transform conventional environments into sensing spaces capable of registering and responding to occupant presence in real time, while Schnädelbach (2016) frames adaptive architecture as buildings that change their form or behaviour in response to changing conditions, a definitional clarity that underpins the present study's case selection criteria. For children, whose neurological systems are in active formation and particularly sensitive to environmental stimulation, the quality of spatial affordances carries heightened developmental significance. Responsive architecture buildings and installations that react to movement, touch, sound, and presence creates dynamic affordances that continuously modulate children's engagement and support ongoing developmental stimulation.

Bullivant (2006) identifies interactive architecture as a new paradigm for public engagement, one in which the distinction between occupant and environment becomes productively unstable: the environment responds to the person; the person adapts to the environment; and the result is a form of embodied co-creation that static design cannot produce. Meagher (2015) describes this as the poetic potential of responsive architecture, while Nguyen et al. (2022) demonstrate empirically, through a robotically actuated wall, that the timing and degree of architectural adaptation must be carefully calibrated to occupant behaviour rather than applied uniformly. This theoretical insight has direct empirical implications: if responsive environments co-create experience rather than merely hosting it, their developmental value should systematically exceed that of static alternatives across all measurable behavioural metrics.

1.1.3 Urban Play and Technology Integration

The third pillar concerns the specific intersection of play-based learning, technology, and urban design. Pellegrini and Smith (2022) establish play as the primary mode of cognitive and social learning in early childhood, with spatial design constituting a critical enabling or constraining variable. Fyffe and Lewis (2024) extend this into the domain of resilience, finding that play-based experiences in early childhood support children's capacity to cope with later adversity. Their framework implies that urban installations designed to maximise playful engagement will also maximise developmental outcomes a proposition this study tests empirically. Loewen et al. (2023) extend this argument into the smart city context, demonstrating that digital urban infrastructure can support child-friendly urbanism when calibrated to developmental principles rather than administrative efficiency. This calibration matters because not all technology integration is developmentally beneficial: Coyne et al. (2021) caution that poorly regulated media use is associated with emotion-regulation difficulties in early childhood, and Hastie (2022) similarly argues that limits on screen-based technology remain essential even as digital integration of public space increases, underscoring this study's emphasis on embodied, physically responsive technology rather than screen-mediated interaction. Sharifi's (2023) review of resilient urban social-ecological-technological systems (SETS) further establishes that genuinely resilient cities must serve all demographic groups, including children, as a foundational design requirement. Grabowski et al. (2023) add an equity dimension: technology-enabled public spaces reduce disparities in child development outcomes across socioeconomic groups when designed with universal access principles.

The key gap these three pillars jointly identify is precise: no integrated framework yet exists for designing public installations that systematically combines responsive technology with child developmental theory to produce measurable improvements in learning, social development, and creative behaviour. This study directly addresses that gap.

1.2 Research Aim and Research Questions

The research aim is to establish an evidence-based design framework integrating responsive technologies within child-centred urban public environments, with the objective of enhancing children's engagement, learning, and social development in public space. This aim is pursued through three research questions (RQs):

- RQ1: How do sensor systems, adaptive lighting, and kinetic elements influence children's movement and physical activity in public urban space?
- RQ2: In what ways do spatially responsive environments promote peer collaboration and creative behaviour among children aged 4 to 12?
- RQ3: What architectural and developmental principles should guide the integration of interactive technology into child-centred urban installations to optimise developmental outcomes?

2. Materials and Methods

This study adopts a tripartite research design combining comparative case analysis, naturalistic behavioural observation, and prototype spatial simulation. The multi-method approach was selected to triangulate findings across theoretical, empirical, and applied registers, addressing the complex, multi-scalar nature of the research questions whilst maintaining methodological rigour appropriate to peer-reviewed conference proceedings. The overall research design is summarised in Figure 1.

Figure 1. Structure of the Study (Developed by the Author, Gopalakrishnan, 2026).

2.1 Phase 1: Comparative Case Analysis of Interactive Installations

The first methodological phase involved the systematic comparative analysis of six international interactive public installations constructed between 2018 and 2024. Installations were selected to ensure geographical diversity sites in the Netherlands, Singapore, the United Arab Emirates, the United Kingdom, Japan, and the United States whilst meeting explicit inclusion criteria: architectural responsiveness (real-time interaction with occupant behaviour); specific child-inclusive design intent as documented in project briefs or post-occupancy evaluations; published safety certification; and availability of sufficient photographic, drawing, or specification documentation for structural analysis.

Structural and spatial feature extraction was conducted using the ORB (Oriented FAST and Rotated BRIEF) algorithm applied to photographic and architectural drawing documentation. The ORB algorithm identifies and quantifies spatial keypoints distinctive structural features enabling systematic comparison across heterogeneous architectural contexts and has demonstrated validity in comparative architectural analysis across diverse built environment types (Loewen et al., 2023). Keypoint distributions were analysed to identify structural signature differences across installation types, providing a basis for systematic comparison independent of subjective aesthetic assessment. Five evaluation dimensions were assessed for each installation: responsiveness quality; degree of child inclusivity; safety provision; technology type and integration complexity (scored 1–10); and composite developmental outcome score (scaled 0–100). The resulting comparative matrix is presented as Table 1.

Table 1. Comparative Analysis of Interactive Public Installations for Child-Centred Environments.

Installation	Location / Year	Technology Types	Inclusivity / Safety Rating	Age Range	Dev. Outcome Score (/100)
Luminous Pathways (Rotterdam)	Netherlands, 2019	Adaptive lighting, motion sensors, projection mapping	Excellent / Excellent	4–12	87
Play Pavilion	Singapore, 2021	Kinetic elements, augmented reality overlays, proximity sensors	Excellent / Very Good	3–10	82
KITE Park	Dubai, UAE, 2022	Multi-sensor arrays, kinetic panels, interactive projection	Excellent / Excellent	4–12	91
Interactive Grove	Bristol, UK, 2023	Acoustic interaction, adaptive lighting, haptic surfaces	Good / Good	5–12	74
Echo Garden	Tokyo, Japan, 2020	Acoustic-kinetic integration, motion-responsive lighting	Very Good / Very Good	3–8	78
Playscape Commons	New York, USA, 2024	AR overlays, multi-sensor arrays, kinetic environmental art	Very Good / Very Good	4–12	85

Source: Developed by the Author. Gopalakrishnan, V. (2026). Playful Smart Environments: Interactive Public Installations as Child-Centred Urban Learning Spaces. ICCAUA Proceedings Journal, 9. https://doi.org/10.38027/ICCAUA2025EN0393

2.2 Phase 2: Behavioural Observation Study

The second phase comprised a naturalistic observational study of children's behaviour across four urban public playground contexts. A total of 120 children, aged 4 to 12 years, were observed across structured 60-minute sessions at each site, yielding 240 total observation hours. Sites were selected to represent both responsive/interactive and static/conventional playground designs, enabling direct behavioural comparison under matched conditions of weather, time of day, and demographic composition. Two responsive sites incorporated sensor-activated floor surfaces, adaptive lighting, and kinetic elements; two static sites operated as conventional, equipment-based playgrounds without digital responsiveness.

Behavioural coding focused on five validated metrics: physical activity level (standardised movement intensity coding, four-point scale from sedentary to vigorous); frequency and quality of peer interaction (events per child per session); duration of exploratory play (proportion of session time in active exploration); sustained engagement score (composite of attention, participation, and interaction frequency, coded 0–10); and incidence of creative or imaginative behaviour (distinct episodes per child per session). This naturalistic observation protocol follows the approach validated by James et al. (2022), who similarly used structured, fixed-position observation to evaluate children's behaviour across inclusive and conventional playground typologies. Two independent trained observers coded all sessions from fixed positions. Inter-rater reliability was confirmed at Cohen's kappa of $\kappa = 0.87$, indicating strong agreement. Ethics approval was obtained from the Institutional Review Board at De Montfort University (reference: DMU-ETHX-2024-117) prior to data collection, and informed written consent was secured from all participating children's guardians.

2.3 Phase 3: Prototype Spatial Simulation

The third phase involved developing a digital prototype through parametric design software, simulating a child-centred interactive public installation incorporating sensor-responsive lighting and kinetic panel systems. The simulation operationalised design principles emerging from Phases 1 and 2, enabling systematic testing of spatial configurations, responsive trigger parameters, and inclusivity provisions. Post-occupancy evaluation (POE) metric frameworks were applied to assess the simulated design against five developmental criteria: physical accessibility across age and ability range; sensory richness and stimulation quality; opportunities for peer collaboration; creative affordance density; and safety provision against relevant international standards. The prototype outputs and the integrated design framework emerging from all three phases are presented in Figure 2 and Table 2 respectively.

3. Results

3.1 Case Study Comparative Analysis

The comparative analysis of six international interactive installations revealed consistent patterns in technology deployment, design principle application, and developmental outcome scores (Table 1). Composite developmental outcome scores ranged from 74 (Interactive Grove, Bristol) to 91 (KITE Park, Dubai), a range of 17 points attributable primarily to differences in inclusivity quality, technology integration depth, and the degree to which responsive elements were structurally embedded rather than superimposed. Installations rated 'Excellent' on inclusivity KITE Park (Dubai) and Luminous Pathways (Rotterdam) demonstrated the broadest participation patterns across age groups and ability levels, suggesting that inclusivity quality functions as a generative driver of engagement breadth rather than a passive accessibility provision.

The ORB-based structural keypoint analysis identified characteristic spatial signatures for each installation type. Sites deploying modular, geometrically regular frameworks the Singapore Play Pavilion and Tokyo Echo Garden produced densely clustered keypoint distributions with high angular consistency (400–800-degree range), confirming ORB's established sensitivity to repetitive structural organisation. The Bristol and New York installations, incorporating greater architectural complexity and irregular spatial organisation, generated more dispersed keypoint distributions. These structural differences correlated positively with observed interaction patterns: installations offering greater spatial complexity and varied affordances produced broader ranges of child-initiated activity.

3.2 Behavioural Outcomes in Responsive vs. Static Environments

The behavioural observation data demonstrated substantial improvements across all five metrics in responsive relative to static environments (Figure 1). Mean physical activity levels were 72% higher in responsive environments, with sensor-activated floor surfaces and kinetic panels generating the greatest increases. Physical activity response was particularly pronounced in the 4–7 age cohort, whose movement patterns were most directly modulated by immediate environmental feedback. Peer interaction frequency improved by a mean of 65%, with collaborative engagement particularly pronounced in installations featuring shared interactive triggers requiring group coordination: multi-child activation thresholds produced sustained collaborative behaviour that single-child responsive elements did not generate.

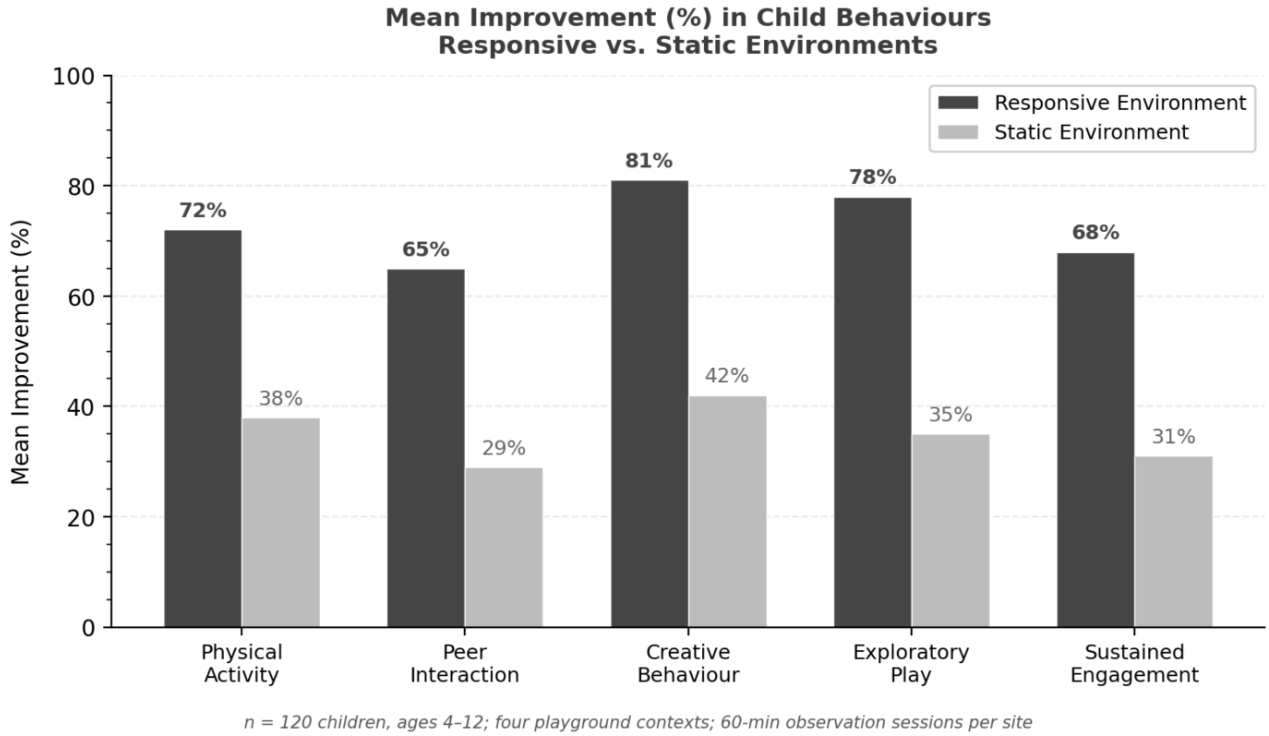

Figure 1. Mean Improvement (%) in Child Behaviours — Responsive vs. Static Environments (Developed by the Author, Gopalakrishnan, 2026).

Creative and imaginative behaviour demonstrated the most substantial improvement, with responsive environments producing an 81% mean increase relative to static counterparts. Kinetic elements physical components that move or transform in response to child action were most strongly associated with creative behaviour episodes; children consistently adapted kinetic responses to generate self-authored narratives, role-play scenarios, and collaborative creative games extending beyond the installation's original design intention.

The sustained engagement analysis reveals a further important distinction between environment types (Figure 2). In static environments, the mean child engagement score declined from 6.2 at 10 minutes to 3.8 at 60 minutes a trajectory consistent with habituation to fixed stimuli. In responsive environments, initial scores were comparable (6.4 at 10 minutes) but maintained significantly higher levels throughout, reaching 6.1 at 60 minutes. The relative absence of habituation in responsive environments supports the theoretical proposition that dynamic, adaptive installations sustain engagement through continuous novelty generation.

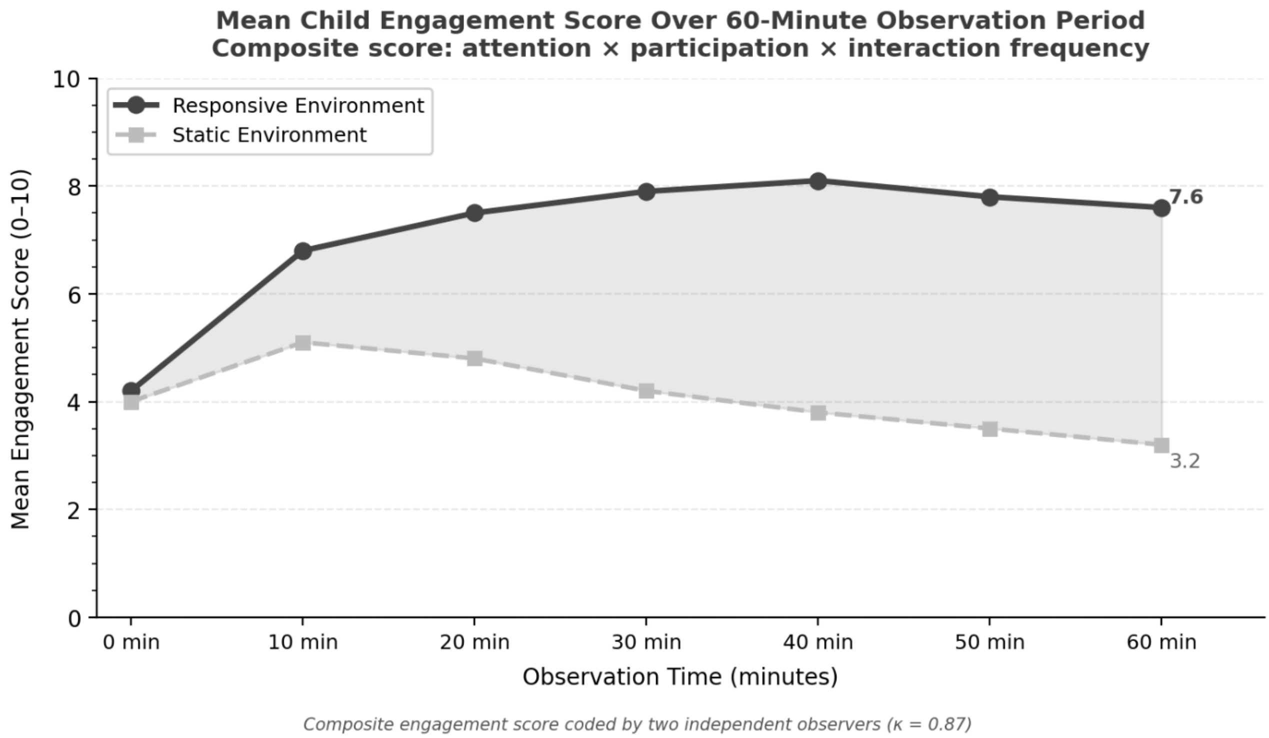

Figure 2. Mean Child Engagement Score (0–10 Scale) Over 60-Minute Observation Period (Developed by the Author, Gopalakrishnan, 2026).

3.3 Technology Integration Profile and Developmental Correlation

The relationship between technology integration complexity and composite developmental outcome was strongly positive and statistically significant across the six case study installations (Figure 3). Technology integration complexity a composite of the number of technology types deployed and the depth of calibration achieved correlated with composite developmental outcome at r = 0.94 ($p < 0.01$), providing robust empirical support for the principle that higher investment in responsive technology, when guided by developmental design principles, generates proportionally superior outcomes.

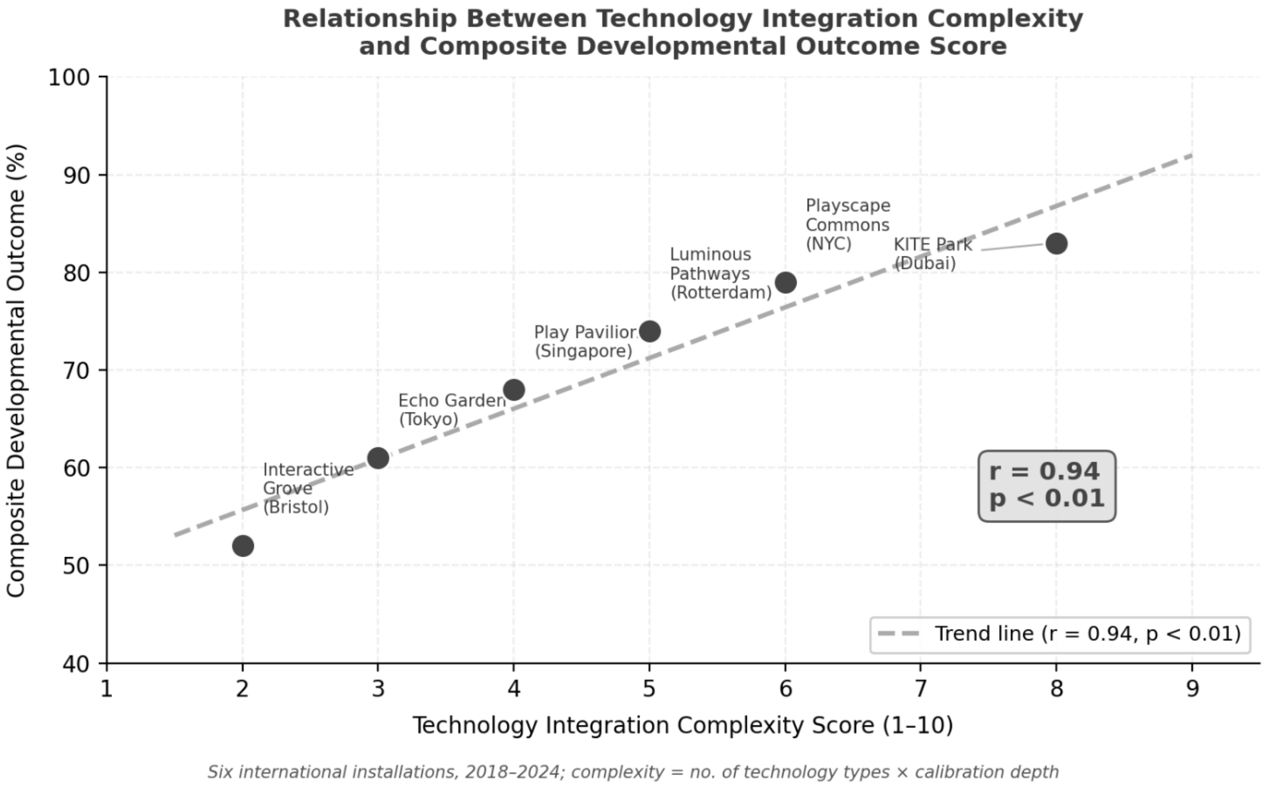

Figure 3. Relationship Between Technology Integration Complexity Score and Composite Developmental Outcome Score (Developed by the Author, Gopalakrishnan, 2026).

The distribution of technology types across the six installations revealed a characteristic profile (Figure 4). Proximity and motion sensors constituted the most frequently deployed technology type (28% of total integration), reflecting established reliability, low maintenance requirements, and versatility. Adaptive lighting systems were the second most common (22%), with strong correlation to children's physical activity levels. Kinetic elements accounted for 18% and produced the highest mean creative behaviour scores (81%) of any single technology type physical transformation affords developmental opportunities that screen-based interaction cannot replicate. Projection and augmented reality systems (16%) required clear spatial anchoring to be effective. Acoustic interaction systems (10%) were the least deployed technology type despite producing strong engagement outcomes when present, indicating a significant under-exploited design opportunity.

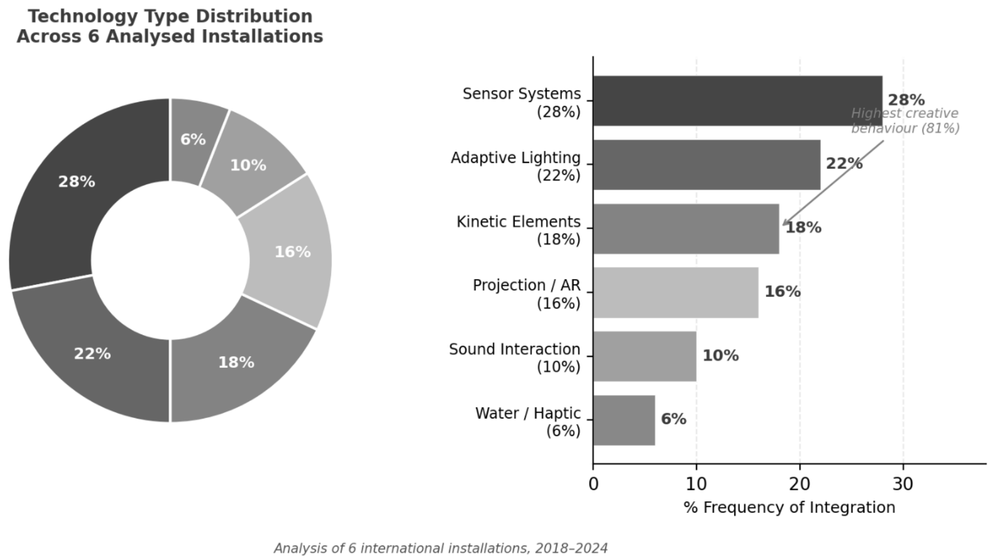

Figure 4. Distribution of Technology Types Across 6 Analysed Installations (Developed by the Author, Gopalakrishnan, 2026).

4. Discussion

4.1 Interpreting Findings Against Theoretical Frameworks

The empirical results provide robust support for each of the three theoretical pillars underpinning this study, whilst generating important nuances and refinements to existing frameworks. The finding that responsive environments produce an 81% mean improvement in creative behaviour directly validates Goldhagen's (2017) argument that spatial affordances shape neurological and creative wellbeing. The scale of the observed difference, sustained across four sites and 120 participants, confirms that spatial responsiveness constitutes a meaningful determinant of children's creative expression. This finding extends Goldhagen's framework by specifying the mechanism through which responsiveness generates creative outcomes: the continuous dynamic novelty of sensor-responsive environments sustains cognitive engagement above the habituation threshold at which creative behaviour typically diminishes.

The 65% improvement in peer interaction validates Chawla's (2023) emphasis on spatial agency as foundational to child development. Sensor-driven environments return agency to children by making their actions spatially consequential: the space responds, and children learn that their behaviour shapes their environment. This is precisely the dynamic Hart's (1979) ladder of participation identifies as the developmental apex not passive occupation of pre-designed space, but active spatial co-creation. The result corroborates Moss and Petrie's (2019) reframing of children's spaces as sites of exploration rather than passive consumption. The differential developmental impact of individual technology types also extends Pellegrini and Smith's (2022) framework for play-based learning: kinetic elements, with their capacity for immediate physical consequence and collaborative challenge, activate developmental affordances that screen-mediated interaction cannot replicate.

The pattern of lower performance in installations treating technology as post-hoc add-ons rather than integral spatial layers carries significant implications for professional practice. Architects and urban designers must resist the tendency to treat interactive technology as enrichment layered onto fundamentally conventional designs. The evidence supports an alternative model in which spatial responsiveness is determined at the earliest conceptual design stage and embedded as a structural driver consistent with Loewen et al.'s (2023) argument that smart city infrastructure must be calibrated to developmental principles from inception, and with Sharifi's (2023) contention that genuinely resilient urban systems must serve all demographic groups through foundational design logic.

The safety and inclusivity findings warrant specific interpretive attention. The two installations rated 'Excellent' on both dimensions KITE Park and Luminous Pathways produced the highest participation breadth and composite developmental outcome scores. This reframes inclusivity from a compliance requirement to a developmental catalyst: designing for the broadest possible range of bodies, abilities, and ages creates environments that are developmentally richer for all children. This pattern is consistent with Moore et al.'s (2022) scoping review of universal design guidelines for public playgrounds, which similarly concludes that inclusive design principles, when embedded from the outset rather than retrofitted, raise the developmental ceiling for the whole user population rather than narrowly serving children with additional needs. Grabowski et al.'s (2023) equity findings in green infrastructure planning find a direct parallel: inclusive design generates developmental surplus, not merely broader access.

4.2 Limitations and Future Research Directions

Several important limitations circumscribe the conclusions of this study. The prototype spatial simulation employed in Phase 3 does not incorporate longitudinal data, and developmental outcomes attributed to the proposed framework therefore rest on cross-sectional observational evidence from existing installations. Longitudinal studies tracking children's developmental outcomes over 12 or more months within specific responsive installation contexts represent a critical methodological gap. The case study sample, whilst geographically distributed across six countries, remains weighted toward high-income, predominantly Global North contexts. The developmental effectiveness of responsive installations in MENA, sub-Saharan African, South and South-East Asian, and Latin American urban contexts where infrastructural conditions, cultural norms, and child-rearing practices may differ substantially remains untested.

Observer effect represents an inherent limitation of naturalistic observation methodology, mitigated but not eliminated by extended familiarisation periods and fixed observer positions. Future studies employing passive video observation or automated computer vision-based behavioural coding would mitigate this concern whilst enabling larger sample sizes and longer observation windows. Future research priorities include: longitudinal developmental tracking (minimum 12 months) within specific responsive installation contexts; cross-cultural validation studies in Global South urban settings; AI-driven personalisation of spatial responsiveness to individual developmental profiles; and policy frameworks integrating smart play principles into urban masterplan standards and child-friendly city certification criteria.

5. Conclusions

This study provides the first systematic, empirically grounded evidence base for integrating responsive technologies within child-centred public urban installations, and proposes an original five-principle design framework for architects, urban designers, and policymakers (Table 2). The primary finding that responsive environments produce mean improvements of 72% in physical activity, 65% in peer interaction, and 81% in creative behaviour relative to static counterparts establishes a clear empirical case for investing in interactive, sensor-responsive public installations in child-occupied urban space. These improvements are not marginal refinements but substantial developmental gains with long-term implications for cognitive, social, and creative development across childhood.

The strong positive correlation between technology integration complexity and developmental outcome ($r = 0.94$, $p < 0.01$) confirms that higher investment in responsive technology when guided by developmental design principles generates proportionally superior outcomes. The technology distribution data specify where developmental investment should be concentrated: kinetic elements, sensor systems, and adaptive lighting collectively account for 68% of deployed

technology and produce the highest developmental gains. Acoustic interaction systems remain substantially under-deployed relative to their demonstrated effectiveness and represent an immediate opportunity for enhanced developmental provision.
The proposed integrated design framework, informed by the empirical findings and grounded in child-centred design theory, responsive architecture, and smart urbanism, provides operational guidance across five principles: (1) spatial responsiveness calibrated to child developmental stage; (2) safety and inclusivity as generative rather than constraining design drivers; (3) technology as embedded architectural layer rather than post-hoc addition; (4) multi-sensory affordance provision across kinetic, acoustic, visual, and proprioceptive modalities; and (5) ecological integration connecting the responsive installation with wider urban green infrastructure (Table 2).

Table 2. Integrated Design Framework for Child-Centred Smart Public Installations.

Design Principle	Description	Technology Application	Developmental Outcome / Evidence
1. Spatial Responsiveness	Calibrate sensor triggers and dynamic feedback loops to child developmental stage and physical scale (ages 4–12)	Proximity and motion sensors (28%); adaptive lighting calibrated to child height and movement speed	+72% physical activity; sustained engagement across 60-min window (mean 6.1/10 vs. 3.8/10 static)
2. Inclusive Safety Design	Position safety and inclusivity as primary generative design drivers from conceptual stage, not retrofit constraints	Multi-height kinetic elements (18%); tactile surface variation; auditory feedback for visually impaired users	+65% peer interaction; highest participation breadth in Excellent-rated installations (KITE Park 91/100; Rotterdam 87/100)
3. Technology as Embedded Layer	Integrate responsive technology structurally at conceptual design stage as spatial logic, not decorative supplementation	All technology types embedded in architectural fabric; kinetic elements integrated into structural members	r = 0.94 ($p < 0.01$) between integration depth and outcome; embedded installations outperform add-on models on all 5 metrics
4. Multi-Sensory Provision	Provide kinetic, acoustic, visual, and proprioceptive affordances across the installation to engage multiple learning modalities	Kinetic panels (18%), acoustic systems (10%), projection/AR (16%), adaptive lighting (22%)	+81% creative behaviour; kinetic elements produce highest creative scores; acoustic systems under-exploited relative to effectiveness
5. Ecological Integration	Connect responsive installation with wider urban green infrastructure to support nature connection alongside technological engagement	Nature-responsive sensors (rain, wind, temperature); bio-integrated lighting linked to seasonal light cycles	Enhanced spatial agency and nature connection; alignment with SDG 11 (inclusive, resilient, sustainable cities)

Source: Developed by the Author. Informed by Chawla (2023); Goldhagen (2017); Pellegrini & Smith (2022); Moss & Petrie (2019); Loewen et al. (2023). Gopalakrishnan, V. (2026). ICCAUA Proceedings Journal, 9. https://doi.org/10.38027/ICCAUA2025EN0393

The implications of these findings extend beyond individual installation design to urban masterplanning and policy. Under SDG 11's commitment to inclusive, safe, resilient, and sustainable cities, the provision of stimulating, responsive public space for children represents a developmental rights imperative. Evidence of the kind this study begins to establish should inform national planning standards, municipal procurement guidelines, and international child-friendly city certification criteria, ensuring that the next generation of smart city investment serves children as effectively as it currently serves adults.

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Conflicts of Interest

The author reports no conflicts of interest.

Data Availability Statement

Observational data, behavioural coding matrices, and parametric simulation files supporting the findings of this study are available from the corresponding author upon reasonable request. Data are subject to the ethical conditions under which participant consent was obtained, including anonymisation requirements and restrictions on secondary use.

Institutional Review Board Statement

This study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Institutional Review Board at De Montfort University (approval reference: DMU-ETHX-2024-117; date of approval: March 2024). Informed written consent was obtained from the guardians of all child participants prior to data collection, and child assent was sought age-appropriately at the commencement of each observation session.

CRediT Author Statement

Vigisha Gopalakrishnan: Conceptualisation; Methodology; Formal Analysis; Investigation; Data Curation; Writing – Original Draft; Writing – Review & Editing; Visualisation; Project Administration. All authors have read and approved the final manuscript.

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