Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Designing Small Urban School Grounds for Nature-Based Learning: A Framework for Fostering Children's Connectedness with Nature

Desirée Falzon

desiree.falzon@um.edu.mt

University of Malta

Elisabeth Conrad

University of Malta

Research Article

Keywords: nature-based learning, connectedness with nature, urban schools, outdoor education, design framework

Posted Date: July 31st, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10347860/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Designing Small Urban School Grounds for Nature-Based Learning: A Framework for Fostering Children's Connectedness with Nature

Abstract

Nature-based learning is increasingly recognised as a means of strengthening children's connectedness with nature and supporting environmental stewardship. However, limited guidance exists on how small urban primary school grounds can be intentionally designed to support curriculum-based outdoor learning where space is highly constrained. This paper presents a theoretically informed design framework that translates research on connectedness with nature, developmental psychology, ecological systems, affordance theory, and environmental design into practical principles for creating nature-based learning environments in urban schools. The framework was developed through a theory-led synthesis of interdisciplinary literature and refined through pilot application in three Maltese primary schools representing different spatial and ecological contexts. Discussions with children, educators, school leaders, and interdisciplinary experts were used to evaluate the framework's clarity, feasibility, and educational relevance, leading to further refinement. Findings indicate that meaningful nature-based learning in small urban schools depends on more than increasing green space. Effective design requires ecologically purposeful planting, opportunities for repeated and sensory-rich encounters with nature, age-responsive learning affordances, and spatial organisation that supports curriculum integration while remaining manageable within school maintenance constraints. Stakeholder feedback also highlighted the importance of teacher confidence, leadership support, and ecological intentionality in translating designed spaces into meaningful learning experiences. The framework demonstrates that even highly constrained urban school grounds can be transformed into educational landscapes that promote connectedness with nature and ecological literacy. By integrating educational, ecological, and spatial perspectives, it provides evidence-informed guidance for educators, school leaders, designers, and policymakers seeking to embed nature-based learning within everyday school practice.

Keywords: nature-based learning, connectedness with nature, urban schools, outdoor education, design framework

Designing Small Urban School Grounds for Nature-Based Learning: A Framework for Fostering Children's Connectedness with Nature

Escalating environmental change and biodiversity loss underscore the urgency of fostering environmentally responsible behaviour (ERB). Understanding the drivers of ERB is critical to inform intervention strategies. Numerous studies have examined connectedness with nature (CWN) as a relevant construct, with consistent evidence linking CWN to pro-environmental attitudes and behaviour (Lengieza et al., 2023; Barragan-Jason et al., 2022). In this paper, CWN is understood as a multidimensional human–nature relationship that positions the individual as an integral part of ecological systems, encompassing affective affinity, cognitive inclusion, and experiential familiarity with the natural world. CWN has been shown to foster motivation to engage in ERB by creating emotional (Mayer et al., 2009) and cognitive (Schultz & Tabanico, 2007) bonds with nature, such that harm to nature may be perceived as harm to the self (Sulfa et al., 2024). Childhood represents a particularly critical developmental period for the formation of environmental identity and moral orientation. Developmental psychology situates early and middle childhood as foundational for cognitive growth, identity formation, and value construction (Bruner, 1990). Empirical evidence indicates that experiences in nature during childhood are strongly associated with later pro-environmental attitudes (Evans et al., 2018; Liefländer et al., 2013). Accordingly, early intervention through repeated, meaningful nature engagement is likely to have durable behavioural implications. However, contemporary patterns of urbanisation, globalisation, and technologically mediated lifestyles have contributed to a decline in direct interaction with natural environments, particularly among children (Beery et al., 2023; Ortega-García et al., 2024), and consequently to a decline in opportunities for developing CWN. This phenomenon, described by Pyle (2003) as the “extinction of experience,” refers to diminishing everyday contact with biodiversity, resulting in weakened emotional attachment and ecological knowledge.

This decline may be especially pronounced in dense urban environments with limited access to natural spaces, exacerbated by the predominance of screen-based entertainment and structured indoor schedules that limit unmediated encounters with living systems (Larson et al., 2019; Soga & Gaston, 2016). Urban areas are not uniformly defined across the globe, with countries employing non-standardised criteria (Ritchie et al., 2024), which frequently reflect national priorities or capacities rather than global comparability. To address challenges in comparing urban areas across countries, the European Commission, in partnership with the OECD and UN-Habitat and endorsed by the United Nations Statistical Commission in 2020, developed the Degree of Urbanisation (DEGURBA) methodology (OECD, 2021). This harmonised, grid-based system uses population density and spatial contiguity to classify and compare territories in terms of their degree of urbanisation. This paper adopts the DEGURBA classification of urban centres as contiguous 1 km² grid cells with at least 1,500 inhabitants per km² and a minimum total population of 50,000, and urban clusters as contiguous cells with at least 300 inhabitants per km² and a minimum population of 5,000.

In urban settings, schools potentially offer a structured and widely available context for facilitating engagement with nature for all children. Nature-based learning (NBL), broadly defined as learning that occurs in, about, and through nature (Jordan & Chawla, 2019), provides a pedagogical vehicle for embedding nature experiences within formal curricula. The Nature Based Learning Research Network further conceptualises NBL as learning through exposure to natural settings or nature-based elements incorporated into built environments (Jordan & Chawla, 2019). Integrating NBL within primary schools offers a means of mitigating inequities in access to natural spaces and ensuring regular contact with living systems for children in dense cities (Mann et al., 2022; Stevenson et al., 2020). However, despite increasing advocacy for NBL and urban greening, there remains limited evidence-based guidance regarding the physical design of small, urban primary school grounds to support curriculum-integrated NBL. Much of the literature focuses on programme outcomes, socio-economic factors, or broader urban

greening strategies (Flax et al., 2020; Berman et al., 2018), while spatial design considerations specific to school grounds remain underdeveloped. In contexts characterised by land scarcity, heavy footfall, pollution exposure, and ecological simplification, the quality and intentionality of spatial design may be decisive in enabling or constraining meaningful nature engagement.

A recent systematic review of the evidence identified an absence of evidence-based guidance for designing nature-based learning spaces in small, urban primary schools, despite increasing recognition of the educational value of nature-based learning (Falzon & Conrad, 2024). Building on these findings, this study develops and iteratively refines a theoretically grounded framework for designing nature-based learning spaces for children aged five to eleven. The framework integrates environmental psychology, developmental theory, ecology, and landscape design principles, and was explored through pilot applications in three urban primary schools in the small island state of Malta. The research seeks to answer: (1) which theoretical constructs are most relevant to informing the design of small, urban school grounds to foster CWN; (2) how these constructs can be translated into spatial and vegetative design principles; and (3) how stakeholder appraisal of pilot applications informs refinement of the framework under conditions of spatial constraint.

Methodology: Framework Development and Interpretive Validation

This research develops a design framework for NBL spaces in small, urban primary schools, grounded in theories of CWN, developmental psychology, ecological systems, and environmental design. The study translates constructs associated with ERB into spatial variables capable of operating within constrained urban school grounds. The framework emerges from the interplay between constructs of nature connectedness, knowledge and ecological relationships, affordances theory and the restorativeness of nature on attention within a context of urban stressors. These are presented not as discrete stages but as mutually constitutive dimensions.

The framework was derived through a top-down, theory-led process guided by three organising questions: (i) what is the aim of the framework? (ii) who are its primary users? and (iii) under what contextual conditions must it function?

Development proceeded through parallel and hierarchical inquiry (Gwizdka & Lopatovska, 2009). Parallel inquiry surveyed constructs across environmental psychology, ecology, developmental science, and landscape theory associated with CWN. Hierarchical inquiry interrogated how these constructs could be expressed spatially within small, high-density school grounds. The result is not a prescriptive design template but an integrated set of spatial principles through which ecological, sensory, developmental, and pedagogical dimensions converge.

Following theoretical derivation, the framework was interpreted within three pilot urban primary schools in Malta, with schools representing diverse typologies of size, population density, and soft landscape provision. Stakeholder consultations with pupils, teachers, administrators, and interdisciplinary experts then assessed interpretive clarity and contextual feasibility. These discussions functioned as conceptual stress-tests, refining zoning logic, maintenance realism, and pedagogical alignment without altering the theoretical core.

Eliciting Elements Connected to the Framework Aim

The central aim of the framework is the cultivation of CWN during early and middle childhood (ages 5–11), a developmental stage widely recognised as formative for identity, moral orientation, and worldview formation (Bruner, 1990; Evans et al., 2018). Given evidence linking CWN with pro-environmental behaviour (Lengieza et al., 2023; Barragan-Jason et al., 2022), the framework seeks to specify the material conditions under which such connectedness may be fostered within institutional settings. Fostering ERB through CWN in schools requires green spaces that lend themselves to curriculum-based NBL. Despite growing interest in human–nature interactions, much scholarship remains situated within the social sciences, with comparatively limited ecological integration (Keniger et

al., 2013). This gap constrains clarity regarding which environmental characteristics most effectively support CWN.

The first step towards eliciting elements for the design framework involved identifying what constitute meaningful CWN experiences in early and middle childhood. Theoretical literature on children's connectedness was reviewed to extract recurring themes. These were clustered under broader categories including knowledge, affect, stewardship, contact, and experiential recurrence (Table 1).

Table 1

Broad Themes and Key Descriptive Phrases in Literature on CWN Through NBL

Broad theme	**Key descriptive phrases**	**Source**
Knowledge about environment and ecological systems	Environmental literacy	(Erdogan, 2011)
	Environmental awareness	(Erdoğan & Özsoy, 2007)
	Ecology-based nature education; environmental knowledge about flora, fauna and the ecosystem through real contact with nature	(Erdogan, 2011; Otto & Pensini, 2017)
	Environmental knowledge	(Erdogan, 2011; Otto & Pensini, 2017; Theimer & Ernst, 2012)
	Subjective environmental knowledge: deep understanding of causal connections; the workings of natural processes	(Carmi et al., 2015; Coyle, 2005; Roczen et al., 2014)
Awareness of human-nature ecological relationship	Understanding the relationship between man and natural environment	(Chawla, 2018; Erdogan, 2011; International Union for the Conservation of Nature and atural Resources, 1971; Ross, 2020; A. Taylor, 2017)
	Observation of cause – effect relationships in the natural environment	(Erdogan, 2011; Otto & Pensini, 2017)

Broad theme	Key descriptive phrases	Source
	Thinking collectively about commonalities between human – nature	(Elliott & Davis, 2020; Ross, 2020; A. Taylor, 2017)
Direct experience and involvement	Immersion in natural environment	(Louv, 2005)
	Involvement in activities in nature	(Giusti et al., 2018a; Yue & Chen, 2023)
	Direct contact with the environment	(Chawla, 2018)
	Experience of patterns of change at various temporal and spatial dimensions	(Dennis Jr et al., 2014)
	Engagement of the senses	(Giusti et al., 2018)
Integration of NBL to ensure regularity of direct experience	Immersion in natural environment	(Louv, 2008)
	Involvement in activities in nature	(Giusti et al., 2018; Yue & Chen, 2023)
	Direct contact with the environment	(Chawla, 2018)
	Experience of patterns of change at various temporal and spatial dimensions	(Dennis et al., 2014)
	Engagement of the senses	(Giusti et al., 2018)
	Extended periods in natural areas	(Barrable, 2019; Chawla, 2018)
	Curricular connections	(Dennis et al., 2014; Erdogan, 2011)
	Creating, engaging and broadening space for nature connection	(Grimwood et al., 2018)
Nature connectedness and affect	Feeling connected to nature together with acquiring environmental knowledge	(Otto & Pensini, 2017)
	Connectedness to nature as a motivational component	(Chawla, 2018; Giusti et al., 2018; Green et al., 2016; Kals et al., 1999b; Otto & Pensini, 2017)
	Reflection on the relationship between people and nature	(Høyem, 2020)

Broad theme	Key descriptive phrases	Source
	Affect; pleasant experiences while in direct contact with nature	(Erdogan & Özsoy, 2007; Giusti et al., 2018; Lumber et al., 2017; Rosa et al., 2018)
	Engaging with the inner world of emotions and identities	(Barbaro & Pickett, 2016; Barrable, 2019)
	Mindfulness (heightened awareness and attention to the present moment)	(Barbaro & Picket, 2016)
	Environmental emotions mediate the translation of knowledge acquired about environmental issues into environmentally responsible behaviour	(Carmi et al., 2015)
	Attractiveness of natural environment impacts attitudes, motivation, and behaviour	(Carson, 1956; Ballantyne & Pecker, 2020; Barrable, 2019;)
	Comfort in nature	(Giusti et al., 2018; C. Green et al., 2016)
	Engagement with nature's beauty; aesthetic experience triggered by nature	(Barrable, 2019; Giusti et al., 2018b; Ng et al., 2023; P.-C. Wang & Yu, 2018a)
Stewardship	Involvement in biodiversity conservation	(Chawla, 2018)
	Understanding and caring for the natural world	(Chawla, 2018; Jordan & Chawla, 2019)
	Environmental stewardship	(Taylor, 2017)

The theme of knowledge extended beyond recognition of individual species to encompass ecological systems and causal relationships (Barakat et al., 2019). Accordingly, the framework emphasises visible ecological processes. This means more than exposure to green space; it requires encounters that reveal ecological relationships and processes in ways that are cognitively and emotionally meaningful. The literature on CWN consistently emphasises that affective engagement and experiential contact mediate the relationship between environmental knowledge and behaviour (e.g.,

Roczen et al., 2013; Chawla, 2018). Knowledge alone rarely produces sustained behavioural change (Erdogan, 2011; Frick et al., 2004). Rather, ecological understanding becomes behaviourally significant when it is embedded in lived experience and linked to emotional resonance.

Accordingly, the framework emphasises visible ecological processes. Children should be able to witness pollination, decomposition, seasonal variation, habitat formation and stewardship practices in action. Within primary school contexts, this implies that NBL spaces must foreground ecological cause-and-effect relationships and create opportunities for repeated observation. Designing school grounds to reveal such relationships requires intentional selection of vegetation, habitat features, and spatial organisation. This creates conditions under which ecological literacy can emerge through direct engagement with living systems rather than through abstract instruction alone.

Curriculum integration is essential to ensure frequency and continuity of experience. Review of curriculum-linked NBL programmes indicates a predominance of life-science content (Falzon & Conrad, 2024). Consequently, the planting scheme becomes central to pedagogy due to plants' foundational role in food webs and ecosystem functioning (Dobson et al., 2023). Ensuring the presence of native plants and associated fauna increases opportunities for sustained inquiry across year groups. While school grounds are inherently constructed environments, the use of native flora and fauna enhances authenticity of ecological experience, strengthens place-based learning, and aligns with ecological research demonstrating their contribution to local biodiversity and ecosystem functioning (Berthon et al., 2023). In small urban sites, diversity and structural layering may compensate for limited area, enabling children to encounter a range of organisms and ecological processes within constrained spatial boundaries.

However, knowledge alone rarely shifts behaviour (Erdogan, 2011; Frick et al., 2004). The framework therefore integrates affective dimensions, recognising that emotional engagement mediates the knowledge–behaviour relationship (Roczen et al., 2013). Spatial design must invite curiosity, delight,

and care through tactile involvement, sensory richness, and opportunities for stewardship. These processes transform abstract curricular content into lived ecological experience where nature mediates learning through direct experience of nature in settings where urbanisation has thwarted our competence and confidence towards the natural world (Barrette et al., 2022). Designing NBL spaces for children's direct engagement with nature can be achieved through variety, where plant diversity foregrounds ecological relationships through the potential faunistic diversity associated with such flora, allowing children to experience cause and effect relationships. Footpaths maximise the potential of such opportunities by allowing regular student access to different areas while restricting trampling. Designing winding rather than straight footpaths increases nature contact where spatial limitations reduce opportunities for direct experience.

Effective stewardship education also requires skilled educators, carefully planned hands-on experiences, and opportunities for reflection that help children understand the significance of their actions. The implications for design are that NBL spaces should approximate authentic ecological experiences, even in urban settings. A diversity of indigenous plants, habitats, seasonal cycles, and learning zones can increase biodiversity, reveal ecological dynamics, and provide varied affordances for learning. Such variety enriches educational experiences, deepens children's connection with nature, and strengthens their capacity for stewardship and ecological understanding (Dobson et al., 2023; Sharma-Brymer et al., 2018).

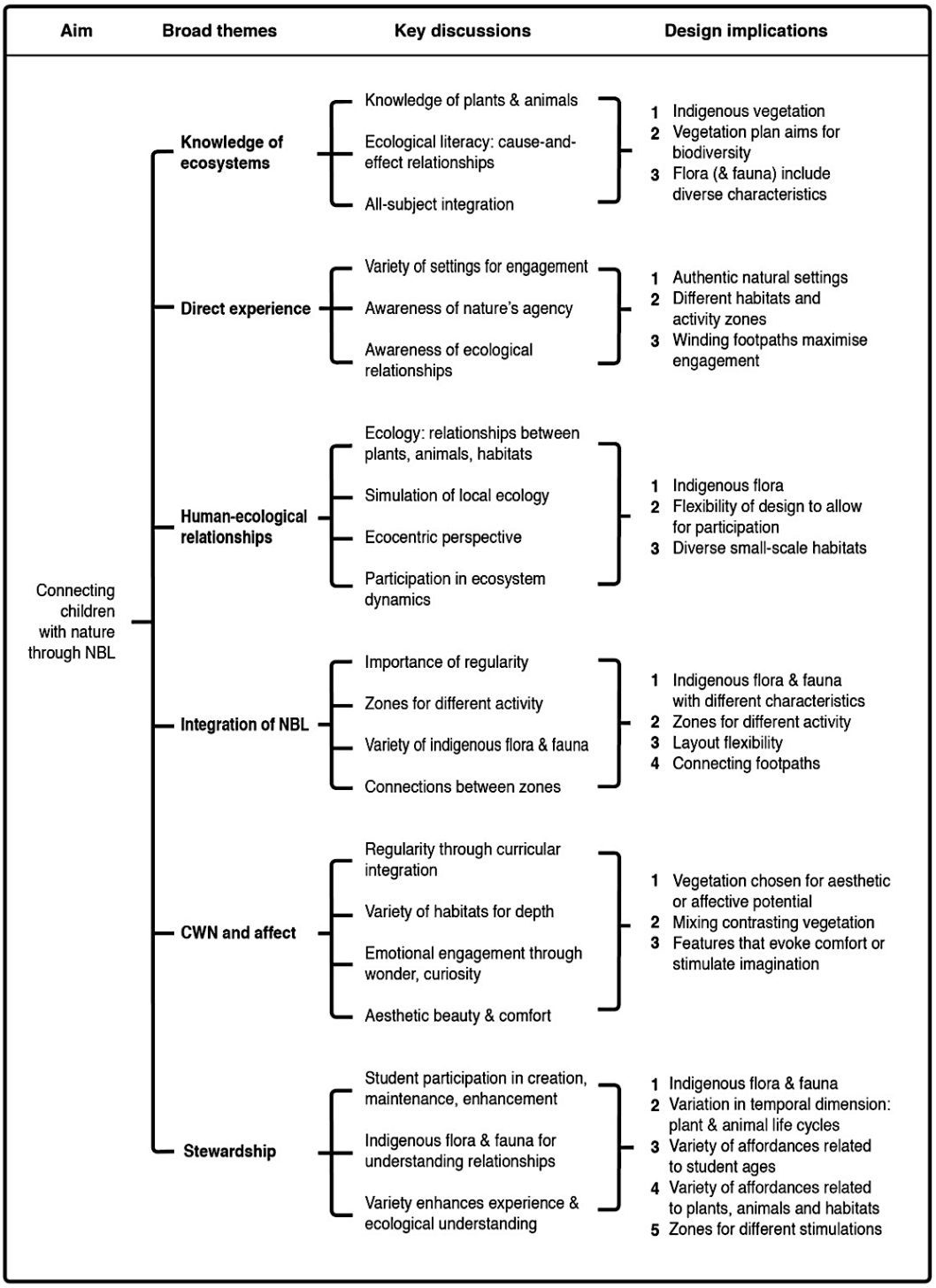
Integrating NBL within the curriculum is essential for fostering meaningful and sustained connections with nature. Because nature-based activities are inherently interdisciplinary, they help learners connect theory and practice while building relationships across subject areas (Erdoğan, 2011). Such integration enables experiential recurrence. Regular, repeated engagement with natural environments has been shown to strengthen children's connection with nature over time (Barrable, 2019). When accompanied by reflection and linked to curriculum goals, these recurring experiences

become particularly powerful educational opportunities. Consequently, NBL spaces should incorporate diverse vegetation, pathways, and learning zones that support repeated use for a range of curricular purposes.

Figure 1 outlines the broad themes and key findings related to the *aim* section of the framework.

Figure 1

Outline of Broad Themes and Key Findings Informing Elements Relevant to Aim


Aim
Broad themes
Key discussions
Design implications
Connecting children with nature through NBL
Knowledge of ecosystems
Knowledge of plants & animals
Ecological literacy: cause-and-effect relationships
All-subject integration
1 Indigenous vegetation
2 Vegetation plan aims for biodiversity
3 Flora (& fauna) include diverse characteristics
Direct experience
Variety of settings for engagement
Awareness of nature's agency
Awareness of ecological relationships
1 Authentic natural settings
2 Different habitats and activity zones
3 Winding footpaths maximise engagement
Human-ecological relationships
Ecology: relationships between plants, animals, habitats
Simulation of local ecology
Ecocentric perspective
Participation in ecosystem dynamics
1 Indigenous flora
2 Flexibility of design to allow for participation
3 Diverse small-scale habitats
Integration of NBL
Importance of regularity
Zones for different activity
Variety of indigenous flora & fauna
Connections between zones
1 Indigenous flora & fauna with different characteristics
2 Zones for different activity
3 Layout flexibility
4 Connecting footpaths
CWN and affect
Regularity through curricular integration
Variety of habitats for depth
Emotional engagement through wonder, curiosity
Aesthetic beauty & comfort
1 Vegetation chosen for aesthetic or affective potential
2 Mixing contrasting vegetation
3 Features that evoke comfort or stimulate imagination
Stewardship
Student participation in creation, maintenance, enhancement
Indigenous flora & fauna for understanding relationships
Variety enhances experience & ecological understanding
1 Indigenous flora & fauna
2 Variation in temporal dimension: plant & animal life cycles
3 Variety of affordances related to student ages
4 Variety of affordances related to plants, animals and habitats
5 Zones for different stimulations

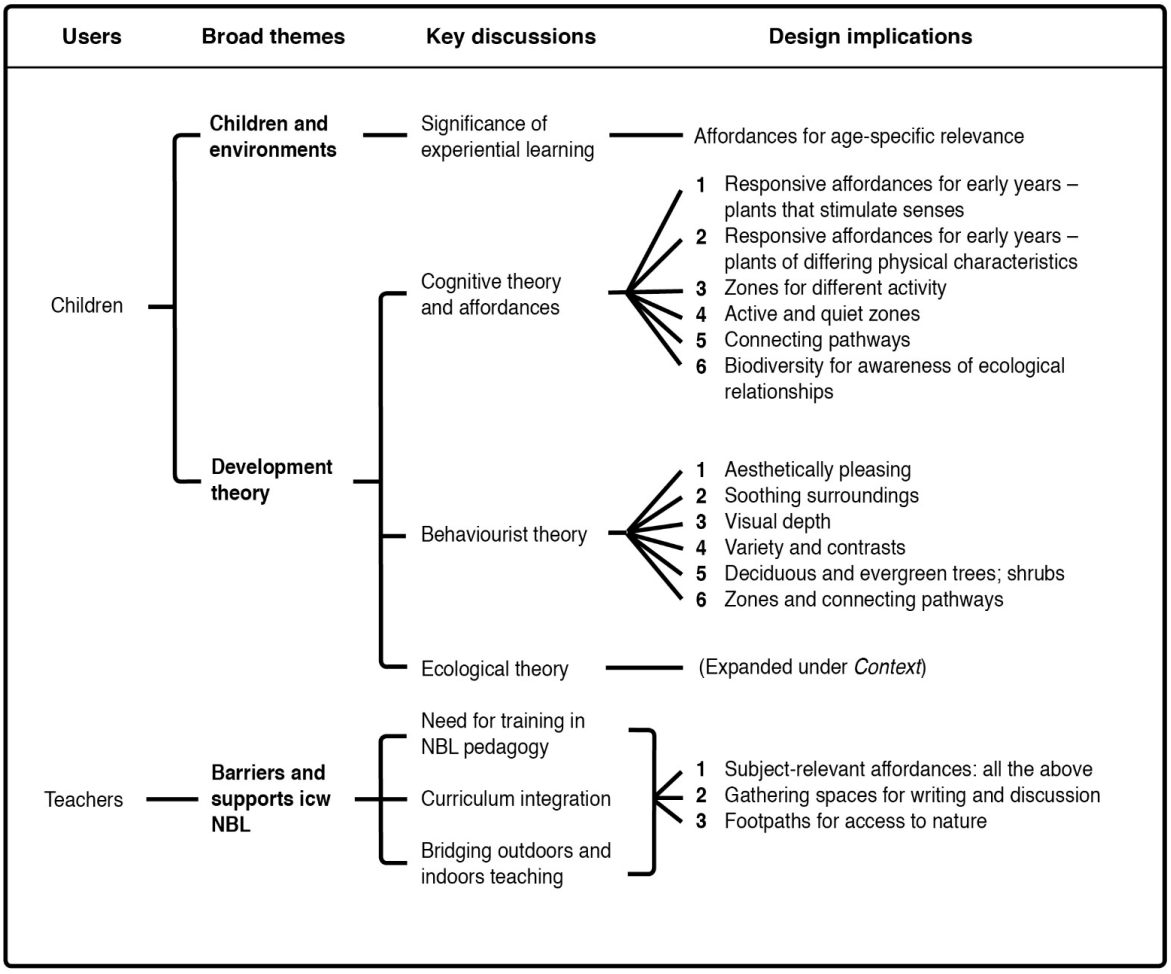
Eliciting Elements Connected to Users of the NBL Space

The second guiding question (Who are the users?) required engagement with developmental and pedagogical theory. While school grounds are used by a broad range of stakeholders, including administration, ancillary staff, parents, and visitors, the primary users of the NBL space targeted by this framework are children aged five to eleven and the educators who facilitate their learning. This section of the framework is thus anchored in ecological psychology, which examines organism–environment relationships (Gibson & Rader, 1979). Because pathways from NBL to behavioural outcomes are not fully understood (Jordan et al., 2017), the framework draws on established theories of how children relate to place and how learning unfolds through interaction. Froebel's early advocacy for hands-on engagement with the natural world positioned exploration and care as central pedagogical principles (Froebel, 1826/1887). This emphasis resonates with Chawla's (1999) account of "significant life experiences," in which memorable encounters with nature, often mediated by mentors, shape identity and values. Erikson's psychosocial theory further suggests that children build industry and competence through active, real-world tasks (Erikson, 1950). Within a NBL context, such tasks may involve planting, monitoring habitats, or observing ecological change. Cognitive development theory situates children as active constructors of knowledge (Saracho, 2021). Piaget's account of stage-like operational structures (Piaget, 1952) suggests that cognitive capacities evolve through interaction, maturation, and social mediation. Vygotsky (1934/1962) foregrounded the sociocultural mediation of cognition, arguing that learning occurs through participation in culturally structured activities scaffolded by more capable others. These perspectives converge in highlighting the importance of interaction, guided participation, and meaningful context. Affordance theory (Gibson, 1979) provides a conceptual bridge between developmental theory and environmental design. Affordances are relational action possibilities arising from the complementarity between environmental properties and the capabilities of the organism. In the context of NBL, affordances represent the opportunities for action, exploration, and learning that

school grounds offer to children at different developmental stages. Although critics note that affordance theory can underplay social and cultural mediation (Norman, 2004; Heft, 2010), affordances are not static properties; they are perceived through ongoing interaction and shaped by social practices. As children mature, their perception of affordances evolves, reflecting cognitive growth and changing competencies (Saracho, 2023). In spatial terms, this implies that affordances must be legible and responsive to children's developmental capacities. Young children preferentially attend to proximal stimuli (Khan & Kellert, 2002), and early primary years are characterised by strong sensory integration (Ayres & Robbins, 2005). NBL spaces should therefore privilege manipulable soils, visible water flow, textured surfaces, and immediate perceptual feedback. In middle childhood, cognitive capacities for classification, explanation, and abstraction expand (Mah & Ford-Jones, 2012). Affordances can therefore evolve toward structured ecological inquiry, including monitoring species diversity, tracking seasonal change, and participating in stewardship practices. Social mediation remains central; teachers shape perception of affordances by directing attention and legitimising certain forms of engagement (Chawla et al., 2014; Reed, 1996). The framework thus integrates cognitive development with affordance theory by specifying how environmental features can scaffold perception–action loops across age groups. School grounds are therefore conceived not as passive settings but as active participants in learning processes, where affordances are intentionally calibrated to support the development of connectedness with nature. Figure 2 outlines the broad themes and key findings informing the *users* section of the framework.

Figure 2

Themes and Key Discussions Leading to Elements of Design Framework Related to Users



Eliciting Elements Connected to Context

The third guiding question, relating to context, situates the framework within small, urban primary schools characterised by high density, limited outdoor area, and exposure to environmental stressors.

Urban populations are increasing globally (Zhang, 2016), placing pressure on school infrastructure. Many urban schools operate within constrained footprints and experience elevated air pollution levels due to vehicular traffic (Taylor & Wright, 2020). Children are particularly vulnerable to pollution due to physiological and developmental factors (Johnson et al., 2021; Lin et al., 2023). Urban noise further affects cognitive functioning and wellbeing (Clark & Sörqvist, 2012; Terzakis et al., 2022). The framework treats these conditions not simply as constraints but as design conditions requiring

intensified intentionality. Urban primary schools often operate within spatial and ecological limitations, including limited land availability, high enrolment density, heavy footfall, and reduced biodiversity. Rather than viewing these factors as barriers, the framework conceptualises them as conditions that shape design responses. In small sites, zoning becomes critical to protect ecological cores from excessive disturbance. Circulation pathways can channel movement and reduce soil compaction, while distinct zones for active exploration and quiet reflection enable diverse educational affordances to coexist within limited space.

Vegetation plays a central role in responding to urban stressors. Vegetation can mitigate certain pollutants and improve perceived environmental quality (Nowak et al., 2019; Sicard et al., 2018). Layered shrub buffers can attenuate noise and create separation between activity zones (Ferrini et al., 2020; Ow & Ghosh, 2017). Although small sites cannot replicate large urban forests, strategic planting and zoning can reduce exposure to environmental stressors while enhancing sensory experience and ecological function.

Urban stressors are also associated with elevated anxiety and mental health challenges among children and adults (Pykett et al., 2020; Xu et al., 2023). Exposure to nature is consistently linked with stress reduction and restoration (Capaldi et al., 2014; Hunter et al., 2019). Attention Restoration Theory (Kaplan, 1992) provides a framework for designing environments that replenish directed attention through being away, extent, fascination, and compatibility. In small urban school grounds, restoration must therefore be designed intentionally. Layered vegetation can create visual depth and a sense of immersion even within limited boundaries. Fascination may be evoked through natural patterns, seasonal change, and movement in foliage, while compatibility requires alignment between environmental features and pedagogical goals. Table 2 outlines the framework guidelines on zones, together with layout suggestions, based on the space aims, and common elements of urban schools as defined in this paper.

Table 2

Zones, description, and layout suggestions

Zone	Description	Layout suggestion
Ecological	Zones of highest biodiversity for curriculum-linked activity. Comprises variety of flora, habitats, and features that attract fauna	• Sense modalities: plants for variety of smell and texture and visual stimulation in fauna variety attracted (e.g. insect-pollinated plants), for multisensory affordances; to be laid out in sensory stations, or along sections of footpath, or bordering classrooms with overlooking, close views • Habitat biodiversity to be planned in spaces according to function, namely: (a) in least disturbed areas away from noisy school activity such as foot traffic or playground areas, (b) areas with views from classrooms, (c) in habitat zones, (d) bordering footpath, and to include: variety of indigenous flora matching habitat type; flora selection related to local ecosystem and fauna diversity; flora selection related to desired curriculum outputs (e.g. butterfly food plant); physical elements habitats, (e.g. water bodies, dry stone wall), animal homes (e.g. hibernaculum, stone piles), or features attracting animals (e.g. bird table, bat boxes); water bodies to be located in areas that flood, or in areas with partial shade (due to evaporation); vegetation selection to take advantage of physical features (e.g. slopes, microclimatic factors and contours) and characteristics of the land (e.g. sunny/shady areas)
Gathering	Seating areas for sedentary activity such as reading, meditation, art, writing and	• Whole class seating with or without writing table in central location

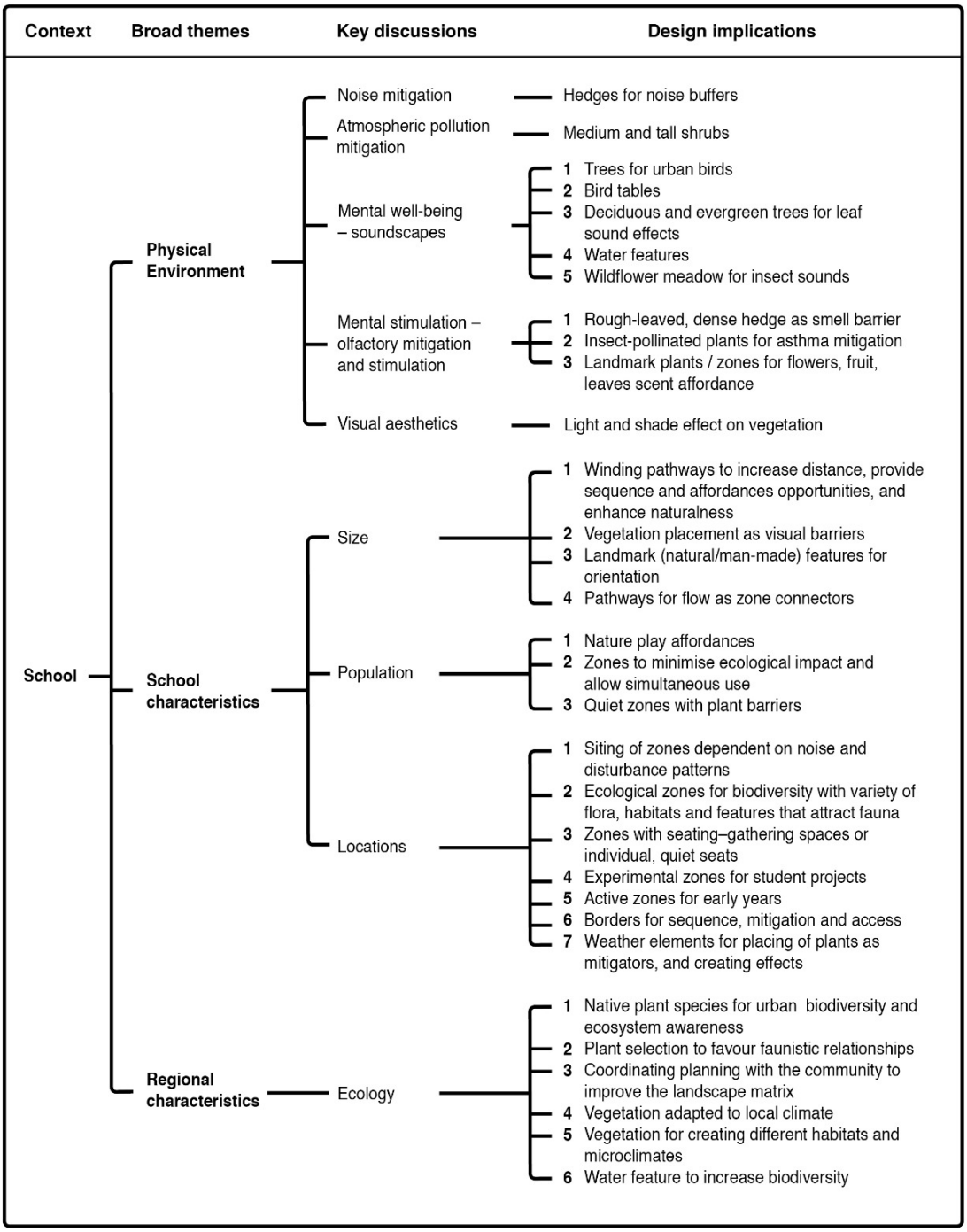
	fieldwork follow-up, or discussion	• Quiet single benches under atmospheric trees, or at viewpoint
Experimental	Areas that allow for flexibility in student projects that enhance ownership, not necessarily high in biodiversity	Zone size proportional to ecological spaces, but also to number of classes undertaking experimental projects with soil; to be located away from ecological and quiet zones; to accommodate student artefacts or lesson activity products (e.g. changeable art displays, nature notices, weather station)
Active	Zones for early years nature play, low in biodiversity	Zone size proportional to whole-school use of space to be located furthest from ecological and quiet zones, and close to early years classrooms for easy, regular access
Borders		• Mitigation effect: noise and pollution hedge barrier for spaces abutting roads; hedge barrier enclosing different zones e.g. gathering spaces for visual privacy, noise control, or wind attenuation; evergreen trees for shade to be planted where this is desired, e.g. in gathering spaces; deciduous trees for light penetration during winter, e.g close to classrooms • Sequence effect along pathway borders; vegetation transitions to reflect movement from one zone to another; perimeter plants attractive for viewing by school visitors; orientation effects of stretches of similar shrubs/trees defining pathway sections; landmark effects of character shrub or trees at zone entrances, or pathway forks • Access: breaks in borders allow children to access habitat, active, and experimental zones; low borders allow sightlines onto habitats or habitat features; high borders screen views

Environmental perception is also shaped by cultural and institutional norms (Soper, 1995; Latour, 1999; Descola, 2012). In urban contexts, children's engagement with soil, insects, or mess may be mediated by cleanliness norms, parental attitudes, and school policies (Sugiyama et al., 2021; Kandemir & Sevimli-Celik, 2023). Severe weather and safety concerns further influence feasibility (Largo-Wight et al., 2020). The framework therefore does not prescribe universal spatial solutions but acknowledges that design must be locally adapted. Shelter, drainage, and maintenance capacity must be considered alongside ecological ambition**.**

Figure 3 outlines the broad themes and key findings related to the *context* section of the framework.

Figure 3

Themes and key discussions leading to elements of design framework related to context



Collectively, the framework treats the vegetation plan as the structural backbone for ecological literacy and specifies sensory design (soundscapes, olfaction, light and visual coherence), as core affordances, supported by age-appropriate zoning, paths, and gathering spaces. In contexts where outdoor areas are constrained and nature exposure is unequal; these principles translate the CWN

literature into actionable guidance for everyday school practice. An expansion of design aspects to consider in relation to key design elements (trees, shrubs, herbaceous plants, paths, zones, affordances, and additional features) is provided in supplementary material S1–S6.

Pilot Testing

Three schools were selected to test the framework, based on diversity (school type, population size, footprint, landscape profile), accessibility to the researchers, and willingness to participate in the study (Table 2). The schools were located in Malta as a representative research context due to its high population density and predominantly urbanised landscape. With an estimated population of 574,250 (National Statistics Office, 2024), Malta's urbanisation rate stands at 95% (The World Bank, 2022). Culturally, Malta presents a distinctive context for the integration of NBL within school grounds due to a system that has historically emphasised classroom-based, teacher-directed instruction (Peresso, 2016), and where policy attempts towards learner-centred or cross-curricular teaching often remains limited due to prescriptive materials, strict timetables, and resource constraints (Xerri Hili & Schembri, 2022).

The three selected schools represent a spectrum of institutional, spatial, and ecological conditions typical of Maltese primary schools (Table 3).

Table 3

Profiles of the three pilot schools engaged in desgin framework testing. School localities were manually cross-referenced with 1 km² population density grids from the Global Human Settlement Layer (GHSL) (Carioli et al., 2023). DEGURBA classifications were inferred by visually assessing contiguity and population thresholds across grid cells surrounding each school. Areas meeting the criteria for urban clusters or centres were classified accordingly.

Characteristic	School A	School B	School C
Type	Church	State	Church
Population	600 (primary school only)	150	320
Classes per year group	4	1	2
Year groups	Years 1 – 6	kindergarten 1 and 2[1] Years 1 – 6	Years 1 – 6
Gender	Boys	Mixed	Girls
School footprint	21,849 m^2	5,418 m^2	2,278 m^2
Soft landscape	4,445 m^2	1,290 m^2	0 m^2
Percentage soft landscape	14.6%	23.8%	0%
Proposed NBL area	3,700 m^2	970 m^2	70 m^2
DEGURBA classification	Urban centre	Urban centre	Borderline between urban centre and urban cluster

Their differences in footprint size, soft landscape availability, surrounding landscape matrices, and openness to pedagogical innovation offer a valuable opportunity to explore how the proposed NBL framework can be contextually applied. Each design was developed through a structured sequence of steps that involved repeated visits to the schools between November 2020 and January 2022 (Table 4).

Table 4

Methology for development of pilot school designs

[1] Kindergarten ages: 3 – 5 years; Years 1 – 6 ages: 5 – 11 years

Step	General description	Details of procedure and links to guiding rationale	School
1	School visits to discuss with senior management.	Two to three meetings with each schools to discuss: • concept and advocacy for NBL as part of the curriculum • identification of a suitable area • information-gathering on current use (if any) of the area and any wishes for the area • accommodation of these uses in the NBL space and possible relocation of conflicting uses • final decision on area, its aim, and users • funding options	A, B, C
2	Remote: created outline plan of proposed NBL area.	• Outline drawn using graphics pad, based on satellite images of the area from Google Earth (https://earth.google.com/) and Mapserver (https://pamapserver.pa.org.mt/) • Hard copies produced, for in situ annotation	A, B, C
3	Site visit 1: populating the outline plan with current information	Boundaries visually confirmed and adjustments made where necessary.	A, B, C
		Notes made on current vegetation, noting species and placement, using a tape measure to calculate plant positions. A key for plant names was created and used to avoid notes-cluttering. Where plants were unknown, photos were taken and identified through plant identification apps (e.g. PlantNet), later confirmed from field guides. • shrubs • trees • annuals For annuals, note was made of the general area where these were growing.	A & B
		Notes made on wildlife (birds, reptiles, insects) and locations noted. For unidentified species, photos were taken for later identification, or a general note made where photography was not possible.	A & B
		Notes made on date, time of day and sun/shade pattern, marking areas on a separate copy of the plan.	A, B, C

		Notes made on soundscape, distinguishing between keynote sounds, soundmarks and signal sounds.	A, B, C
		Notes made on perceived soil depth and composition (abundance of stones, underlying bedrock, areas with leaf litter, humus).	A & B
		Notes made on any teacher/student use of the area.	A, B, C
4	Site visit 2–4: further detailing current site information	Over a number of visits during different seasons and at different times of the scholastic day, note made of changes/new information, or notes confirming previous observations about: • annual plants • soundscape • wildlife • sun/shade pattern • student movement in relation to footfall	A & B, C (where relevant)
5	Remote: using A Designer's Perspective (Chapter 4) Tables 4.3–4.9, to interpret site observations	Vegetation plan – trees: site characteristics pertaining to size, light pattern, and soil characteristics were matched with native trees for location suitability. For each school, suitable species were further selected according to aesthetic effect, faunistic associations and variety of characteristics for ecological, environmental, and curricular outputs, like flowering season, leaf, smell, shape, texture, light & sound effects and others in Table 4.3. Finally, preference was given to insect pollinated plants.	A & B
		Vegetation plan – shrubs: site characteristics pertaining to zoning, sound and pollution mitigation needs were matched with native shrubs. For each school, suitable species were further selected according to characteristics for sensory stimulation, flowering season variety, visual effects and others as in Table 4.4. Plant suitability for the given location was matched with soil and light requirements and desired habitat effect.	A, B, C
		Vegetation plan – herbaceous plants: location of native annual plants chosen according to site characteristics pertaining to zoning, size and orientation for maximum	A, B, C

		faunistic associations, as listed in Table 4.5. Location also based on light requirements of herbaceous plants.	
		Pathways: designed to respect the zoning plan, create connection between these areas and to maximise distance and provide flow with respect to site shape and size (Table 4.6).	A, B, C
		Zones: conceptualised under four types (ecological, gathering, experimental, active) as illustrated in Figures 6.5, 6.7, and 6.9 to accommodate affordances (Tables 4.7 and 4.8). Choice of zone inclusion was matched with school population needs. Placing of zones was based on flow logic, function compatibilities in tems of noise or accessibility to wildlife and to students, and access vis-à -vis classrooms and flow through the garden.	A & B, C (where relevant)
		Affordances: during consideration of all other elements care was taken to ensure that all affordances listed in Table 4.8 were included. These included ensuring variety of sensory stimulations, visual effects, NBL subject opportunies and maximisation of ecological relationships through vegetation variety.	A, B, C
		Features: once other aspects were considered, locations within zones were considered for suitability of different features (Table 4.9) to create more affordances for wildlife and for subject-based links.	A, B, C
6	Refinement and final designs	Final designs: personal sketches made during Steps 3–4 were used to create a preliminary design during Step 5. These were discussed with and subsequently rendered into final designs by the researcher and an educator colleague and artist, practised in landscape design for ecological purposes. This process required several iterations during which Tables 4.3–4.9 were used as a ticklist to ensure alignment with the design framework.	A, B, C

The Designs

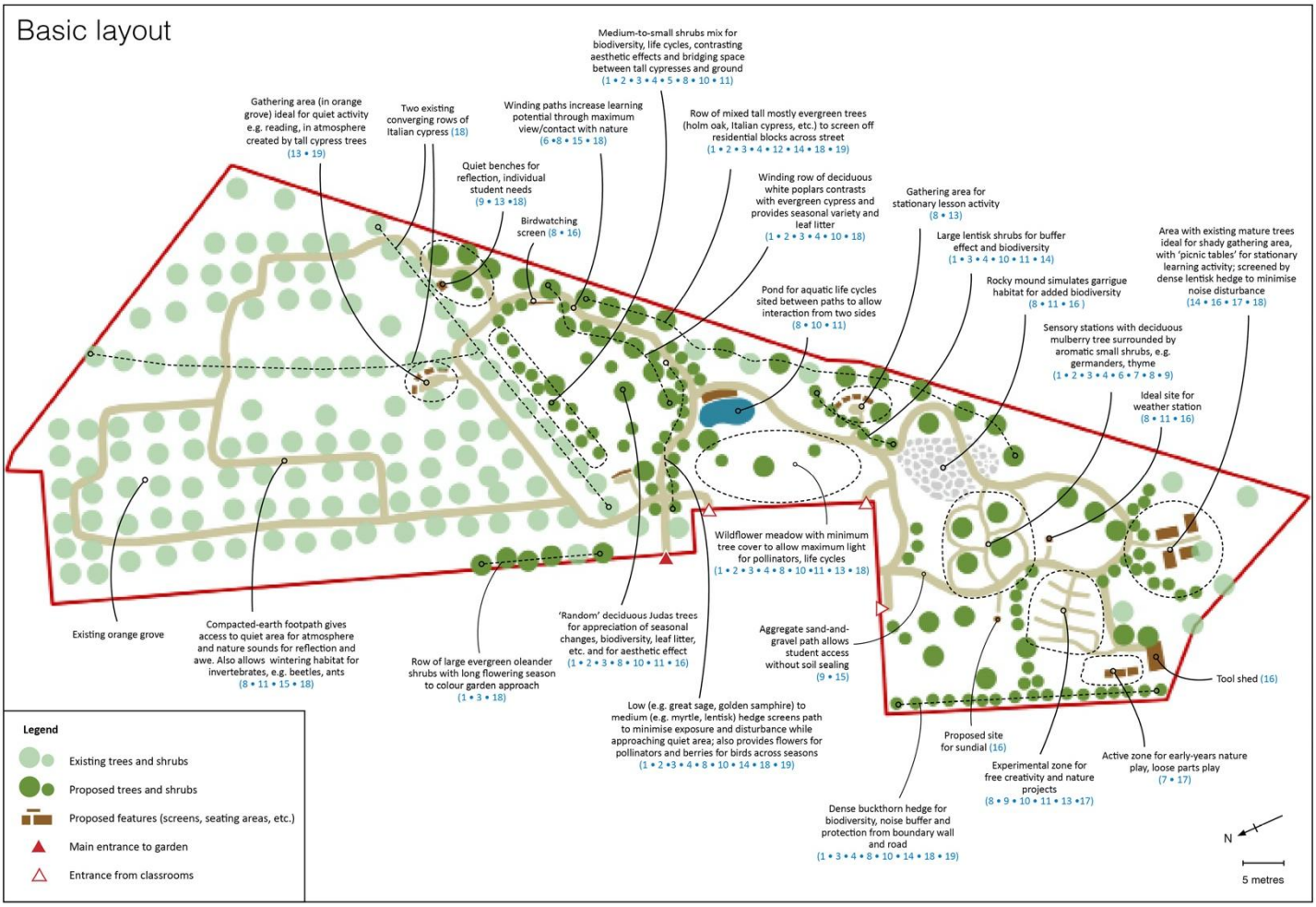
Three pilot designs, one for each school, are presented below to illustrate how the framework can be applied in different urban school contexts. Informed by site visits, ecological observations, and

existing site conditions, the designs demonstrate one possible interpretation of the framework and are intended as adaptable rather than fixed solutions, capable of evolving through stakeholder input, ecological processes, and changing school needs.

The design for School A (Fig. 4) demonstrates how the full framework can be implemented when spatial conditions are favourable. With its relatively large footprint and existing vegetation, this site offered an opportunity to explore how the complete range of NBL affordances can be spatially configured while responding to the specific ecological and curricular characteristics of a boys-only, upper-primary-focused school.

Figure 4

Pilot school A green space design based on the framework showing existing vegetation in lighter green and proposed vegetation in darker green, and notes and annotations.



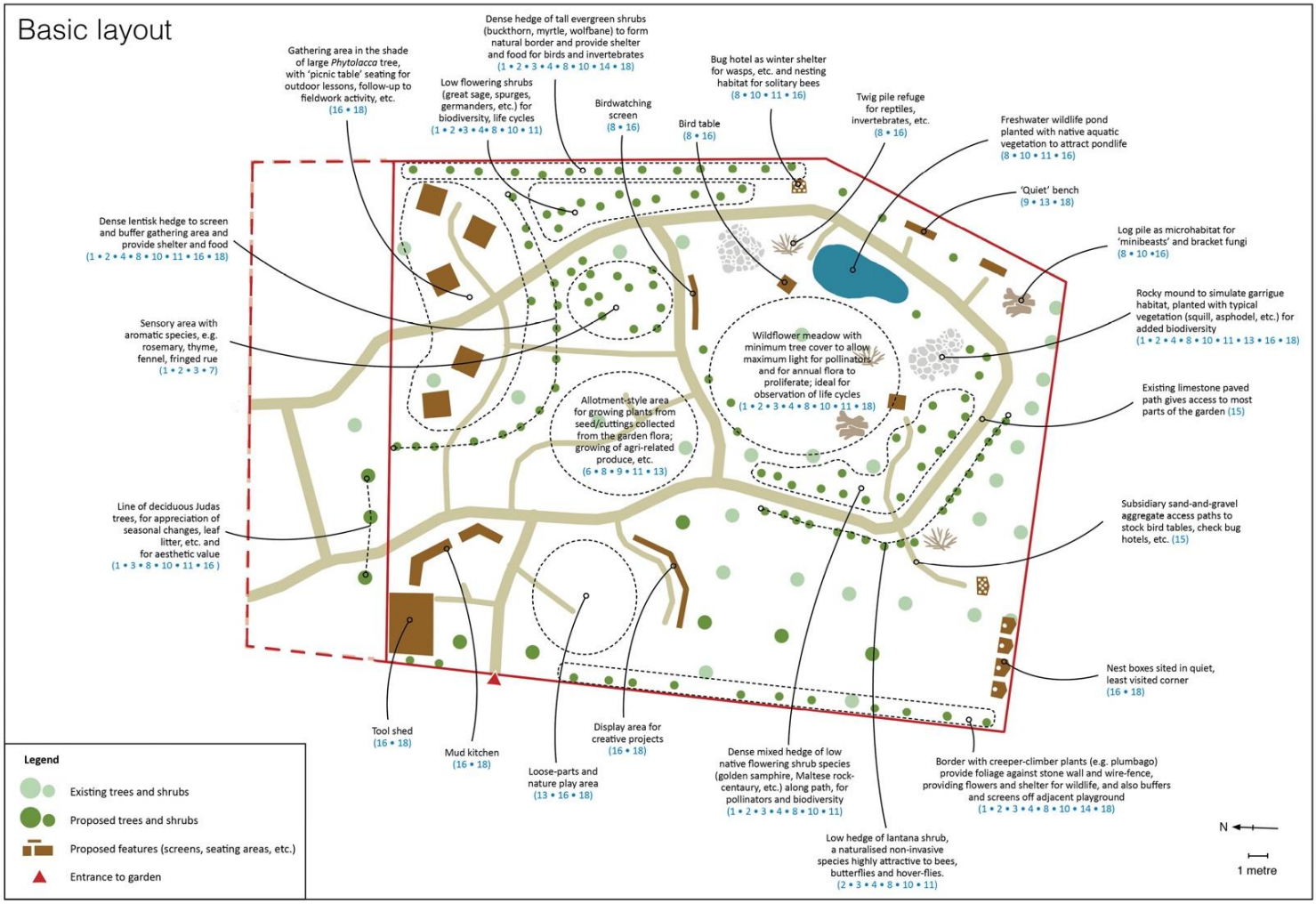
1 Indigenous flora
2 Species variety
3 Variety of physical characteristics
4 Shelter and food for fauna
5 Landscape and climate adaptations
6 Differentiated learning
7 Early years
8 Subject-based
9 Special/individual needs
10 Flora/fauna knowledge and awareness
11 Ecological knowledge and awareness
12 Human impact knowledge and awareness
13 Zones for different functions
14 Buffers/screens
15 Pathways
16 Placement of features
17 Balance of requirements
18 Size, shape and location
19 Surrounding landscape
20 Climate and local ecology

The design rationale for School B (Fig. 5) illustrates how the framework was interpreted to reflect a stronger emphasis on ecological diversity and year-round usability, in line with the school's emergent curriculum potential and recent leadership support for outdoor learning. The plan highlights

how zones were tailored to serve younger learners while preserving ecological richness and functional variety.

Figure 5

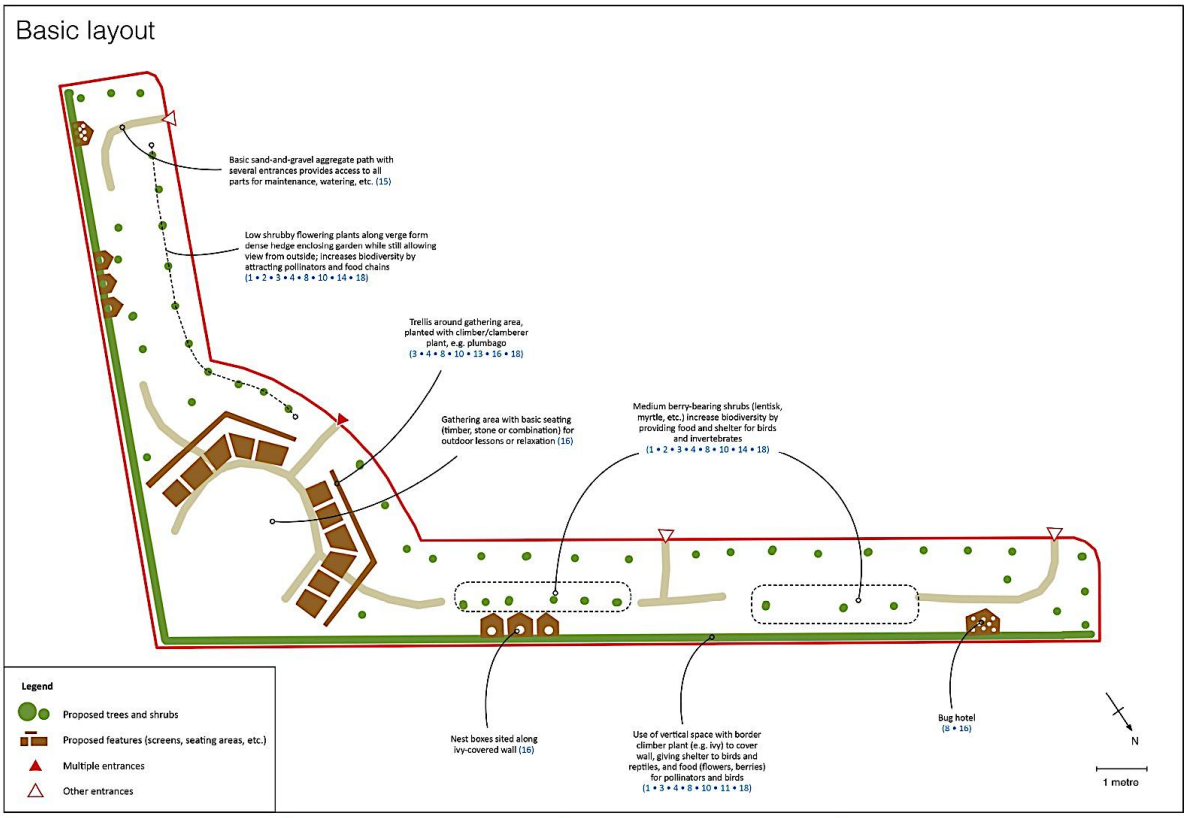
Pilot school B green space design based on the framework, with existing vegetation shown in lighter green, proposed vegetation in darker green, and notes and annotations. Greyed out annotations refer to elements not included in School B.



The design for School C (Fig. 6) foregrounds the adaptability of the framework under highly constrained conditions. With no existing soft landscaping and a minimal site area, the challenge was to explore whether even the most spatially restricted schools can host meaningful NBL interventions. Boundary planting, vertical structures, and modular biodiversity features were used to embed educational potential and ecological value into a site previously dismissed as too small for outdoor learning. The design reflects both feasibility and fidelity to NBL practices within an urbanised, high-density context. This school presents the most challenging conditions, in terms of both size and shape. Since the school has no kindergarten, it was decided not to include a nature play area, which is more suited to early years, and which would have occupied most or all the available space. This was not an ideal omission, but it represented a necessary trade-off to prioritise a nature-based learning space for whole-school curriculum integration.

Figure 6

Pilot school C green space design based on the framework, with notes and annotations



1 Indigenous flora
2 Species variety
3 Variety of physical characteristics
4 Shelter and food for fauna
5 Landscape and climate adaptations
6 Differentiated learning
7 Early years
8 Subject-based
9 Special/individual needs
10 Flora/fauna knowledge and awareness
11 Ecological knowledge and awareness
12 Human impact knowledge and awareness
13 Zones for different functions
14 Buffers/screens
15 Pathways
16 Placement of features
17 Balance of requirements
18 Size, shape and location
19 Surrounding landscape
20 Climate and local ecology

Stakeholder discussions

Discussions were held with different categories of stakeholders to obtain their perspectives on the pilot designs and on the design framework. Group discussions were conducted with children, educators and senior management teams in the three pilot schools, using child-friendly versions of the designs with students and full plans with educators. Common discussion prompts were used to ensure consistency across schools while allowing participants to raise issues relevant to their context. In all, discussions were held with 487 children and 89 teaching staff, as primary users of the spaces, while seven administration members (Heads of School, Assistant Heads) from across the schools were included as an extension of this category. Ethical approval and the necessary permissions to conduct research in schools were obtained from the relevant state education and church authorities.

Information sheets and consent documentation were provided to participating educators and school administrations, while parents were informed through an opt-out procedure.

To complement in-school stakeholder discussions, semi-structured interviews were conducted with experts selected through purposive sampling. Participants were chosen to represent the range of disciplines informing the framework and included individuals with expertise relevant to school design, education, ecology and related fields. Prior to the interviews, participants received background information on the project, profiles of the pilot schools, and discussion prompts. Interviews were conducted online or face-to-face and explored both the conceptual framework and its application within the pilot school designs.

This process enabled triangulation of perspectives from end users and subject specialists, providing validation of the framework and providing insights to enable refinements to the designs.

Results

The stakeholder process yielded broadly positive appraisals from children and educators. Pupils expressed enthusiasm for sensory-rich areas and stewardship opportunities. Pupil feedback added a crucial layer of validation by showing how the framework is experienced in practice. Children responded most positively to opportunities for exploration, sensory engagement, and autonomy, suggesting that less structured activities enhanced curiosity and meaningful interaction with nature. At the same time, some responses suggested that, without pedagogical guidance, engagement with nature may remain largely descriptive. For example, children commonly associated bees with flowers, honey, or stings, and frequently referred to birds in general terms, yet none identified particular species despite the presence of common and easily observable birds such as robins and sparrows within the school grounds. Again, children commented about butterfly pupae they saw hatching, but none could tell which type of butterfly this was, nor did their observations extend to the plants on which they found the butterfly. Such findings suggest familiarity with broad nature concepts but limited attention to ecological detail.

Additionally, in several discussions, deeper ecological considerations appeared only after prompting. For example, when debating the inclusion of a greenhouse, children initially supported both conservation and greenhouse construction simultaneously, with more nuanced reasoning about habitat accessibility for wildlife emerging only through facilitated dialogue. Pupils also highlighted practical barriers (e.g., limited time, environmental discomfort, or unclear task purpose), which affect engagement and learning depth.

Teachers similarly demonstrated strong enthusiasm for NBL but variable ecological knowledge. Discussions frequently revealed curiosity and willingness to learn, yet explanations of ecological phenomena were often tentative, suggesting that effective implementation may depend on accompanying professional development that supports ecological interpretation as well as pedagogical practice. For example, one teacher described observing large numbers of butterflies during a lesson yet acknowledged being unable to identify the species or explain why they were present ("Did you know what butterfly it was?" – "No"; "Did you know why you were seeing a lot?" – "Cos of the shrubs, I think. I don't know. I'm not confident"). In general, teachers supported the framework through their willingness to apply it in practice, indicating strong alignment with classroom priorities, while emphasising the importance of gathering spaces and clear supervision lines and sharing feasibility concerns.

Expert feedback was broadly supportive of the framework and its underlying aim of facilitating connectedness with nature through school grounds design, while simultaneously highlighting important tensions in its implementation. A recurring theme was the need for stakeholder engagement at multiple levels, with experts emphasising that the success of NBL spaces depends not only on physical design but also on leadership support, teacher confidence, and meaningful participation by school communities. Discussions also revealed disciplinary differences in how the framework was initially interpreted. Experts with interdisciplinary backgrounds tended to recognise the relationship between ecological and pedagogical objectives more readily, whereas those working primarily within a single domain often

required further explanation of the framework's integrative logic. Several experts challenged aspects of the design, particularly the balance between child-led exploration and ecological protection, raising concerns that structured spaces might constrain opportunities for free engagement with nature. However, these critiques frequently evolved into recognition that the ecological limitations of small urban sites necessitate intentional design strategies capable of generating repeated and meaningful encounters with living systems while safeguarding ecological function. Another important observation concerned the risk of providing what one expert described as "sanitised" nature experiences, where children observe nature without engaging with ecological processes in situ. Collectively, these discussions reinforced the framework's central premise that effective NBL spaces require more than the introduction of green elements; they require deliberate integration of ecological, educational, and social considerations to transform limited urban school grounds into environments capable of supporting both ecological literacy and long-term stewardship.

These discussions informed refinement of the framework, particularly in clarifying zoning logic, reinforcing teacher-oriented spatial features, and ensuring planting strategies remained manageable within school maintenance capacities.

Limitations

The siting of this study within a specific cultural and geographic context constitutes its main limitation. While the framework is designed for adaptability, its application in other regions will require calibration to local ecological, climatic, and institutional conditions. Additionally, the validation process would be enhanced by a longitudinal perspective; further research is thus needed to examine whether and how sustained exposure to such environments influences CWN and pro-environmental behaviour over time.

Furthermore, the stakeholder appraisal evaluated the framework's perceived relevance and feasibility rather than its impact on children's learning or connectedness with nature. Future research

should therefore focus on empirical testing of behavioural and cognitive outcomes associated with framework implementation, including longitudinal studies that record changes in children connection with nature, ecological literacy, and wellbeing. There is also scope to explore integration with emerging approaches such as citizen science and nature-based solutions, as well as to investigate maintenance models and policy mechanisms that support widespread adoption in urban school systems.

Conclusion

This study responds to an important gap in outdoor and environmental education by providing an evidence-informed framework for designing nature-based learning spaces in small, urban primary schools. Building on research into connectedness with nature, developmental psychology, ecology, and environmental design, the framework translates interdisciplinary theory into practical guidance for school-ground planning within the spatial constraints typical of densely urbanised settings.

Rather than viewing limited outdoor space as a barrier to nature-based learning, the framework demonstrates how thoughtful vegetation planning, age-responsive affordances, ecological processes, and curriculum-linked spatial organisation can transform even small school grounds into meaningful learning environments. The pilot applications further suggest that successful implementation depends not only on physical design but also on teacher confidence, leadership support, ecological knowledge, and realistic maintenance planning. These findings reinforce the view that school grounds should be considered integral components of teaching and learning rather than peripheral recreational spaces.

For outdoor and environmental education, the framework offers a practical resource that bridges theory and practice. It provides educators, school leaders, designers, and policymakers with guidance for creating learning environments that encourage regular, meaningful engagement with nature while supporting ecological literacy and the development of children's connectedness with nature. Although developed within the context of Malta, the framework is intended to be adaptable to

other urban settings where land availability is limited and schools face similar challenges in providing everyday opportunities for nature-based learning.

Future research should move beyond framework development to examine its implementation and long-term educational outcomes, including its influence on children's connectedness with nature, ecological understanding, environmental stewardship, and wellbeing. Longitudinal evaluation across diverse educational and cultural contexts would further strengthen the evidence base for designing school grounds that support high-quality outdoor and environmental education.

Clinical trial declaration

Clinical trial number: not applicable.

Funding declaration

This article was adapted for publication in Journal of Outdoor and Environmental Education, from a doctoral dissertation supported by the Tertiary Education Scholarship Scheme.

References

Ayres, A. J., & Robbins, J. (2005). *Sensory integration and the child: Understanding hidden sensory challenges*. Western psychological services.

Barakat, H., Bakr, A., & El Sayad, Z. (2019). Nature as a healer for autistic children. *Alexandria Engineering Journal*, *58*. https://doi.org/10.1016/j.aej.2018.10.014

Barbaro, N., & Pickett, S. M. (2016). Mindfully green: Examining the effect of connectedness to nature on the relationship between mindfulness and engagement in pro-environmental behavior. Personality and Individual Differences, 93, 137–142. https://doi.org/10.1016/j.paid.2015.05.026

Barrable, A. (2019). Refocusing environmental education in the early years: A brief introduction to a pedagogy for connection. *Education Sciences*, *9*(1), 61-. https://doi.org/10.3390/educsci9010061

Barragan-Jason, G., de Mazancourt, C., Parmesan, C., Singer, M. C., & Loreau, M. (2022). Human–nature connectedness as a pathway to sustainability: A global meta-analysis. *Conservation Letters*, *15*(1), e12852-n/a. https://doi.org/10.1111/conl.12852

Barrette, Boyer, W., Naylor, P., & Harper, N. (2022). Defining a nature-based literacy: A research synthesis review of health-promoting literacies to promote nature engagement. *Journal of Adventure Education and Outdoor Learning*, *24*(3), 365–385. https://doi.org/10.1080/14729679.2022.2067201

Beery, T., Stahl Olafsson, A., Gentin, S., Maurer, M., Stålhammar, S., Albert, C., Bieling, C., Buijs, A., Fagerholm, N., Garcia-Martin, M., Plieninger, T., & M. Raymond, C. (2023). Disconnection from nature: Expanding our understanding of human–nature relations. *People and Nature*, *5*(2), 470–488. https://doi.org/10.1002/pan3.10451

Berman, J. D., McCormack, M. C., Koehler, K. A., Connolly, F., Clemons-Erby, D., Davis, M. F., Gummerson, C., Leaf, P. J., Jones, T. D., & Curriero, F. C. (2018). School environmental conditions and links to academic performance and absenteeism in urban, mid-Atlantic public schools. *International Journal of Hygiene and Environmental Health*, *221*(5), 800–808. https://doi.org/10.1016/j.ijheh.2018.04.015

Berthon, K., Thomas, F., Baumann, J., White, R., Bekessy, S., & Encinas-Viso, F. (2023). Floral resources encourage colonisation and use of green roofs by invertebrates. *Urban Ecosystems*, *26*(6), 1517–1534. https://doi.org/10.1007/s11252-023-01392-2

Borsos, É., Banos-González, I., Boric, E., Lyngved Staberg, R., & Fekete, A. B. (2022). Trainee teachers' perceptions of outdoor education. *Environmental Education Research*, *28*(10), 1490–1509. https://doi.org/10.1080/13504622.2022.2031901

Bruner, J. (1990). *Acts of meaning* (pp. xvii, 179). Harvard University Press.

Capaldi, C. A., Dopko, R. L., & Zelenski, J. M. (2014). The relationship between nature connectedness and happiness: A meta-analysis. *Frontiers in Psychology*, *5*. https://doi.org/10.3389/fpsyg.2014.00976

Carmi, N., Arnon, S., & Orion, N. (2015). Transforming environmental knowledge into behavior: The mediating role of environmental emotions. The Journal of Environmental Education, 46, 183–201. https://doi.org/10.1080/00958964.2015.1028517

Carson, R. (1956). Help your child to wonder. *Woman's Home Companion*, 73, 38–39, 118–120.

Chawla, L., & Rivkin, M. (2014). Early childhood education for sustainability in the United States of America. In *Research in Early Childhood Education for Sustainability*. Routledge.

Chawla, L. (2018). Nature-based learning for student achievement and ecological citizenship. *Curriculum and Teaching Dialogue*, *20*(1–2).

Chawla, L. (1999). Life paths into effective environmental action. *The Journal of Environmental Education*, *31*(1), 15–26. https://doi.org/10.1080/00958969909598628

Clark, C., & Sörqvist, P. (2012). A 3 year update on the influence of noise on performance and behavior. *Noise and Health*, *14*(61), 292-296.

Coyle, K. (2005). *Environmental literacy in America: What ten years of NEETF/Roper research and related studies say about environmental literacy in the U.S.* National Environmental Education & Training Foundation. https://files.eric.ed.gov/fulltext/ED522820.pdf

Dennis Jr, S., Wells, A., & Bishop, C. (2014). A Post-Occupancy Study of Nature-Based Outdoor Classrooms in Early Childhood Education. Children, Youth and Environments, 24. https://doi.org/10.7721/chilyoutenvi.24.2.0035

Descola, P. (2012). Beyond nature and culture. HAU: Journal of Ethnographic Theory, 2, 473. https://doi.org/10.14318/hau2.1.021

Dobson, A., Hutchinson, M. C., & Batterman, S. (2023). Plant communities and food webs. *Frontiers in Ecology and Evolution*, *11*. https://doi.org/10.3389/fevo.2023.1253084

Erdoğan, M. (2011). The effects of ecology-based summer nature education program on primary school students' environmental knowledge, environmental affect and responsible environmental behavior. *Educational Sciences: Theory & Practice*, *11*, 2233–2237.

Erdoğan, M., & Özsoy, A. M. (2007). Graduate students' perspectives on the human-environment relationship. Journal of Turkish Science Education, 4(2), 21–30. https://www.tused.org/index.php/tused/article/view/665

Elliott, S., & Davis, J. M. (2020). Challenging taken-for-granted ideas in early childhood education: A critique of Bronfenbrenner's ecological systems theory in the age of post-humanism—Southern Cross University (pp. 1119–154) https://researchportal.scu.edu.au/esploro/outputs/bookChapter/Challenging-taken-for-granted-ideas-in-early-childhood/991012821947302368

Erikson, E. (1950). *Childhood and society*. Norton & Company.

Evans, G. W., Otto, S., & Kaiser, F. G. (2018). Childhood origins of young adult environmental behavior. *Psychological Science*, *29*(5), 679–687. https://doi.org/10.1177/0956797617741894

Falzon, D., & Conrad, E. (2024). Designing primary school grounds for Nature-based learning: A review of the evidence. *Journal of outdoor and environmental education*, *27*(3), 437-468.

Ferrini, F., Fini, A., Mori, J., & Gori, A. (2020). Role of vegetation as a mitigating factor in the urban context. *Sustainability*, *12*(10), 4247.Flax et al., 2020

Frick, J., Kaiser, F. G., & Wilson, M. (2004). Environmental knowledge and conservation behavior: Exploring prevalence and structure in a representative sample. *Personality and Individual Differences*, *37*(8), 1597–1613. https://doi.org/10.1016/j.paid.2004.02.015

Fröbel, F. (1826). *The education of man* (H. E. Hailmann, Trans.). D. Appleton and Company.

Gibson, E., & Rader, N. (1979). Attention: The perceiver as performer. In *Attention and cognitive development* (pp. 1-21). Boston, MA: Springer US.Gwizdka & Lopatovska, 2009

Giusti, M., Svane, U., Raymond, C. M., & Beery, T. H. (2018b). A framework to assess where and how children connect to nature. Frontiers in Psychology, 8, 2283–2283. https://doi.org/10.3389/fpsyg.2017.02283

Green, C., Kalvaitis, D., & Worster, A. (2016). Recontextualizing psychosocial development in young children: A model of environmental identity development. Environmental Education Research, 22(7), 1025-1048.

Grimwood, B. S. R., Gordon, M., & Stevens, Z. (2023). Cultivating nature connection: Instructor narratives of urban outdoor education. Journal of Experiential Education, 41(2), 204. https://doi.org/10.1177/1053825917738267

Heft, H. (2010). Affordances and the perception of landscape: An inquiry into environmental perception and aesthetics. *Innovative Approaches to Researching Landscape and Health*, 9–32.

Høyem, J. (2020). Outdoor recreation and environmentally responsible behavior. *Journal of Outdoor Recreation and Tourism*, *31*, 100317.

Hsu, C.-H. (2025). Outdoor environmental education as a nature-based solution for “education” and “environment”: A new conceptual framework and its pilot application in a coastal community case study in Taiwan. *Journal of Coastal Conservation*, *29*(1), 13. https://doi.org/10.1007/s11852-025-01099-w

Hunter, R. F., de La Haye, K., Murray, J. M., Badham, J., Valente, T. W., Clarke, M., & Kee, F. (2019). Social network interventions for health behaviours and outcomes: A systematic review and meta-analysis. *PLoS medicine*, *16*(9), e1002890.

International Union for the Conservation of Nature and natural Resources. (1971). European working conference on environmental conservation education. Biological Conservation, 4(1), 39. https://doi.org/10.1016/0006-3207(71)90054-1

Johnson, N. M., Hoffmann, A. R., Behlen, J. C., Lau, C., Pendleton, D., Harvey, N., Shore, R., Li, Y., Chen, J., Tian, Y., & Zhang, R. (2021). Air pollution and children's health—A review of adverse effects associated with prenatal exposure from fine to ultrafine particulate matter. *Environmental Health and Preventive Medicine, 26*(1), 72. https://doi.org/10.1186/s12199-021-00995-5

Jordan, C., & Chawla, L. (2019). A coordinated research agenda for nature-based learning. *Frontiers in Psychology, 10, 766.*

Jordan, C., Charles, C., & Cleary, A. (2017). Enhancing the impact of research: Experimenting with network leadership strategies to grow a vibrant nature-based learning research network. *Interdisciplinary Journal of Partnership Studies*, *4*(3). https://doi.org/10.24926/ijps.v4i3.175

Kandemir, M., & Sevimli-Celik, S. (2023). No muddy shoes, no dirty clothes! Examining the views of teachers and parents regarding children's outdoor play and learning. *Journal of Adventure Education and Outdoor Learning*, *23*(3), 301–322. https://doi.org/10.1080/14729679.2021.2011339

Kaplan, S. (1992). The restorative environment: Nature and human experience. In D. Stokols & I. Altman (Eds), *Human behavior and environment: Advances in theory and research* (Vol. 6, pp. 1–16). Springer. https://www.semanticscholar.org/paper/The-Restorative-Environment%3A-Nature-and-Human-Kaplan/84bb4e22b16ea2be45a79300bed28197103cd1d9

Keniger, L. E., Gaston, K. J., Irvine, K. N., & Fuller, R. A. (2013). What are the benefits of interacting with nature? *International Journal of Environmental Research and Public Health*, *10*(3), 913–935. https://doi.org/10.3390/ijerph10030913

Khan, P. H., & Kellert, R. K. (Eds). (2002). *Children and Nature Psychological, Sociocultural, and Evolutionary Investigations*. The MIT Press Cambridge, Massachusetts London, England.

Largo-Wight, E., Guardino, C., & Hall, K. (2020). Cultivating healthy schools: The feasibility of an outdoor classroom in a public elementary school. *Florida Public Health Review*, *17*(1). https://digitalcommons.unf.edu/fphr/vol17/iss1/7

Larson, L. R., Szczytko, R., Bowers, E. P., Stephens, L. E., Stevenson, K. T., & Floyd, M. F. (2019). Outdoor time, screen time, and connection to nature: Troubling trends among rural youth? *Environment and Behavior*, *51*(8), 966–991. https://doi.org/10.1177/0013916518806686

Latour, P. (1999). *Politics of nature: How to bring science into democracy*. La Découverte.

Lengieza, M. L., Aviste, R., & Swim, J. K. (2023). Nature as community: An overlooked predictor of pro-environmental intentions. *Journal of Environmental Psychology*, *91*, 102127. https://doi.org/10.1016/j.jenvp.2023.102127

Liefländer, A. K., Fröhlich, G., Bogner, F. X., & Schultz, P. W. (2013). Promoting connectedness with nature through environmental education. *Environmental Education Research, 19(3), 370–384. Https://Doi.Org/10.1080/13504622.2012.697545*.

Lin, L. Z., Chen, J.-H., Yu, Y.-J., & Dong, G.-H. (2023). Ambient air pollution and infant health: A narrative review. *EBioMedicine*, *93*, 104609. https://doi.org/10.1016/j.ebiom.2023.104609

Louv, R. (2005). Last child in the woods: Saving our children from nature-deficit disorder. Algonquin Books.

Mah, V. K., & Ford-Jones, E. L. (2012). Spotlight on middle childhood: Rejuvenating the 'forgotten years'. *Paediatrics & Child Health*, *17*(2), 81–83. https://doi.org/10.1093/pch/17.2.81

Mann, J., Gray, T., Truong, S., Brymer, E., Passy, R., Ho, S., Sahlberg, P., Ward, K., Bentsen, P., Curry, C., & Cowper, R. (2022). Getting out of the classroom and into nature: A systematic review of nature-specific outdoor learning on school children's learning and development. *Frontiers in Public Health*, *10*, 877058. https://doi.org/10.3389/fpubh.2022.877058

Mayer, F. S., Frantz, C. M., Bruehlman-Senecal, E., & Dolliver, K. (2009). Why Is nature beneficial? The role of connectedness to nature. *Environment and Behavior*, *41*(5), 607–643. https://doi.org/10.1177/0013916508319745

National Statistics Office. (2024). *Regional statistics Malta. 2024 edition*. https://nso.gov.mt/wp-content/uploads/Regional-Statistics-2024-Digital-final.pdf

Ng, S. T., Leung, A. K. -y., & Chan, S. H. M. (2023). Through the lens of a naturalist: How learning about nature promotes nature connectedness via awe. Journal of Environmental Psychology, 92, 102069. https://doi.org/10.1016/j.jenvp.2023.102069

Norman, D. (2004). Affordances and design. *Unpublished article, available online at: http://www. jnd. org/dn. mss/affordances-and-design. html*, *14*

Nowak, D. J., Hirabayashi, S., Bodine, A., & Greenfield, E. (2014). Tree and forest effects on air quality and human health in the United States. *Environmental Pollution*, *193*, 119–129. https://doi.org/10.1016/j.envpol.2014.05.028

OECD. (2011, September 29). *Designing for Education*. OECD. https://www.oecd.org/en/publications/designing-for-education_9789264112308-en.html

Oh, R. R. Y., Suarez-Castro, A. F., Fuller, R. A., Tervo, M., Rozario, K., Peters, B., Chowdhury, S., von Gönner, J., Friedrichs-Manthey, M., Berger, A., Schultz, T., Dean, A. J., Tulloch, A., & Bonn, A. (2025). Using nature-based citizen science initiatives to enhance nature connection and mental health. *Frontiers in Environmental Science*, *13*. https://doi.org/10.3389/fenvs.2025.1461601

Otto, S., & Pensini, P. (2017). Nature-based environmental education of children: Environmental knowledge and connectedness to nature, together, are related to ecological behaviour. Global Environmental Change, 47, 88–94. https://Doi.Org/10.1016/j.Gloenvcha.2017.09.009.

Ortega-García, J. A., Martínez-Gómez, C., Bach, A., Benitez-Rodríguez, L., & Ramis, R. (2024). A growing disconnection from nature. Urgent call to action for a nature prescription global health alliance. *Anales de Pediatría (English Edition)*, *100*(6), e10–e12. https://doi.org/10.1016/j.anpede.2024.03.004

Ow, L. F., & Ghosh, S. (2017). Urban cities and road traffic noise: Reduction through vegetation. *Applied Acoustics*, *120*, 15-20.

Peresso, R. (2016). *Malta+5: Insights on the pedagogical culture in Maltese primary schools through international comparisons*.

Piaget, J. (1952). *The psychology of the child*. Basic Books.

Pykett, J., Osborne, T., & Resch, B. (2020). From urban stress to neurourbanism: how should we research city well-being?. *Annals of the American Association of Geographers*, *110*(6), 1936-1951.

Pyle, R. M. (2003). Nature matrix: Reconnecting people and nature. *Oryx*, *37*(2), 206–214. https://doi.org/10.1017/S0030605303000383

Reed, E. S. (1996). *Encountering the world: Toward an ecological psychology* (pp. vii, 214). Oxford University Press.

Ritchie, H., Samborska, V., & Roser, M. (2024). Urbanization. Our World in Data. https://ourworldindata.org/urbanization

Roczen, N., Kaiser, F. G., Bogner, F. X., & Wilson, M. (2014). A competence model for environmental education. *Environment and Behavior*, *46*(8), 972–992. https://doi.org/10.1177/0013916513492416

Ross, N. (2020). Anthropocentric tendencies in environmental education: A critical discourse analysis of nature-based learning. Ethics and Education, 15(3), 355–370. https://doi.org/10.1080/17449642.2020.1780550

Saracho, O. N. (2023). Theories of child development and their impact on early childhood education and care. *Early Childhood Education Journal*, *51*(1), 15–30. https://doi.org/10.1007/s10643-021-01271-5

Schultz, P. W., & Tabanico, J. (2007). Self, identity, and the natural environment: Exploring implicit connections with nature. *Journal of Applied Social Psychology*, *37*(6), 1219–1247. https://doi.org/10.1111/j.1559-1816.2007.00210.x

Sharma-Brymer, V., Brymer, E., Gray, T., & Davids, K. (2018). Affordances guiding Forest School practice: The application of the ecological dynamics approach. *Journal of Outdoor and Environmental Education*, *21*(1), 103–115. https://doi.org/10.1007/s42322-017-0004-3

Sicard, P., Agathokleous, E., Araminiene, V., Carrari, E., Hoshika, Y., De Marco, A., & Paoletti, E. (2018). Should we see urban trees as effective solutions to reduce increasing ozone levels in cities? *Environmental Pollution*, *243*(Pt A), 163–176. https://doi.org/10.1016/j.envpol.2018.08.049

Soga, M., Gaston, K., Yamaura, Y., Kurisu, K., & Hanaki, K. (2016). Both direct and vicarious experiences of nature affect children's willingness to conserve biodiversity. *International Journal of Environmental Research and Public Health, 13(6), 529-. Https://Doi.Org/10.3390/Ijerph13060529*.

Soper, Ka. (1995). *What is nature? Culture, politics and the non-human*. Blackwell.Stevenson et al., 2020

Sugiyama, N., Hosaka, T., Takagi, E., & Numata, S. (2021). How do childhood nature experiences and negative emotions towards nature influence preferences for outdoor activity among young adults? *Landscape and Urban Planning*, *205*, 103971. https://doi.org/10.1016/j.landurbplan.2020.103971

Sulfa, D. M., Suwono, H., & Husamah, H. (2024). Human Connection with Nature Improves Wellbeing and Pro-Environmental Behavior: A Literature Review. *Journal of Biological Education Indonesia (Jurnal Pendidikan Biologi Indonesia)*, *10*(2), 698-713.

Taylor, H., & Wright, S. (2020). *Urban schools: Designing for high density*. RIBA Publishing. https://doi.org/10.4324/9780429348099

Terzakis, M. E., Dohmen, M., van Kamp, I., & Hornikx, M. (2022). Noise indicators relating to non-auditory health effects in children—A systematic literature review. *International Journal of Environmental Research and Public Health*, *19*(23), 15633.

The World Bank. (2022). *World development report 2022: Finance for an equitable recovery* [Text/HTML]. World Bank. https://www.worldbank.org/en/publication/wdr2022

United Nations Development Program. (n.d.). *Sustainable development goals*. UNDP. Retrieved 15 September 2025, from https://www.undp.org/sustainable-development-goals

United Nations General Assembly. (2022). *The human right to a clean, healthy and sustainable environment* (Resolution A/RES/76/300). United Nations. https://digitallibrary.un.org/record/3983329

Vygotsky, L. (1934). *Thought and Language* (E. Hanfmann & G. Vakar, Trans.). https://mitpress.mit.edu/9780262720014/thought-and-language/

Wang, P.-C., & Yu, C.-Y. (2018a). Aesthetic experience as an essential factor to trigger positive environmental consciousness. Sustainability, 10(4), 1098. https://doi.org/10.3390/su10041098

Xerri Hili, C., & Schembri, H. (2022). Cross-curricular teaching within the learning outcomes framework: The experiences of primary teachers in two state schools in Malta. *Malta Journal of Education*, *3*(2), 231–258. https://doi.org/10.62695/JEGZ4440

Xu, J., Liu, N., Polemiti, E., et al. (2023). *Effects of urban living environments on mental health in adults*. *Nature Medicine, 29*(6), 1456–1467. https://doi.org/10.1038/s41591-023-02365-w

Yue, Z., & Chen, J. (2023). Direct, indirect, and vicarious nature experiences collectively predict preadolescents' self-reported nature connectedness and conservation behaviors. PeerJ, 11, e15542. https://doi.org/10.7717/peerj.15542

Zhang, X. Q. (2016). The trends, promises and challenges of urbanisation in the world. *Habitat International*, *54*, 241–252. https://doi.org/10.1016/j.habitatint.2015.11.018

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementarymaterial.docx