

Original Article

# An In-Depth Study of the Impact of Pollinator Gardens on Neurodivergent and Underprivileged Children and Social Inclusion Goals: A Primary Analysis

Gunisha Kaur

*Independent Researcher, Ludhiana, India.*

*Corresponding Author : [gunisha10ldh@gmail.com](mailto:gunisha10ldh@gmail.com)*

Received: 10 December 2025

Revised: 13 January 2026

Accepted: 02 February 2026

Published: 21 February 2026

**Abstract** –Rapid urbanization has led to pollinator decline and unequal access to green spaces, especially by neurodivergent and underprivileged children. This study examines pollinator gardens as a combined nature-based intervention designed to enhance biodiversity while supporting psychosocial development among vulnerable children. The research is conducted across fifteen urban and institutional sites in Ludhiana, India, through the Buzzing Blooms initiative over a period of 24 months. A convergent mixed-methods design has been used, which combines ecological monitoring of pollinator species richness and visitation frequency with structured behavioral assessments and qualitative observations of participating children. Results indicate a 155% increase in pollinator species richness, along with a substantial increase in pollinator activity across the sites. Simultaneously, participating children show measurable improvements in task completion, emotional regulation, sensory engagement, and peer interaction. Qualitative analyses identified remarkable changes in sensory integration, sustained engagement, collaborative activity, and self-efficacy. The results suggest that pollinator gardens can function as an effective dual-impact intervention that supports ecological restoration as well as inclusive psychosocial development of vulnerable children. It also highlights the importance of nature-based interventions within urban sustainability and inclusion frameworks.

**Keywords** - Ecological Restoration, Mixed-Methods Research, Pollinator Gardens, Psychosocial Intervention, Sustainable Development.

## 1. Introduction

Rapid urbanization has significantly reshaped city ecosystems. Expanding infrastructure and intensive land use patterns have fragmented habitats, reduced flowering plant diversity, and increased exposure to harmful agricultural chemicals.

In many cities, green spaces continue to exist, but their design often prioritizes aesthetic appeal over ecological function, limiting their long-term environmental value.

Alongside ecological degradation, urban environments are also marked by social inequities. Access to safe, pollinator-rich green spaces remains uneven. Neurodivergent children, including those with Autism Spectrum Disorder (ASD), Attention-Deficit/Hyperactivity Disorder (ADHD), and intellectual disabilities, as well as children from socioeconomically disadvantaged backgrounds, are particularly affected by this lack of access. Their daily routines are frequently confined to indoor or highly structured institutional settings, reducing opportunities for informal outdoor engagement that supports sensory

regulation, exploratory learning, and social interaction. Interaction with living pollinators introduces movement, color, and sensory input into the garden environment, which can be particularly engaging for neurodivergent children. This unequal access to nature reflects a form of environmental injustice that can further intensify existing social vulnerabilities.

Research addressing these two challenges has largely been conducted separately. Urban ecology studies have extensively documented pollinator decline and explored habitat restoration strategies such as native planting and ecological corridors. At the same time, research in environmental psychology, therapeutic horticulture, and special education has shown that structured exposure to natural environments can improve attention, emotional regulation, and social participation, particularly among neurodivergent children. However, these fields rarely intersect in applied research.

Recent analyses suggest that biodiversity-focused urban greening initiatives and psychosocial nature-based interventions are typically evaluated in isolation rather than



as integrated social–ecological systems (Bratman et al., 2021). This separation limits understanding of whether biodiversity-rich green spaces can be intentionally designed to function as inclusive environments that support both ecological restoration and child development.

Pollinator gardens present a promising, yet underexplored, intervention within this intersection. When designed as ecologically functional habitats with native nectar-rich plants, nesting structures, and chemical-free maintenance, and combined with inclusive, child-centered engagement strategies, these gardens can serve dual purposes. They can support pollinator communities while also creating meaningful spaces for participation, learning, and social connection for children who are often excluded from conventional green infrastructure. Despite their growing use in conservation and education, the combined ecological and psychosocial impacts of pollinator gardens remain insufficiently documented, particularly within urban cities in India.

To address this gap, the present study examines pollinator gardens implemented across 15 different urban and institutional sites in Ludhiana, Punjab. Within this research, ‘impact’ is defined across two domains:

### **1.1. Ecological Impact**

It is measured through changes in pollinator species richness, abundance, and habitat use.

### **1.2. Psychosocial Impact**

It is assessed through observable changes in task completion, emotional regulation, anxiety indicators, and peer interaction among participating children.

### **1.3. Social Inclusion**

Social inclusion is understood as the process of fostering active participation and a sense of belonging. This was observed through cooperative engagement, collaborative task completion, and leadership opportunities, including roles such as Buzzing Bloom Ambassadors.

Using a longitudinal, convergent mixed-methods design, this study explores whether ecologically functional pollinator gardens can simultaneously enhance urban biodiversity and support psychosocial development among neurodivergent and socioeconomically underprivileged children.

The study contributes in three key ways:

1. It links quantified pollinator diversity data with distinct psychosocial indicators within a single intervention framework.
2. It evaluates a low-cost, scalable model across real-world institutional settings over a two-year period.
3. It integrates therapeutic engagement principles within biodiversity-focused habitat design, positioning

ecological restoration and social inclusion as mutually reinforcing goals.

By bringing these domains together, the research contributes to interdisciplinary understanding across urban ecology, inclusive education, therapeutic practice, and environmental justice, offering a practical framework for multifunctional urban green spaces.

## **2. Literature Review**

### **2.1. Urban Pollinator Decline and Garden-Based Ecological Restoration**

Reduction in pollinators due to habitat loss, pesticide use, and climate change is seen in urban areas. Findings show that gardens prioritizing native, nectar-rich plant species with sequential blooming periods can significantly boost local pollinator species richness and visitation rates, even within a densely built environment (Majewska & Altizer, 2020). Beyond floral diversity, current studies do not take into account the critical importance of habitat structure that includes nesting places like bee hotels, bare ground, leaf litter, and water sources that support the life cycles of pollinators. When these elements are incorporated, gardens move beyond decorative spaces and function as sustaining ecological habitats (Mader et al., 2011). Further urban ecology studies show that even small, florally diverse garden patches can significantly improve pollinator richness and stability within dense city settings, emphasizing the conservation value of distributed, community-scale habitats (Hall et al., 2022). Despite this ecological focus, an important limitation that exists in the current research literature is that these pollinator gardens are mostly evaluated on the basis of biodiversity indicators like “*Species Counts*” and “*Pollinator Abundance*”. The role of gardens as lived, social spaces remains unexplored. Limited attention has been given to how people interact with these habitats and also how their specific ecological qualities might influence human behavior and individual well-being. As a result, pollinator gardens are primarily considered as conservation tools rather than as a potential multifunctional asset that supports both the environment and human well-being.

### **2.2. Therapeutic Horticulture and Nature-Based Interventions for Neurodivergent Youth**

A strong body of research in environmental psychology, occupational therapy, and special education highlights the psychosocial benefits of nature exposure. For neurodivergent children who may experience sensory sensitivity and increased stress in conventional indoor settings, engagement with natural environments has been linked to improvements in attention, emotional regulation, sensory integration, and social interaction (Chawla, 2015; Bratman et al., 2012). Theoretical frameworks such as Attention Restoration Theory (ART) suggest that natural settings support cognitive recovery through experiences of “Soft Fascination,” where attention is gently held without mental fatigue.

However, an important methodological gap remains. In many studies, the environmental setting is treated in broad terms, such as “Garden Programs” or “Green Spaces,” without clearly describing or measuring the ecological quality of these environments (Ohly et al., 2016). Factors such as biodiversity levels, habitat complexity, or pollinator presence are rarely documented. As a result, it becomes difficult to determine whether a species-rich pollinator garden offers different therapeutic benefits compared to a manicured lawn or decorative green area. This approach treats nature as a static background rather than as a dynamic, measurable component of the intervention.

### **2.3. Social Inclusion, Community Gardening, and Environmental Justice**

Community and school gardens are widely recognized as spaces that promote social inclusion, civic engagement, and skill development, particularly within underprivileged communities (Alaimo et al., 2008). These shared environments encourage collaboration, responsibility, and a sense of ownership among children, helping build confidence and long-term community participation. Children from underprivileged backgrounds often lack exposure to safe, biodiverse parks or community nature spaces, which limits their childhood experiences, such as observing butterflies, watching bees, or freely interacting with outdoor environments.

This gap is even more pronounced for neurodivergent children, for whom opportunities for inclusive outdoor participation remain limited. Even within schools, it is uncommon to see neurotypical and neurodivergent children working together on shared educational activities such as Gardening. In addition, many schools lack supportive provisions such as visual cues, sensory markers, or adaptive navigation aids that could help neurodivergent children engage more comfortably in these spaces.

During study, success is often measured through social cohesion, food production, or learning gains with little assessment of biodiversity contributions (Kellert, 2005). This creates a disconnect: spaces valued for inclusion may offer limited ecological value, while biodiversity-rich habitats may remain inaccessible to marginalized groups. Addressing this divide calls for integrated models that combine ecological restoration with inclusive participation.

### **2.4. Theoretical Frameworks for Integration**

This research draws on interdisciplinary theoretical frameworks that help explain how biodiverse pollinator gardens can influence children’s well-being while supporting environmental health.

#### **2.4.1. Attention Restoration Theory (ART):**

This theory helps explain how natural environments restore mental focus. Experiences of “soft fascination”, such

as watching butterflies, bees, or other gentle garden activity, allow the mind to relax without becoming disengaged. Over time, this reduces cognitive fatigue and supports improved attention, emotional regulation, and task persistence among children.

#### **2.4.2. Biophilia Hypothesis**

The Biophilia Hypothesis suggests that humans have an innate tendency to connect with living systems. Biodiverse pollinator gardens filled with movement, color, and life strengthen this connection more deeply than static or ornamental green spaces. For children, especially those who are neurodivergent, this living interaction can increase curiosity, comfort, motivation, and emotional bonding with nature.

#### **2.4.3. Environmental Justice Framework**

From an environmental justice perspective, the issue extends beyond simply providing green space. It involves ensuring equal access to nature. Pollinator gardens located within schools and community institutions help bring biodiversity directly into spaces that serve marginalized and underprivileged children, positioning them not just as beneficiaries but as active ecological participants.

#### **2.4.4. Social–Ecological Systems Theory**

This framework views human and ecological systems as interconnected rather than separate. In pollinator gardens, children’s care practices like planting, watering, and maintaining habitats directly influence biodiversity outcomes. At the same time, interacting with thriving ecosystems shapes children’s behaviors, emotions, and social relationships. The garden, therefore, functions as a dynamic, reciprocal system where ecological and social processes continuously reinforce one another.

### **2.5. Comparative Analysis of Integrated Interventions and the Identified Gap**

Recent work has begun to explore nature-based interventions, for example, “Green Care” farms that track participant well-being along with basic biodiversity parameters and schoolyard greening projects that monitor student engagement along with simple ecological parameters. A critical analysis has revealed certain limitations that need to be addressed:

1. Most studies have retained a primary focus on either ecological or social metrics, treating the other as a secondary, often superficially measured.
2. Interventions for neurodivergent youth frequently occur in clinical settings, limiting scalability and relevance to everyday community institutions.
3. Scarcity of integrated research exists in the urban environment where social inequities are acute and institutional contexts and resources differ greatly.
4. Few researchers have employed a convergent mixed-methods design where ecological and psychosocial data

are collected with equal emphasis and integrated analytically to explore relationships.

*This primary research has included the following parameters to make it inclusive:*

- The measuring of ecological and psychosocial outcomes has been given equal importance and is combined within a unified design.
- Shifting the setting from clinic to community and from special needs schools and care homes to test a real-world, scalable model.
- Linking theory and practice, using ART and Environmental Justice as foundational design principles for garden habitats and engagement activities rather than bringing them together at the conclusion.

**2.6. Synthesis and Research Gap**

Research on pollinator conservation, therapeutic nature engagement, and social inclusion has mostly been studied separately. As a result, little evidence exists on how pollinator gardens function as spaces that support both

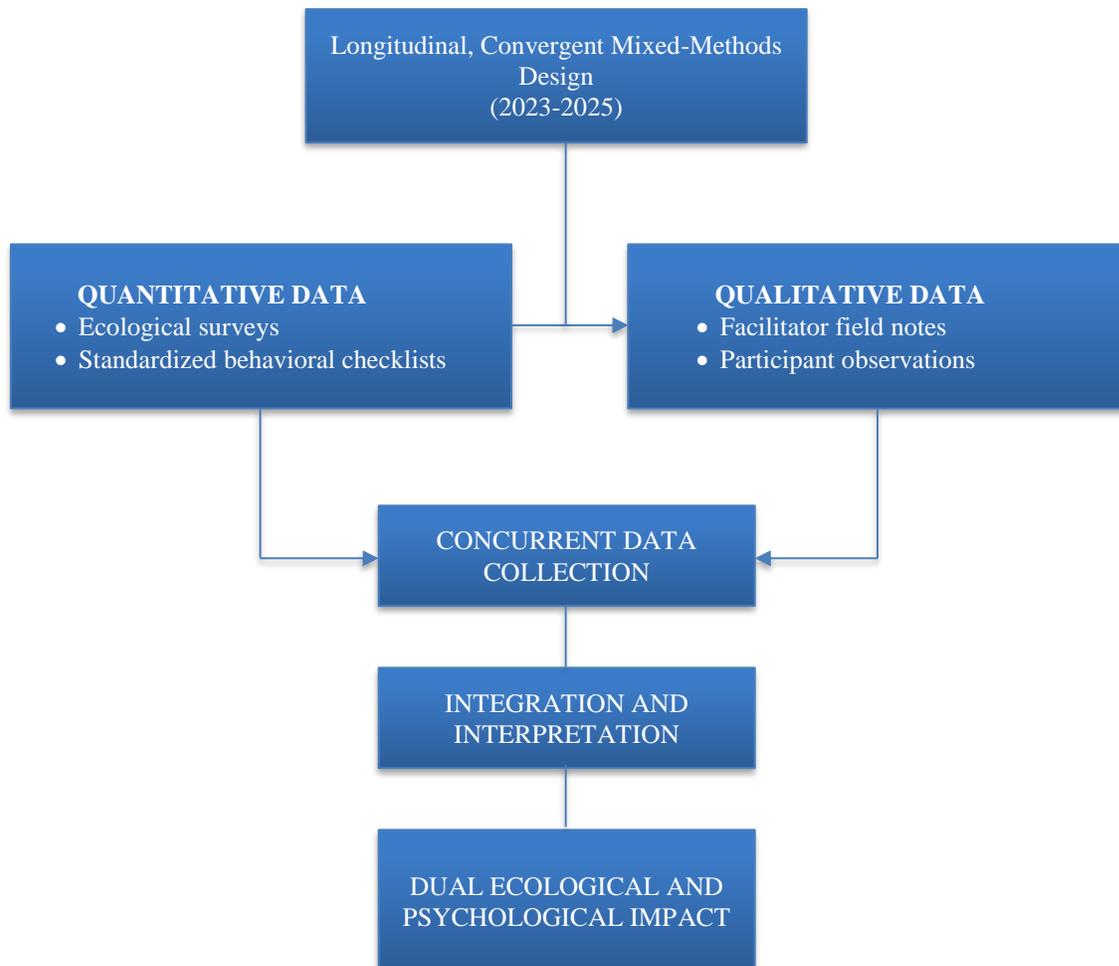
biodiversity and child development, especially for neurodivergent and underprivileged groups in urban spaces.

This study addresses that gap by presenting pollinator gardens as integrated social–ecological systems where ecological restoration and psychosocial well-being grow together through inclusive design.

**3. Materials and Methods**

**3.1. Study Design**

A longitudinal convergent parallel mixed-methods design was used to evaluate the ecological and psychosocial impacts of the “Buzzing Blooms” pollinator garden initiative (2023-2025) across 15 sites involving diverse participant groups. Quantitative (ecological surveys, behavioral checklists) and qualitative (field notes, observational records) data were collected over a period of 24 months and integrated during the interpretation phase to enable cross-validation and better understanding. This approach allowed both ecological and social changes to be studied together within a single nature-based intervention.



**Fig. 1** Longitudinal Convergent Mixed–Methods Research Design (2023-25)

Source: Data collected by the author during the study

**3.2. Study Sites and Participants**

The intervention was implemented across 15 different sites in Ludhiana, Punjab, India, including schools, residential complexes, community parks, and government-supported care facilities. Sites were selected to include children from different social and economic backgrounds and different neurocognitive needs.

**Table 1. Characteristics of Study Sites and Implementation Features of the Pollinator Garden Intervention (2023–2025)**

Serial number	Study Site	Participant Profile
1	Researcher’s Backyard	Researcher and family
2	Researcher’s Neighbour	Neighbouring Family
3	Researcher’s Relatives	Family Relatives
4	Researcher’s Friend	Family Participants
5	Dugri Community Park	Dugri Residents
6	State After Care Centre	Youth Residents
7	Juvenile Observation Home	Juveniles
8	Sahyog Halfway Homes	Children with special needs
9	Home away from home(Orphanage)	Orphan children
10	Humara village Microforest project	Children from slums and remote villages
11	Millennium World School	Neurodiverse and Neurotypical children
12	Government Primary School	Neurodiverse and Neurotypical children
13	Government Senior Secondary School, Ludhiana	Neurodiverse and Neurotypical children
14	Bal Bawan for the blind	Visually impaired children
15	Sri Harkrishan School	Neurodiverse and Neurotypical children

**3.2.1. Participant criteria were defined**

· *Neurodivergent Children* included those with formal diagnoses of Autism Spectrum Disorder, ADHD, intellectual disability, or visual impairment.

**3.2.2. Socioeconomically Underprivileged Children**

Socioeconomically Underprivileged Children included those studying in government-supported institutions, orphanages, or participating in community programs that serve low-income families.

Children (aged 6-16) took part in structured weekly garden activities. More than 200 children were included in detailed assessments, while awareness workshops reached over 3,000 students. Informed consent was obtained from caregivers and institutional authorities.

**3.3. Intervention Design: The Buzzing Blooms Model**

**3.3.1. Ecological Components (Standardized across sites)**

*Floral Diversity*

Native, nectar-rich species selected for the Punjab region, planted to ensure sequential flowering across seasons.

*Habitat Structures*

Installation of bee hotels, butterfly puddling stations, and leaf-litter zones to support nesting, resting, and reproduction.

*Chemical-Free Management*

No synthetic chemicals were used; pest control was controlled by companion planting and manual removal.

*Sustainable Care*

Regular watering, improving soil with organic matter, and pruning to support plant health.

To ensure meaningful engagement of neurodivergent children, visually distinct flowering plants, fragrant species, and textured planting zones were used to support sensory regulation and curiosity. Visual navigation aids such as color-coded beds, picture-based plant labels, and step-wise activity charts were introduced to improve comprehension and independence.

Following detailed interactive workshops, seed kits along with Buzzing Blooms guidelines for developing pollinator gardens were distributed among participating children. To ensure inclusive participation, separate engagement guidelines were designed to support both neurotypical and neurodivergent learners, enabling each group to engage with garden activities comfortably and effectively.

For neurodivergent participants, the guidelines emphasized visual communication over text-heavy instruction. Pictorial task cards, color-coded markers, and step-based activity charts were used to simplify processes, improve comprehension, and reduce cognitive load. This approach supported independent participation while ensuring that children could confidently contribute to the creation and maintenance of pollinator gardens alongside their peers.

### 3.3.2. Child-Centered Engagement Components

Sensory integration activities involved guided exploration of soil, plants, and insects using touch, smell, and sight.



**Fig. 2 Structured Engagement of Neurodivergent Participants in Pollinator Garden Activities During Intervention Implementation**  
Source: Actual image taken during the experiment



**Fig. 3 Participant Involvement in Soil Preparation and Tactile Gardening Activities as Part of the Intervention Framework**  
Source: Actual image taken while conducting the experiment

Group activities, including planting and watering, allowed children to take turns, communicate with each other, and share responsibility.



**Fig. 4 Collaborative Gardening to Support Insect Biodiversity Within Garden Sites**

Source: Actual image taken while conducting the experiment

Children took the lead in creative tasks like designing the garden and constructing a small habitat, which developed a sense of ownership and encouraged peer connection.



**Fig. 5 Neurodiverse, Undereprivileged, and Neurotypical Children Together Create and Design a Pollinator Garden in School Premises**  
Source: Actual image taken while conducting the experiment

The *Buzzing Blooms Ambassador program* was established to expand the number of pollinator gardens and to develop leadership skills among students. After conducting workshops in several public and private schools, a team of at least three trained students was carefully selected in each school to guide and encourage their peers in expanding and taking care of pollinator gardens. To promote social inclusion, children from diverse backgrounds were intentionally included in each ambassador team.



**Fig. 6 Buzzing Blooms Ambassador Leading Peer Engagement and Conservation Activities Across Study Sites**

Source: Actual image taken while conducting the experiment

Peer-inclusive participation models, including buddy systems and ambassador programs, encouraged collaborative learning and reduced social barriers. Predictable routines, safe insect-observation practices, and adaptive tools such as lightweight tools, raised beds, adaptive grips, and color coding further ensured that children of differing physical, cognitive, and social needs could participate comfortably and confidently. Gardening tasks like watering, seed sorting, soil mixing, seed sowing, mulching, planting, and pollinator observation enabled participants to co-create and expand garden spaces collectively while fostering empathy, cooperation, and shared environmental stewardship.

**3.4. Data Collection**

**3.4.1. Ecological Monitoring**

Ecological monitoring was carried out using standardized weekly pollinator walk surveys. Observations were conducted for 10 minutes along fixed 50-meter transects and only under suitable weather conditions.

*Data Collected Included*

- Species richness: Number of different pollinator species observed.
- Pollinator Abundance: The total number of pollinators recorded during each observation period.
- Habitat Use: How the pollinators used the habitat was noted through visible behaviors such as foraging, resting, and nesting.

Pollinator identification was done using regional field guides and photographic records. To ensure consistency, observations were cross-checked through inter-observer reliability checks.

*Psychosocial Assessment*

- *Quantitative assessment:* Pre- and Post-intervention behavioral checklists were used and filled out by trained facilitators. These assessed children’s ability to complete tasks, regulate their emotions, especially anxiety, interact with peers, and engage with their senses during activities.
- *Qualitative assessment:* Qualitative data were collected through facilitator field notes, semi-structured observations, and reflective journals. These records captured patterns of engagement, social interactions, and children’s expressions and responses during the garden activities.

**3.5. Data Analysis**

**3.5.1. Quantitative Analysis**

Paired-sample t-tests were used to compare pre- and post-intervention scores for ecological and psychosocial variables at site and participant levels (within-subject design). Effect sizes (Cohen’s d) were calculated for all significant results to estimate magnitude. Descriptive statistics summarized central tendencies.

**3.5.2. Qualitative Analysis**

Inductive thematic analysis was employed to identify recurring patterns related to engagement, cooperation, and self-efficacy.

**3.5.3. Integration**

Quantitative and qualitative findings were brought together during interpretation to triangulate results and provide contextual depth following a convergent parallel analysis strategy.

**3.6. Ethical Considerations**

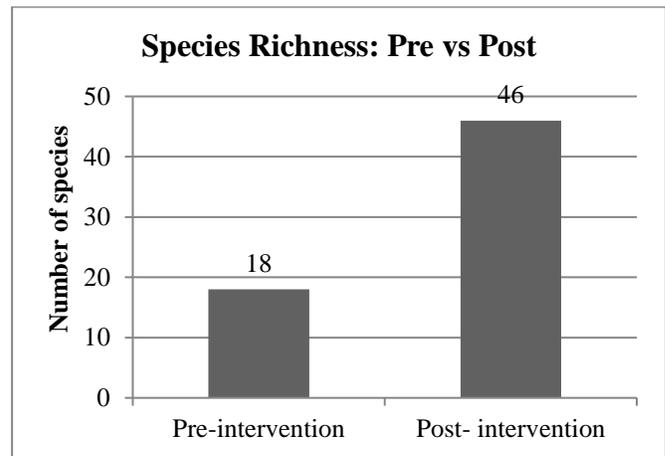
Ethical approval for the study was obtained from the participating institutions. All activities were voluntary, non-invasive, and designed to support educational and therapeutic goals. Care was taken to ensure that no harm or discomfort was caused to the children at any stage of the study.

Confidentiality was strictly maintained, and no personally identifiable information was collected. The study also followed a benefit-sharing approach, ensuring that participating institutions continued to retain ownership, care, and use of the pollinator gardens and related resources after the research period.

**4. Results**

**4.1. Ecological Outcomes**

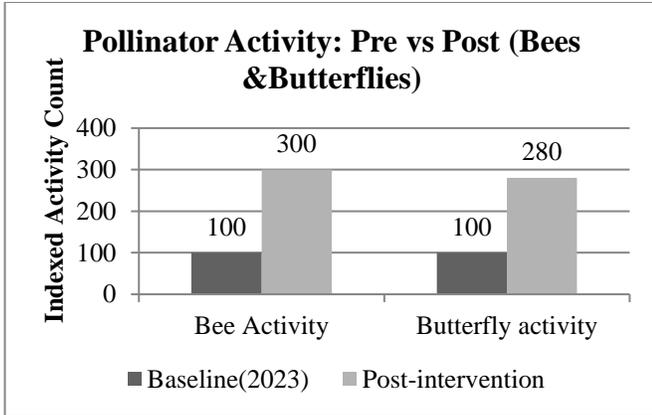
Pollinator Species Richness increased significantly from a baseline mean of 18 species per site to 46 species post-intervention, a 155% gain ( $t(14) = 8.75, p < .001, d = 2.26$ ). This increase was consistent across all 15 sites.



**Fig. 7 Pollination Species Richness Before and After the Buzzing Blooms Intervention**

Source: Primary data

Pollinator Abundance and Activity showed substantial growth: bee visitation increased by ~200% and butterfly visitation by ~180%. Statistical analysis confirmed significant increases in bee activity ( $t(14) = 9.12, p < .001, d = 2.35$ ) and butterfly activity ( $t(14) = 7.84, p < .001, d = 2.01$ ). Gains persisted across seasonal cycles.



**Fig. 8 Changes in Pollinator Activity (Bee and Butterfly Activity) Before and After the Buzzing Blooms Intervention**

Source: Primary data

Habitat Utilization observations showed that gardens functioned as active habitats. Pollinators followed regular foraging routes, repeatedly used bee hotels, and visited butterfly puddling. This shows that spaces supported nesting, resting, and feeding activities.

#### 4.2. Psychosocial Outcomes

Quantitative Behavioral Changes (n=200+ children) showed clear improvements across all domains:

##### 4.2.1. Task Completion

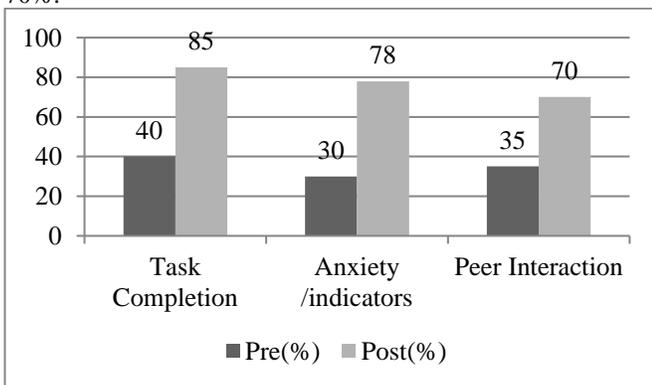
Scores increased significantly ( $t(199) = 11.42, p < .001$ ), with group-level completion rates rising from 40% (baseline) to 85% (post-intervention).

##### 4.2.2. Anxiety Indicators

Anxiety-related indicators decreased significantly ( $t(199) = 12.05, p < .001$ ), with improved regulation observed in 78% of participants post-intervention versus 30% at baseline.

##### 4.2.3. Peer Interaction

Frequency of cooperative peer interactions increased significantly ( $t(199) = 9.87, p < .001$ ), rising from 35% to 70%.



**Fig. 9 Pre- and Post-Intervention Psychosocial Improvements Across Three Behavioral Domains**

Source: Primary data

Subgroup analysis showed that positive changes were seen in both neurodivergent and underprivileged children. No group showed a decline in any of the areas studied.

The qualitative findings supported the quantitative results. Facilitator observations consistently highlighted the following patterns:

- Children were more likely to start tasks on their own and focus for longer periods.
- Children showed better tolerance to different sensory experiences, such as texture and sounds.
- Cooperative behavior increased with children often helping peers and solving problems together.
- Many children experienced a growing sense of pride, ownership, and understanding of the natural environment.

#### 4.3. Integration of Outcomes

A clear connection was observed between ecological activity and children's engagement. Times when pollinator activity increased, such as during peak flowering, often matched with longer periods of child participation and more frequent group activities. Gardens with greater floral diversity and higher pollinator presence were generally linked to better focus among children and stronger cooperative behavior. This suggests that healthier, more active garden environments may support higher levels of engagement and social interaction among participants.

### 5. Discussion

#### 5.1. Principal Findings and Novel Contribution

This study shows that carefully designed pollinator gardens can work as effective spaces where social and ecological benefits come together. The considerable increase in biodiversity confirms that even small, well-planned urban gardens can support ecological restoration. Significant improvement in psychosocial outcome suggests that these bio-diverse spaces can play an important role in fostering inclusion and development among vulnerable youth.

What makes this study novel is that it brings together two outcomes that are usually studied separately. By examining ecological change and psychosocial development within the same intervention, this research shows how nature-based solutions can address environmental and social challenges at the same time. The study also presents a model that is low-cost, scalable, and suitable for urban settings in India based on observations over a 24-month period.

#### 5.2. Comparative Analysis with Analogous Green Interventions

Compared with conventional therapeutic programs, pollinator gardens provide similar psychosocial benefits in everyday non-clinical settings such as schools and community institutions. This challenges the assumption that effective nature-based interventions must be highly

controlled. Instead, the findings highlight the value of biodiverse living systems, where regular interaction with pollinators supports sensory needs and improves focus among neurodivergent children.

Many community gardening initiatives emphasize social participation but do not systematically assess ecological outcomes. This study differs by giving equal importance to biodiversity and psychosocial change. The results show that ecological restoration and social inclusion are not competing goals. When pollinator gardens are intentionally designed and inclusively managed, benefits for pollinators and children develop together, complementing one another.

### **5.3. Theoretical Implications**

The findings of this study help support and apply several important theories. Children showed sustained attention and calm interest while observing pollinators, a response often described as “soft fascination.” This supports Attention Restoration Theory and shows that even small pollinator gardens in urban spaces can help children feel more regulated and included.

From an environmental justice perspective, the intervention helped reduce inequality by bringing biodiverse green spaces into schools and institutions that usually have limited access to such pollinator-friendly environments. Children were not just visitors but active participants, which supported equality in both access and decision-making. The sense of care, responsibility, and connection that developed among the children also supports the Biophilia Hypothesis, suggesting that humans have a natural tendency to connect with living systems.

### **5.4. Ethics, Co-Design and Reflexivity**

This project followed a community co-design approach within institutional limits. While children were not involved in every formal design decision, their participation was central throughout the process. Activities were adapted to meet different sensory needs, children’s ideas and creative work were included in the gardens, and leadership roles were introduced to build confidence, ownership, and a sense of belonging.

To support inclusion and continuity, a Pollinator Ambassador program was introduced. Selected students helped guide their peers and take responsibility for garden care. This program was designed as a participatory and ethical practice rather than a measured outcome. It helped children, especially neurodivergent and underprivileged participants, feel valued as active contributors rather than passive recipients. The ambassador model also encouraged long-term care of the gardens beyond structured sessions.

Regular collaboration with teachers, caregivers, and institutional partners ensured that activities were culturally appropriate and could continue after the study ended. A key

learning from this process was the need to balance research structure with the flexible and changing routines of community institutions. Future projects would benefit from earlier and more detailed co-planning with teachers, caregivers, and institutional partners.

### **5.5. Policy and Practice Implications**

The Buzzing Blooms initiative offers actionable insights for educators, therapists, urban planners, and public health practitioners seeking to integrate ecological restoration with inclusive child development.

#### **5.5.1. For Educators and Therapists**

School green spaces can function as powerful experiential learning environments. Sensory-friendly planting zones, visually distinct flowers, textured planting areas, and quiet corners can support sensory regulation. Visual supports such as picture-based plant labels, color-coded beds, and step-by-step activity charts improve comprehension and independence. Structured yet flexible gardening tasks such as watering, seed sorting, and soil mixing allow children with varying abilities to participate meaningfully.

Pairing neurotypical and neurodivergent students, creating mixed gardening teams, and introducing ambassador or buddy systems foster empathy, cooperation, and social inclusion while reducing stigma. Establishing predictable routines such as fixed garden days and visual schedules improves comfort, engagement, and task completion.

#### **5.5.2. For Urban Planners and Environmental Agencies**

Urban greening policies should move beyond ornamental landscaping toward biodiverse, socially inclusive ecological infrastructure. Pollinator gardens in hospitals, community parks, and low-income neighborhoods can simultaneously address biodiversity loss and inequitable access to restorative green space. Including accessibility features like raised beds, adaptive tools, and barrier-free pathways ensures participation across physical and cognitive ability levels.

#### **5.5.3. For Public Health Systems**

Nature-based interventions such as pollinator gardens represent cost-effective, preventive mental health supports, particularly for vulnerable and underserved children. Cross-sector collaboration between health, education, and environmental departments can scale such interventions as community well-being assets. Growing evidence positions bio-diverse green spaces as protective environments that enhance emotional resilience, social functioning, and developmental outcomes.

### **5.6. Methodological Reflections, Challenges, and Best Practices**

Implementing this research in real school and community settings offered important practical insights.

Using a baseline and post-intervention assessment design was a realistic and ethical choice as it allowed all children to participate in the intervention. However, this approach limits the ability to make strong cause-and-effect conclusions. Future studies may strengthen design rigor by using phased implementation or waitlist control approaches where feasible.

Collecting behavioral data in active garden settings provided a realistic picture of children's engagement and interactions. However, it also required careful facilitator training and consistency checks to ensure reliable observations. Combining direct observation with teacher or caregiver feedback may further strengthen future assessments.

Maintaining the gardens after the formal study period emerged as a key challenge. Long-term success depended on including garden care in institutional routines such as eco-clubs and ensuring staff involvement. These experiences highlight the importance of planning sustainability, training, and ownership from the beginning and then implementing similar interventions.

### 5.7. Limitations and Future Research Directions

This study has some limitations. The absence of a randomized control group limits effective conclusions. Observations were conducted in real-world settings, which may introduce observer bias despite consistency checks. In addition, findings may be influenced by local institutional and cultural contexts and may not be directly generalizable to all settings.

Future research should strengthen causal evidence by using controlled or quasi-experimental designs where feasible. Studies should also explore which aspects of pollinator gardens, such as biodiversity levels, caregiving activities, or child leadership roles, contribute most strongly to psychosocial outcomes. Long-term follow-up studies are needed to examine whether both ecological and psychological benefits persist over time. Further research across diverse cultural, climatic, and institutional contexts would help assess the adaptability of this model. Finally, evaluating economic and ecosystem service outcomes could support stronger policy and planning integration of pollinator-based interventions.

## References

- [1] Katherine Alaimo et al., "Fruit and Vegetable Intake among Urban Community Gardeners," *Journal of Nutrition Education and Behavior*, vol. 40, no. 2, pp. 94-101, 2008. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [2] Katherine C.R. Baldock et al., "Where is the UK's Pollinator Biodiversity? The Importance of Urban Areas for Flower-Visiting Insects," *Proceedings of the Royal Society B: Biological Sciences*, vol. 282, no. 1803, pp. 1-10, 2015. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [3] Gregory N. Bratman, J. Paul Hamilton, and Gretchen C. Daily, "The Impacts of Nature Experience on Human Cognitive Function and Mental Health," *Annals of the New York Academy of Sciences*, vol. 1249, no. 1, pp. 118-136, 2012. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]

## 6. Conclusion

This study demonstrates that pollinator gardens, when designed with ecological functionality and inclusive engagement at their core, can serve as powerful dual-impact interventions. Across 15 urban sites in India, these gardens generated significant gains: a 155% increase in pollinator richness and substantial improvements in task completion, emotional regulation, and peer interaction among over 200 neurodivergent and underprivileged children. By linking measured ecological data with clear psychosocial indicators, this research moves beyond disciplinary boundaries and provides a replicable model for integrated social-ecological work.

The findings confirm that the goals of urban biodiversity restoration and social inclusion are not merely compatible but can be mutually reinforcing. The pollinator garden emerges not only as a habitat for declining species but as a vital, inclusive community space that nurtures human well-being, agency, and connection.

For policymakers, planners, educators, and therapists, this work offers a low-cost blueprint for creating multifunctional green infrastructures that address the challenges of ecological degradation and social equity in our rapidly urbanizing world.

## Funding Statement

The "Buzzing Blooms" intervention was supported by community-based partnerships and modest grants from local NGOs (approx. ₹25,000) and Corporate Social Responsibility funds (approx. ₹35,000). These funds covered initial material costs and had no role in study design, data analysis, or interpretation. Long-term maintenance was supported by institutional adoption and volunteer activities.

## Acknowledgments

The author extends sincere gratitude to Prof. Meera Malhan (University of Delhi) for academic guidance; the Cambridge Centre for International Research for methodological training, and the participating schools, care institutions, facilitators, and children of Ludhiana for their invaluable collaboration. Preliminary findings were presented at the Cambridge Centre for International Research Winter Symposium.

- [4] Louise Chawla, "Benefits of Nature Contact for Children," *Journal of Planning Literature*, vol. 30, no. 4, pp. 433-452, 2015. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [5] J.K. Mader et al., *Attracting Native Pollinators: Protecting North America's Bees and Butterflies*, North Adams, MA: Storey Publishing, 2011. [[Publisher Link](#)]
- [6] Heather Ohly et al., "Attention Restoration Theory: A Systematic Review of the Attention Restoration Potential of Exposure to Natural Environments," *Journal of Toxicology and Environmental Health, Part B*, vol. 19, no. 7, pp. 305-343, 2016. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [7] Stephen R. Kellert, *Building for Life: Designing and Understanding the Human-Nature Connection*, Washington, DC: Island Press, 2005. [[Google Scholar](#)] [[Publisher Link](#)]
- [8] Jill S. Litt et al., "The Influence of Social Involvement, Neighborhood Aesthetics, and Community Garden Participation on Fruit and Vegetable Consumption," *American Journal of Public Health*, vol. 101, no. 8, pp. 1466-1473, 2011. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [9] Clare Hume et al., "Community Gardens and their Effects on Diet, Health, Psychosocial and Community Outcomes: A Systematic Review," *BMC Public Health*, vol. 22, pp. 1-66, 2022.
- [10] Philip Donkersley et al., "A Little does a Lot: Can Small-scale Planting for Pollinators Make a Difference?," *Agriculture, Ecosystems & Environment*, vol. 343, pp. 1-10, 2023. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]