Journal of Outdoor and Environmental Education
https://doi.org/10.1007/s42322-023-00142-4

REVIEW PAPER

Designing primary school grounds for Nature-based learning: A review of the evidence

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Accepted: 18 October 2023

Abstract

Nature-based learning within the primary school curriculum offers numerous potential benefits. However, there is a lack of clarity about how school grounds can be designed to enable effective nature-based learning. There is also little knowledge of how specific features within green school grounds contribute to specific desirable outcomes, such as improved academic performance or health. To address this gap, a systematised review of peer-reviewed academic literature was undertaken, with 173 databases searched from January to December 2021. The search included studies of nature-based learning on school grounds and literature concerned with the design of green school grounds for fostering nature connectedness and broader educational outcomes for primary school children aged 5 to 11. No date or geographical restrictions were applied. Of a total of 285 articles initially identified, 11 matched the inclusion criteria. Results from these indicate significant research gaps on the design of green learning spaces in schools. While studies note apparent positive links between nature-based learning in school grounds and improved subject-specific learning, wellbeing, and nature connectedness, there is very little empirical evidence of how specific design features are linked to specific outcomes. Furthermore, the current evidence base is poorly representative of different social, cultural, and geographical contexts and not fully reflective of all primary schooling ages. The challenging contexts of urban schools and schools with small footprints are also inadequately addressed. These findings indicate an urgent need for increased research to guide the design of school grounds for the implementation of nature-based learning programmes for primary school learners.

Keywords Nature-based learning · School grounds · Urban · Design · Nature connectedness

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Published online: 27 November 2023

Introduction

Connecting children with nature has attracted increasing attention in the field of education due to its multiple benefits to children's health (McCormick, 2017), socio-emotional development (Mygind et al., 2021), and educational outcomes (Mann et al., 2021). Among these benefits are enhanced concentration, improved academic performance, reduced aggression, and a lower risk of obesity among children (Faber Taylor & Kuo, 2011). In this context, nature-based learning (NBL) has emerged as an approach that integrates principles of nature into educational practice while enhancing the overall learning experience for children. NBL is defined as "learning through exposure to nature and nature-based activities, [which] occurs in natural settings and where elements of nature have been brought into built environments" (Jordan & Chawla, 2019, p. 2). This is distinct from nature-based play (Miller et al., 2021), which refers to unstructured activity in nature, where the extent of the nature experience cannot be assumed (Raith, 2017). While we recognise that "nature" is an ambiguous concept, in this paper we adopt a definition rooted in the practical application of nature as a medium for learning outside the classroom: "all the animals, plants, and other things in the world that are not caused by people" (Collins English Dictionary, 2023).

Nature-based learning can be facilitated in multiple ways, including by using nature for supporting the teaching of curriculum subjects (Chawla, 2018). Embedding nature in the mainstream educational curriculum has the advantage of providing opportunities for regular experiences in nature to children in urban environments, thus mitigating inequity of children's access to nature (Stevenson et al., 2020). A NBL approach to the curriculum fosters knowledge and affective domains simultaneously (Palmberg & Kuru, 2000), both of which are important to motivate environmental action (Liu et al., 2020). This study makes the assumption that to achieve this combination of elements, NBL must occur in a nature-based environment *outside* the classroom where the experience has the potential to be immersive. This assumption stems from an ecological psychology framework that views the most effective learning in a learning context as that which emerges from a person-environment relationship and utilizes both the functional and relational properties of this environment (Sharma-Brymer et al., 2018). This also relates to Gibson's theory of affordances and the properties of an environment that support development (Khan et al., 2020). Since the quality of nature in the indoors classroom is limited in complexity, unpredictability, multi-sensoriality and multi-dimensionality, it cannot provide the depth of experience necessary for NBL. At the same time, educators may not easily be able to access immersive nature spaces that are suitable for NBL, and there is evidence of considerable inequity in school-based access to nature (Baró et al., 2021; Fernández et al., 2022; van Velzen & Helbich, 2023), with related social justice implications.

This study focuses on the role that school grounds can play in addressing the disparity children face in their access to nature. Use of school grounds has the potential to ensure children's regular access to a natural setting (Collado & Evans, 2019; Wallace, 2019; White et al., 2018), while eliminating costs (financial, environmental, or

time-related) of trips to and from destinations outside school. In this way NBL on school grounds directly reflects the concept of nature-based solutions, i.e. solutions inspired and supported by nature which are cost-effective, provide environmental, social and economic benefits, and bring more, and more diverse, nature and natural features and processes into cities (European Commission, n.d.). However, despite growing interest in green schoolyards and in the NBL approach (Danks, 2010; Jansson & Mårtensson, 2012; Van Dijk-Wesselius et al., 2020), there is a lack of clarity about *how* school grounds can be designed to enable effective NBL. Furthermore, there has been little explicit exploration of the link between specific design features of nature spaces in school grounds and specific desired outcomes (e.g., cognitive-academic, physical, emotional benefits). This is important in view of the fact that implementing changes to school grounds to support NBL requires financial investment and trade-offs that make it important for school administrators and policy-makers to know whether particular design features are linked to desired benefits. This is especially relevant to schools sited in urban areas, which are often built on small footprints, with limited open spaces. Such schools may be making choices between different options for the use of limited open spaces, further underlining the need for a framework to guide design. Indeed, it is of note that while many studies have highlighted the benefits of greening school grounds (Jansson & Mårtensson, 2012; Sedawi et al., 2021; Wells & Lekies, 2006), the natural settings described in several studies are unlikely to be available to small, urban schools. In this context, there is a need to empirically explore whether and how effective NBL learning spaces can also be created within urban schools.

The aim of this study was to determine the current state of knowledge with respect to design of school grounds for NBL. A systematized review of peer-reviewed literature was carried out to answer the following questions:

1. What evidence-based guidance exists for designing school grounds to achieve NBL through the primary school curriculum?
2. To what extent is such guidance applicable to schools in urban areas and/or with space constraints?
3. Are specific design features of green school grounds linked to specific desired outcomes?

The remainder of this paper is structured as follows. The next section elaborates on the contribution of NBL to ecological citizenship through nature connectedness. The following section explains the methods adopted for the systematized review, with results presented in the subsequent section. This is followed by a discussion of significant implications and key conclusions.

Nature-based learning: fostering motivation towards environmentally-responsible behavior

Chawla, (2018) notes that "teachers today work in a changing climate" (p. 1), raising the question of how educators will respond to the considerable challenges of

global environmental change. NBL has emerged as an approach that, in addition to offering various direct benefits to children (as outlined above), also has the potential to contribute to "the development of informed and motivated ecological citizenship" (Chawla, 2018, p. 3), particularly through its ability to foster enhanced nature connectedness. The term connectedness with nature (CN) is used in this paper in a broad sense to refer to the ways in which people identify themselves with the natural environment and the relationships they form with nature (Restall & Conrad, 2015).

Nature connectedness has the ability to generate intrinsic motivation to engage in pro-environment behaviors (Martin & Czellar, 2017; Rosa et al., 2018) by creating an emotional affinity with nature that allows individuals to view its destruction as self-destruction (Müller et al., 2009). In fact, it has been identified by several authors as a strong predictor of environmentally-responsible behavior, thus aiding a transition to more eco-friendly and sustainable practices (Alcock et al., 2020; Geng et al., 2015; Ives et al., 2017; Molinario et al., 2020; Restall & Conrad, 2015; Yang et al., 2018). The provision of environmental knowledge is also an essential component of environmentally responsible behavior. However, it alone is not sufficient in triggering positive behavior towards the environment because it lacks the affective element that stimulates motivation (Tamashiro et al., 2013). While it would be amiss to assume that CN is the only factor motivating environment-friendly behavior (Barrable & Booth, 2022), research has demonstrated that it is essential for mitigating environmental impacts (Otto & Pensini, 2017; Whitburn et al., 2020).

Furthermore, childhood is an important age for developing nature connectedness (Chawla & Gould, 2020) since early intervention tends to be more effective (Barrable & Booth, 2022) and maximizes the potential for the experience to have lifelong impact (Kollmuss & Agyeman, 2002; Liefländer et al., 2013). This is also the developmental period where integration in the social context occurs (Sobel, 1999) and where the motivation to behave in environmentally friendly ways is likely to be formed and to have lifelong impact (Evans et al., 2018; Pinder et al., 2020). Connecting children with nature in today's urbanized societies is increasingly challenging, even as it becomes more relevant (Chawla & Gould, 2020): there are currently more people living in urban areas than in rural areas (United Nations, 2018). As experiences in nature decline, children's interest in nature is likely to diminish (Soga et al., 2016), with various theories predicting a decline in people's opportunities to interact with nature (Soga & Gaston, 2022), increased nature apathy (Kesebir & Kesebir, 2017), a progressive decline in knowledge of nature (Gerl et al., 2021), and a progressive loss of daily interactions with nature (Pyle, 2002). The loss of such a connection is not inevitable and CN can potentially be fostered through various means, amongst which are experiential learning approaches such as place-based education (Smith, 2002; Sobel, 2008), of which NBL is often a component (Anderson, 2017). However, there does seem to be ample evidence supporting the presumption of a general decline in human-nature interactions within urbanised environments.

One solution to addressing these challenges in a global setting is for the connection with nature to be integrated into the schooling experience. This can not only contribute to enhanced CN but can also foster enhanced ecological literacy, defined in this context as an enhanced ablity to understand the organizational principles of natural ecological communities and to apply these to human communities (McBride et al.,

2013). Primary schooling is a highly appropriate global context for CN intervention since education is compulsory across regions and in 192 countries (UNESCO Institute for Statistics, 2004), with most countries having a minimum curriculum of five or six years of primary schooling (UNESCO Institute for Statistics, 2004). Furthermore, the school environment offers the possibility of frequent and regular contact with nature, both of which are characteristics that have been shown to affect development of CN (Cleary et al., 2020), especially in younger children (Kals et al., 1999). The emotional affinity towards nature has also been shown to become stronger the more concrete and specific the contact with nature (Soga et al., 2016). In this context, facilitation of NBL through the formal school curriculum offers a convenient and reliable context for regular and frequent engagement with nature, because it provides a wide subject range of opportunities for the educator to create such experiences.

Methods

Study scope

This review focused on the following:

- NBL that is *curriculum-based*, allowing regular and sustained contact with nature.
- NBL that targets primary schools and their age cohort of children aged 5 – 11. This age bracket was selected as it most commonly corresponds with years of compulsory schooling (UNESCO Institute for Statistics, 2004); these are also the most critical years for developing CN.
- NBL that is facilitated outside the classroom, within school grounds. While there is interest in integrated school design, which seeks to harmoniously blend both indoor and outdoor environments (e.g. Grietēna, 2015; Monsur, 2013), empirical research to support such holistic design remains limited and most NBL programmes presently remain focused on the outdoors.
- NBL that reflects a conceptualisation of nature rooted in the natural sciences, excluding applications such as agriculture. Agricultural practices often involve landscape simplification, which may result in the loss of biodiversity through biotic homogenization, reduced diversity of landcover types, and reduced configurational landscape heterogeneity, all of which have been shown to have ecological filter effects (Gámez-Virués et al., 2015). These may in turn have a detrimental impact on the human-nature connection (Sedawi et al., 2021).

Search strategy

Data were gathered through a systematized review (Grant & Booth, 2009). To the extent possible, PRISMA guidelines on the transparent reporting of systematic reviews and meta-analyses (Page et al., 2021) were followed (Fig. 1).

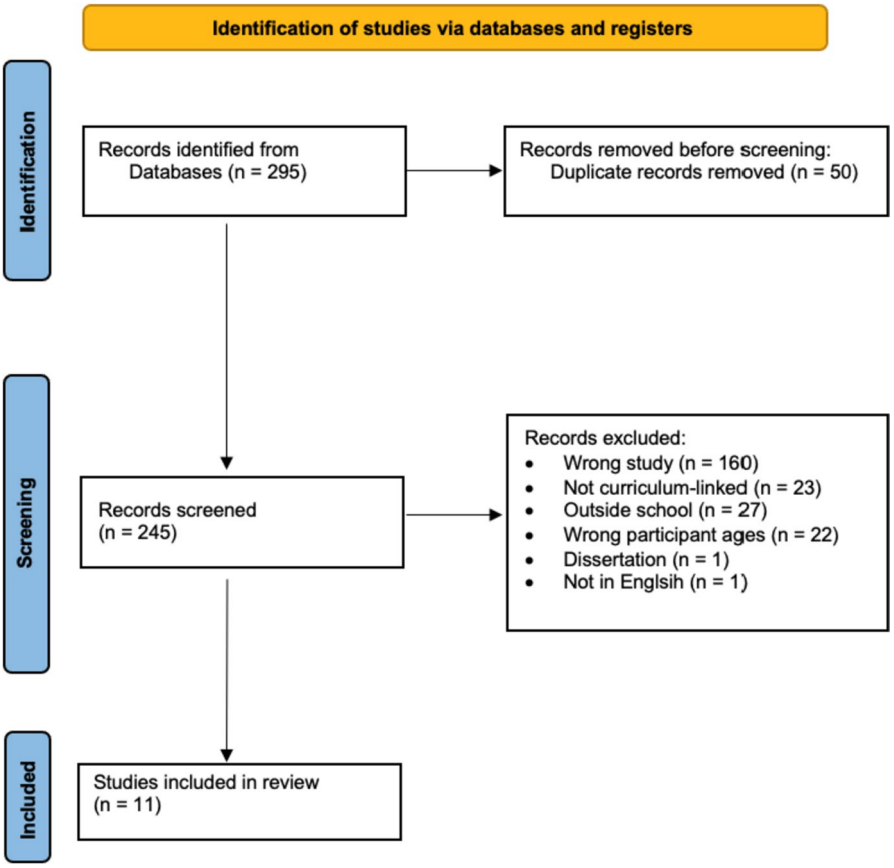

Fig. 1 PRISMA flowchart

A list of search terms was produced in relation to the theme of green school grounds in the context of nature-based learning and design. In order to ensure that the review comprehensively captured relevant literature, we first carried out a general search for terms associated with i) nature-based learning programs and ii) green school grounds. It was found that school grounds are also referred to as "schoolyards" and specific programmes can be carried out in "school gardens". NBL can be referred to in a variety of ways; however, the scanned literature always contained the words "nature" and "learning/education". Most of these terms carry broad interpretations. For example, while NBL is sometimes classified as "environmental education", this term covers a broad field of learning that does not necessarily include direct experience in nature. Likewise, "school gardens" are created for a variety of reasons and may be linked with horticulture or healthy eating, or physical activity, rather than with nature-based learning. Terms were thus adjusted and Boolean operators employed to obtain more focused coverage. The following terms were ultimately used for the systematized search: "green schoolyards", "green*

school grounds", "school gardens", "nature-based learning", "garden-based learning", "nature-based learning" AND (school grounds OR schoolyards), "nature-based education" AND (school grounds OR schoolyards), "outdoor classroom". "outdoor classroom" AND design*, "designing school grounds". No date restrictions were applied, i.e. all studies meeting the search criteria were included, regardless of their date of publication. The search was carried out using a search platform with access to 173 databases (Appendix 2), including Scopus, ScienceDirect, SpringerLink, Education Collection (Proquest), and ERIC.

Eligibility criteria

In line with the study scope, the following inclusion criteria were applied:

1. Scientific papers: only peer reviewed studies involving primary research
2. English language literature
3. Studies related to primary school ages (5 – 11 years)
4. Primary research about NBL programs using green school grounds as part of the formal curriculum experience (subject-based learning), and/or green spaces in school grounds in relation to the curriculum (program or outcomes)

Details of searches showing numbers of search results, and included/excluded studies are given in Appendix 1, Tables 1-3.

Selection process

The filters "peer reviewed journals", "articles" and "children" were applied to reduce the number of irrelevant studies that focused on community urban greening outside schools. The first author read titles and abstracts and screened whole articles where abstracts showed relevance to the inclusion criteria or if relevance was unclear. The second author independently screened two randomly selected samples of 50 results each (comprising 41% of all relevant studies). No disagreements were recorded.

Data extraction

Data from the studies that met the inclusion criteria were extracted by the first author, with results entered manually in Microsoft Excel© 2021 under the following headings:

- Search term
- Database
- Author/s and source of publication
- Included / Excluded (+reason)

Additional data collected for included studies are indicated in Table 1. Extracted data were then checked by the second author.

Table 1 Data collected for included studies

Category heading	Description
Location of study	Country and region characteristics where research was conducted (e.g. urban/rural)
Ages	Age in years ('Grade' translated into age according to the study country's educational system)
Philosophy	Stated principles underlying the design of the nature-based learning area, e.g. Attention Restoration Theory (Kaplan, 1980); architecture as pedagogy (Orr, 1997); place-based education
	Extracted principles of design from study, space or program description, e.g. deciduous trees have higher educational value due to their changing states
Design elements included	Natural elements described in the nature-based learning space and supporting man-made elements, e.g. trees, water feature, pathway, amphitheater
Stated program aims	Aims of nature-based learning program specified in the study
Stated study aims	Aims of the empirical study
Participant profile	Social demography, number of students/schools, use of control group
Study	The intervention: the nature-based learning program, or school grounds use being studied
Research design and features	Methodology for producing/testing outcomes: quantitative, qualitative, mixed, experimental Features: length, frequency, follow up
Outcomes included	Outcomes related to the nature-based learning or design study related to the inclusion criteria, e.g. improvement in academic subject, increase in connectedness with nature

Results were imported into Zotero (6.0) and organised under the tag 'included' if the studies were relevant, or where excluded, under the relevant exclusion tags (Appendix 1 – Table 3). Several excluded studies carried multiple tags. As noted above, in this study we adopted a natural science-based definition of nature; activities and school grounds spaces that focus *exclusively* on harvesting crops were therefore omitted from the review.

Limitations

While this review adhered to the parameters set by the search protocol, it is possible that relevant studies might have inadvertently been excluded. In particular, the empirical focus of this review excludes grey literature, that is, research material not formally published through traditional academic publishing channels, even though it is noted that there is a considerable, and growing, practice of NBL in schools initiated by organisations and the state sector worldwide (e.g., among others: Nature Friendly Schools, and Learning through Landscapes in the U.K.; Natural Start Alliance, and International School Grounds Alliance in the U.S.; Nature Classrooms, and Aranyaka Upanishad Forest School in India; Learning through Nature in South Africa). Additionally, this research excludes literature not in English.

Results

Included studies

A total of 295 studies were found through the systematized search. Following the removal of 50 duplicates identified by Zotero, 245 studies remained, of which 11 were found to be relevant or partially-relevant (Fig. 1). Details of the 11 included studies are presented in Table 2.

Design of school grounds for Nature-based learning

A key aim of this study was to determine whether there is evidence-based guidance for designing school grounds to achieve NBL through the primary school curriculum. None of the 11 studies reviewed include explicit design guidance or made reference to such, with school grounds seemingly designed on an ad hoc and case-by-case basis. All studies espouse a philosophy consistent with the view that green school grounds lead to improved student outcomes. However, only three of the study aims or programmes are linked with a particular green feature; hence, while there are random details of school grounds green spaces, none articulate a design framework. Table 3 thus presents *elements* of the green spaces described in these studies, rather than clear design parameters. The most common elements referred to are: trees, gardens, water features, and plants (n = 5). The most indicative insights as regards specific causal relationships are from Khan et al., (2019), who emphasise that the outdoor classroom or gathering space must be surrounded by natural elements for access during lessons, from Sivarajah et al., (2018), who conclude that diverse tree cover is the most significant vegetation factor contributing to academic performance, from Puhakka et al., (2019), who focus on exposure to biodiversity leading to improved physical and mental states, and from Zaballa et al., (2021), who deliberately introduce plants to increase children's knowledge and understanding of them. The age ranges of the sample populations in these studies, however, vary widely.

This study also seeks to examine what knowledge is available specifically to guide the implementation of NBL in small, urban schools. However, none of the included studies is based in school grounds with small footprints, as can be evidenced by the descriptions of natural spaces provided, though most studies ($n = 7$) are carried out in urban schools, often in poorer neighborhoods. In fact, the research aims in several of these studies are related to the effect of school grounds nature on children in urban schools (Camasso & Jagannathan, 2018; Khan et al., 2019, 2020; Sivarajah et al., 2018; Tucker & Izadpanahi, 2017; Zaballa et al., 2021). Two of the included studies' school grounds appear to have extensive and diverse spaces with pathways connecting multisensorial destinations (gardens, water themed areas, loose parts, opportunites for active learning and passive reflection). White et al., (2018) provide no description of the school grounds; however, by inference from the fact that the program's key focus is

Table 2 Results of systematised search: included studies

Study	Ref	Location of study	Participants	Stated program aims	Stated study aims	The program	Research design	Outcomes included
1	Khan et al., 2020	Bangladesh, poor urban schools, 1 intervention and 1 control	8–11 years (123)	Taking the curriculum outdoors to improve academic achievement, namely in maths and science	To investigate whether the use of the outdoors as a learning environment can help with issues such as low academic attainment	Maths and science taught outdoors in the school grounds over five months	Mixed methods; pre–post design using questionnaires and focus-group discussions	Higher exam scores in maths and science demonstrating that an outdoor space designed with purpose and bearing educational opportunities can enhance the academic achievement in developing countries
2	Khan et al., 2019	Bangladesh, poor urban school	9–11 years (30)	Taking the curriculum outdoors improves academic achievement, namely in maths and science	To investigate the impact of the outdoor classroom on students' learning and engagement; whether, and to what extent, the primary school outdoor environment was supportive of children's learning of the curriculum	The same group of children were taught two consecutive chapters of their science book in the classroom and then two chapters outdoors by their science teacher. Study period was five weeks	Multiple methods including achievement tests, a questionnaire and focus groups with children and teachers	Children's science scores significantly higher after they are taught outdoors, compared to indoors; greater enjoyment of science
3	Puhakka et al., 2019	Finland, the study was conducted in three big cities (with 100,000–300,000 inhabitants) located in the most densely populated and urbanized area of Finland	3–5 years (6 day-care yards)	Use of green materials in the children's various activities including 13 nature-based activities. The children also used the yard freely when they spent time outdoors every day (0.5–2 h in the morning and in the afternoon)	To determine whether simultaneously increasing biodiversity exposure and greening day-care yards is perceived to affect 3–5 years-old children's physical activity and play, their environmental relationships, and their well-being in the urban environment in Finland	Guided play activities in the modified area, for a month	Post-intervention blood samples; data included surveys completed by personnel (teachers and child nurses) and children's parents, and interviews of personnel. Semi-structured interviews one month after intervention	Green, biodiverse yards considered safe, inspiring children's play, diversifying their activities, and increasing physical activity. The greenery offers embodied experiences of nature and provides the children with multi-sensory exploration and diverse learning situations. The dynamic and emotional ways of engaging with the natural environment increase their well-being. The activities related to caring for the yards and exploring them promote the development of environmental relationships

Table 2 (continued)

Study	Ref	Location of study	Participants	Stated program aims	Stated study aims	The program	Research design	Outcomes included
4	Zaballa et al., 2021	Switzerland, two urban state schools, one with green areas in school grounds, the other with practically none	4–7 years (152)	No specific program	To provide the scientific community with additional data regarding the role that green areas within and around educational centres have in the promotion, throughout childhood, of more accurate knowledge about biodiversity and nature	No specific program	Examination of children's drawings of plants after increased exposure to environments with varying levels of greenness	The children in school A, with more accessibility to nature and green areas during their school day, might develop a more detailed and accurate comprehension of the plant world and its diversity. This may positively influence students' academic performance and enhance artistic inspiration
5	Sivarajah et al., 2018	Canada, Toronto: most populous city in Canada	8–9 years and 11–12 years (387 schools)	No specific program	To examine potential effects of tree cover, diversity, and species composition on academic performance-matched data	No specific program	Quantitative surveys using data collected by an independent agency to measure student performance in Grade 3 and Grade 6 for reading, writing, and mathematics between 2006 and 2010, using an independent measure of external challenges affecting student's academic performance	Tree cover is a better predictor of children's academic performance than other vegetation types

Table 2 (continued)

Study	Ref	Location of study	Participants	Stated program aims	Stated study aims	The program	Research design	Outcomes included
6	Camasso et al., 2018	United States, New Jersey elementary school: poor, urban neighborhood	9–13 years (65)	Pilot natural science and environmental education program for children from disadvantaged backgrounds in science and maths and overall academic performance, aligned with the curriculum taught by public school science and maths teachers, plus after-school and summer programs and extra tutoring	To evaluate the program's ability to improve academic outcomes in poor urban schools through NBL	A garden- and outdoor-based curriculum	Experimental design using one school over four years	Increase in mathematics and science scores, with the latter reaching statistical significance
7	Tucker & Izadpanahi, 2017	Australia, 3 newly-built sustainable schools and 4 conventionally built older schools in Victoria from suburban to semi-rural	10–12 years (275)	Based on a natural history paradigm that stresses the beauty and majesty of the natural environment and its capacity to teach as well as comfort	To test the hypothesis that children attending schools designed for sustainability will have attitudes and behaviors to the environment that are more pro-environmental than those attending conventionally designed schools	Varied: animal husbandry, growing plants and vegetables, propagation, planting, composting, and associated scientific concepts / no specific program / garden program	Quantitative, using a scale developed to measure children's environmental attitudes and a scale developed to measure children's environmental behaviors. Data collected from children aged between 10 and 12 years were analyzed using MANOVA	Statistically significant difference between environmental attitudes and behaviors of children attending schools designed for sustainability compared to children attending conventional schools

Table 2 (continued)

Study	Ref	Location of study	Participants	Stated program aims	Stated study aims	The program	Research design	Outcomes included
8 9 10 11	Green & Rayner, 2020 Loureiro & Dal-Farra, 2018 White et al., 2018 Wallace, (2019)	Australia, state school in outskirts of Melbourne Brazil, in an area of 3600 m^2 United Kingdom, 8 primary schools Australia, regional school of 400 students	7 to 12 years (62) 6–12 years (65) 7 – 10 years (220) 9–11 years (400)	Connecting children with nature through a problem-based learning task Activities to provide students with the most contact both with the environment, growing plants, and other species and with ecological aspects integrated into the morphophysiological and taxonomic questions traditionally taught in botany To increase awareness and knowledge of local biodiversity and to promote positive attitudes and behaviour towards the environment Part of a broader study on learning in a kitchen garden aiming to analyze the children's perceptions of their own learning, through their reflections on participation in the kitchen garden program	To investigate the impact of outdoor pedagogy and children's learning in a school ground environment To explore methods of teaching botany in context and link students' specific knowledge to values and practices that contribute to an environmental education that aims to minimize the utilitarian view of nature and move towards a view of human beings as integrated and interdependent with other living and non-living elements To assess individual awareness, knowledge of and attitudes towards birds by primary school children as a result of the program To give insight into whether kitchen garden programs can assist with connecting children to nature and developing ecoliteracy	Environmental learning in the garden and in the broader school ground, at least once a week Botany experiences on the school grounds accompanied by the subject teacher, once weekly over 6 months A six-week bird-feeding and monitoring project conducted within school grounds Weekly timetabled three-hour kitchen garden session. They rotated between gardening, cooking, and science/nature inquiries connected to the kitchen garden; additional access during break	A four-year place-based study conducting semi-structured interviews with three gardening/environmental primary teachers, their respective principals (×3), and 62 children Mixed method analysis of the results of activities through explorations, drawings, dried and pressed specimens, and semi-structured interviews Pre- and post-project questionnaires and a one-year follow-up with teachers to assess continued interest in birds and bird feeding at the class/school level Qualitative study: Focus group interviews, journal collection, and observations; narrative research	Findings showcase the ways outdoor learning can occur in school ground settings since the educational backdrop for children's learning occurred within a school ground environment, highlighting how locally-based curriculum and pedagogy enabled children's outdoor learning with each other, their teacher and the site's ecologies The natural environment can constitute a starting point and a destination for learning activities; it is necessary to establish educational practices that integrate the conceptual, attitudinal, and procedural view that human beings are a part of the environment. Moreover, such practices discourage a utilitarian view of nature and inspire a vision where we are interdependent with other living and non-living elements Increased awareness and interest in local wildlife amongst participating children Familiarity and ownership of the garden through repeated visits;, increased empathy with living creatures and interest in the natural environment

Table 3 Features of natural areas mentioned in included studies

	Study number corresponding to Table 2										
	1	2	3	4	5	6	7	8	9	10	11
Philosophy	Outdoor environment is more conducive to learning and play	Outdoor gathering space must be surrounded by natural elements for access during lessons	Increased natural microbial biodiversity found in forest floor improves physical and mental development	Access to plants contributes to a more detailed and accurate comprehension of the plant world and its diversity	A healthy and diverse array of tree species reduces feelings of anxiety and improves maths performance	Direct experience of nature improves maths and sciecne scores in disadvantaged children	Learning spaces designed for sustainability reflect pro-environmental values that can in turn inform pro-environmental values in children	Relation to place is constituted in stories and other representations and deep place learning occurs within a contact zone of multiple contested stories	The natural environment can constitute a destination for learning activities that can discourage the utilitarian view of nature and inspire a vision of interdependence with it	Experiential learning in nature can increase understanding of local nature and biodiveristy	Kitchen garden programs can assist with connecting children to nature and developing ecoliteracy

Table 3 (continued)

		Study number corresponding to Table 2										
		1	2	3	4	5	6	7	8	9	10	11
FEATURE	Trees		✓		✓	✓	✓		✓			
	Water features	✓					✓	✓	✓	✓		
	Paths linking areas	✓										
	Seating area	✓	✓						✓			
	Shade		✓									
	Separate elements	✓		✓								
	Gardens	✓					✓		✓	✓		✓
	Plants	✓			✓			✓		✓		✓
	Shrubs			✓								
	Planters			✓								
	Vegetable garden			✓			✓	✓	✓			
	Birds						✓				✓	
	Soil	✓										
	Forest floor			✓								
	Composting station with insects						✓					
	Natural play area							✓				
	Butterfly garden						✓		✓			
	Domestic animals							✓				
	Living roofs									✓		
	Vertebrateanimals				✓							
	Fungi				✓							

birdwatching, the school has natural spaces large enough for urban birds to frequent or may be surrounded by natural areas or gardens.

Outcomes of NBL programmes and links with design features

Three studies mention specific curricular outcomes (Camasso & Jagannathan, 2018; Khan et al., 2019, 2020), i.e., improved student performance in mathematics and/or science, though this result relates to older primary or even post-primary children. While the age range of the study by White et al., (2018) is fully within the inclusion criteria, it is unclear whether the six-week bird-feeding and monitoring project is related to the curriculum. Sivarajah et al., (2018) report improved general academic performance, although the age range does not correspond fully with the target age bracket of this research.

Only one of the studies (Khan et al., 2020) provides empirical evidence of links between green school grounds features and specific outcomes, in that it describes a design philosophy and how it translated into elements of the outdoors classroom (Table 3). None of the three studies that record improved outcomes in mathematics and science provide a description of the design elements that are potentially linked with these outcomes (Camasso & Jagannathan, 2018; Khan et al., 2019, 2020). The only descriptors of the green space where these studies are conducted are vague (e.g. "outdoor environment", "direct nature experience"), and general categories of elements (leaves, seeds or sticks from nature) of the natural areas (Table 3). Sivarajah et al., (2018) note tree cover as being a better predictor of children's academic performance than other vegetation, while Zaballa et al., (2021) describe improved comprehension of plants and plant diversity in the school with green areas over the control school**,** though it is not stated whether this knowledge is part of science lessons. None of these studies specifically refers to CN outcomes.

Among results that mention CN-related outcomes (Table 3), the study by Puhakka et al., (2019) is more of a preschool study but has been included in the review since it includes 5-year-olds and describes a program of learning activities; however, the activities mentioned are commonly associated with preschool learning, such as exploration, play, and multisensory experience rather than primary school traditional curriculum subjects. While Tucker & Izadpanahi's, (2017) study includes nature in the school grounds as part of its sustainability design ethos, the study is not designed to distinguish between the effects of the physical design aspects and the natural design aspects on the study's outcomes related to environment attitudes and behaviors.

Study characteristics

The evidence base produced by this review does not cover all primary school ages equally. Participant ages across the 11 studies (Table 3) mostly lie within the upper primary bracket, that is, 7 or 8 years and older (Camasso & Jagannathan, 2018; Green

& Rayner, 2022; Khan et al., 2019; Sivarajah et al., 2018; Tucker & Izadpanahi, 2017; White et al., 2018), with only three studies focusing on early to middle primary (Loureiro & Dal-Farra, 2018; Puhakka et al., 2019; Wallace, 2019; Zaballa et al., 2021).

Research methodologies across the 11 studies also vary greatly, with most employing mixed methods techniques (Camasso et al., 2018; Khan et al., 2019; Green & Rayner, 2020; Khan et al., 2020; Loureiro & Dal-Farra, 2018; Puhakka et al., 2019), two studies using quantitative methodology (Sivarajah et al., 2018; Tucker & Izadpanahi, 2017), one qualitative study (Zaballa et al., 2021), and one study applying experimental design (Camasso et al., 2018). Some studies are carried out over an extended period (Camasso et al., 2018; Green & Rayner, 2020), others hold post-intervention studies (Puhakka et al., 2019) and two studies are based on pre- and post-intervention research (Khan et al., 2020; White et al., 2018). The authors of one study base their main research on images, specifically children's drawings (Zaballa et al., 2021). Validity and generalizability of results also vary across the studies, with sample sizes ranging from one class in one school, to a large number of schools within a city or region.

The 11 studies present a diversity of aims, with dependent variables ranging from academic performance, to physical activity and wellbeing levels, to interest, empathy and attitudes towards the environment. Study aims are reflected in program aims, which either focus on academic subject performance, physical wellbeing, or knowledge and understanding of nature and the environment, with some studies more concerned about a phenomenon related to green school grounds than a specific program. When study aims are matched with results, the outcomes that show the clearest links with NBL are: improved academic performance, specifically in mathematics and science; increased physical activity and play; improved well-being; increased awareness, interest, and understanding of natural elements or the natural environment; and improved relationships with the environment in terms of attitudes and behavior (Table 2).

All relevant studies are relatively recent, having been published since 2017. Since there was no date restriction on the review, the implication is that there is increasing interest in the subject area. However, the evidence base remains small and studies are currently too inconsistent to provide a clear framework for the design of such spaces. Studies also have limited cultural and geographical representativeness. While countries span quite diverse geographical contexts (Fig. 2), not all continents are represented and few countries are represented, mostly by single studies.

Discussion

The eleven included studies provide an indication that there are positive benefits of curricular NBL amongst primary-school children. These results are encouraging and suggest that investment in NBL may well be worth pursuing. At the same time, it is amply clear that there is a need for more evidence. The small number of included studies and the fact that these are representative of a wide variety of geographical contexts limits generalizability. It is also worth noting that climate and ecology are key determining factors for green school grounds design but vary widely across the world. For example, water features (lakes, rivers, fountains) were present in five of

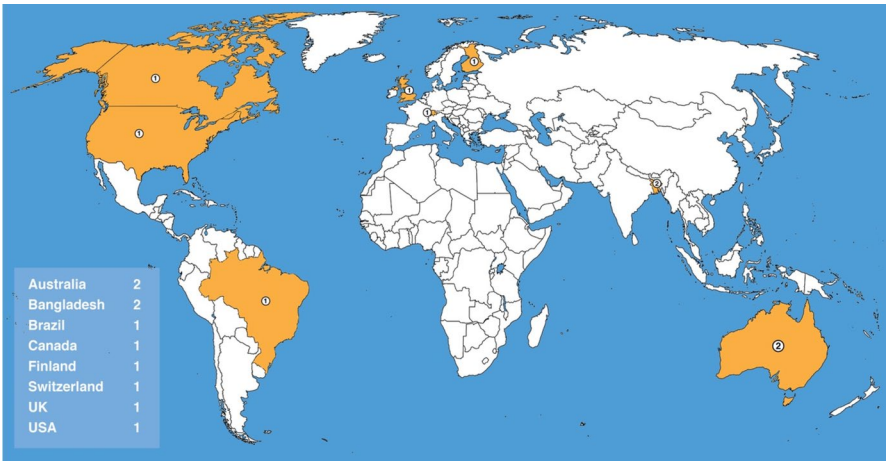

Fig. 2 Studies by geographical region and frequency

the studies in this review, but such features may not be available or sustainable to maintain in arid or semi-arid climatic contexts. In such contexts, an alternate feature leading to the same desired outcomes would therefore need to be sought. If for example, a lake provides an aesthetically pleasing/relaxing effect in one geographical context, it might be replaced by rows of graceful palm trees in a drier context. In this review, Sivarajah et al., (2018) suggest that a varied tree cover is a better predictor of children's academic performance than other vegetation types, raising the question of whether there are natural elements that would generate the same outcome in urban schools that may not have adequate space for a variety of trees, or in climatic contexts where tree growth may be constrained. A third pertinent example from a study by Paddle & Gilliland, (2016) reveals that children perceive the restoration offered by schoolyard trees as being influenced by seasonal changes in foliage, a result that is only applicable where deciduous trees are native to the geographical region. While it is possible that NBL applied through different locally-adapted natural features would have the same effect on children's CN and other NBL outputs, as evidenced by the improvements in outcomes of the different variables tested in the review studies, there nevertheless remains a need for a wider and stronger empirical evidence base that is better representative of different climatic and ecological realities.

Context is also important given evidence that NBL practice is mediated by cultural influences (MacQuarrie, 2018). According to Vygotsky's zone of proximal development theory, a child's psychosocial transformation is mediated by the social context and interaction with the adults in it (Gredler, 2012). For instance, a school that employs a traditional reductionist curriculum (separate subjects) might need a different design approach than a school that adopts a forest school philosophy, where the environment is an integrated context that stimulates cross-curricular learning. Adapting an outdoor education approach necessitates careful cultural consideration, an argument also made in a critique of forest schools in the UK by Leather, (2018). Culture plays a determining

role in creating the learning context and in assisting the child in the learning process that appropriates meaning and enacts competencies found in the learning context (Ferreira, 2014). While much of the nature connectedness literature represents Western perspectives, the human-nature relationship itself is very much a cultural product, and manifests itself differently among different cultural groups (Krettenauer et al., 2020; Sedawi et al., 2021). For instance, while cultural and societal beliefs about education and family backgrounds have been identified as potential barriers to the acceptance of outdoor education and NBL practice (Dyment, 2005; Oberle et al., 2021; Rickinson et al., 2004), this may not be the case in countries traditionally associated with forest schools, such as Denmark. Nevertheless, this review provides little insight into how cultural variables may manifest in different programs and the green school grounds design that would support them, with cultural influences not explicitly addressed.

Another crucial constraint on greening school grounds is available space. The studies in this review predominantly illustrate examples of NBL in large areas: although there is no specific indication of the footprint occupied by different features, it is doubtful whether most of the features themselves (except for the kitchen garden in Wallace, 2019) can be accommodated in small spaces. Based on this review, there appears to be little guidance on how NBL can be implemented within schools with small footprints. However, while the included studies do not provide sufficient design guidelines for different types and footprints of primary schools worldwide, they nevertheless provide valuable insight into elements for inclusion in a design framework. This becomes particularly relevant if viewed through the lens of Gibson's theory of affordances (Gibson, 2015), where the outdoor space can become a series of material possibilities and restrictions for the provision of meaningful experiences (Puhakka et al., 2019). The danger in this case would be to over-simplify the overall influence of a green space in favour of its individual elements as affordances: "Affordances exist in relation to the perceiver, but cannot be constructed subjectively by the perceiver" (Puhakka et al., 2019, pp. 2 – 3). Green school grounds are as much relational as they are situational. More research is thus needed on whether elements of green spaces in large schools can be selectively adapted to schools with a small footprint to achieve the same results. The more frequent features in the studies in this review (Table 3) could provide appropriate subjects for research.

The results of this review also indicate a dearth of research on the middle-to-early primary years in connection with NBL and outdoor learning. It is suggested that effective design of NBL spaces on school grounds should be informed by knowledge of the relevant pedagogy and developmental psychology pertaining to the intervention age besides other participant-related mediating variables (e.g. curriculum, attainment level, desired outcomes). Early years settings, for instance, tend to focus on free play and on viewing the environment as a third teacher that provides a multiliterate learning environment, after the Italian Reggio Emilia approach (Cortés Loyola et al., 2020). Older primary student teaching may tend to follow a subject-based curriculum based on subject learning outcomes. More progressive forms of curricular development adopt a cross-curricular approach or broader areas of learning (Wyse et al., 2018). Such considerations would be of crucial importance to primary schools that wish to implement whole-school NBL on their school grounds in

limited spaces, possibly requiring zoning that is pedagogy, or development, sensitive. Again, the review results offer few insights on how this could be implemented in practice, suggesting avenues for further research.

Conclusion

This study sought to determine the current state of knowledge with respect to the design of natural spaces on primary school grounds for NBL. Key conclusions with respect to the three main research questions are as follows:

1. There is very little evidence-based guidance for designing green school grounds to achieve nature-based learning through the primary school curriculum. Only 11 relevant studies were identified through this review, and these vary widely in their scope, design and context.
2. Urban schools and/or schools that have small footprints are not well addressed within the identified 11 studies. There therefore appears to be a dearth of evidence-based guidance on whether and how NBL could be implemented within such contexts, which face particular challenges in accommodating natural spaces that can sustain teaching programs.
3. Available literature does not provide clear insights on the link between specific design features and programme outcomes. Although some design features are reported, these are often discussed in limited detail and there appear to be few to no studies that specifically consider the contribution of design elements to desired outcomes.

While recent years have seen an increase in research interest in school grounds for NBL, the design of school grounds for learning appears to be an under-addressed research area. The relationship between green school grounds design and mediating variables is complex, as indicated by this research, and as yet, there seems to be little to guide educators and school administrators in making informed choices and decisions when planning the design of available spaces on their school grounds. The provision of clearer and systematic design guidance could potentially provide a framework to guide implementation of NBL in practice, also allowing better comparability of different programs and thus a more robust basis for assessing NBL's ability to contribute to specific outcomes. This therefore emerges as a priority for future NBL research, which also needs to better address a wider spectrum of geographical and cultural contexts. In particular, there is an urgent need for research that addresses the challenges of schools with small urban footprints, which increasingly represent a more common reality but that also face considerable challenges in implementing NBL. This is important not only to foster enhanced ecological literacy for all but also to address social injustices arising from inequitable nature access. Furthermore, it is important to recognise that efforts to implement NBL successfully also require parallel efforts across a variety of related research and practice domains, including teacher training, curriculum development and sustainable financing, among others.

Appendix 1

Table 4 Results of preliminary search using different search terms

	Search term	A Number of hits	B Relevant	C Excluded (participants)	D Excluded (subject)	E Excluded (theory-based)	F Excluded (review criteria)
1	*"nature based learning"*	69	3	8	13	3	3
2	*"green schoolyards"*	51	0	4	24	2	0
3	*"environmental education (in or through) nature"*	166	0	3	21	4	2
4	*"environmental education" AND "connectedness to nature"*	11,969	4	6	18	2	0
6	*"garden based learning"*	118	1	1	16	7	5

Note: Columns B-F are based on a review of the first 30 hits returned per term. Column C shows the number of studies that were excluded because participants did not meet age or profile requirements (e.g. teenagers or adults). Column D shows studies excluded for not focusing on NBL (e.g. with a focus on urban greening, community wildlife gardening, the influence of environmental knowledge on tourism, designing schools for vegetable growing, among others). Column E shows studies excluded because they did not present results of empirical research but focused on theoretical discourses on experiential learning, child development and nature and other related themes. Column F shows studies excluded to ensure that reviewed publications were published within the period 2010–2020 and that review criteria were appplied consistently across articles

Table 5 Detailed search results showing numbers of relevant studies against studies excluded, based on the same criteria as in Table 1

	Search term	A Number of hits	B Relevant	C Excluded (participants)	D Excluded (subject)	E Excluded (theory-based)	F Excluded (review criteria)	G Other
1	*"nature based learning"*	72	6	12	40	7	3	2
2	*"environmental education" AND "children" AND "connectedness to nature"*	150	11	34	87	9	2	9

Note: Exclusions in column G (first row) were a dissertation and a non-English language publication. Exclusions in column G (second row) included five repeats, two studies with inadequate information, one non-English language publication, and one publication, the full text of which was not available

Table 6 Reasons for excluded studies

Reason for exclusion	Study focus
Not curriculum-linked	Gardening activity
	Nature activity in primary school grounds but not linked to curriculum subjects/areas
	Break-time activity in green school ground spaces
Concerns outside-school environments	Nature park
	Forest
	Wildlife park
	Community green areas
	Out-of-school program nature venue
	Both in and out of school with no differentiation between venues in results
	School grounds not mentioned
Subject not relevant to search subject	Not about children
	Not about schools
	Not empirical
	Review
	Concerns unstructured play
	Theoretical discourse about nature-based learning
	Community spaces greening
	Effects of greening neighborhoods
	Concerns health/wellbeing and nature
	Concerns food and nutrition
	Concerns physical activity and nature
	No relation to the theme (e.g. tourism)
	About school grounds but no reference to green spaces
Not curriculum linked	Gardening activity or nature activity in primary school grounds not linked to curriculum subjects or subject areas
	Concerns break-time activity in school grounds natural spaces
Participant age outside category	Children not 5–11 years old
	Families
	Youth
	University students
	Teachers
	Other social groups

Appendix 2: Databases used in Systematized search

1. ABI/INFORM Collection (ProQuest)
2. Academic Search Ultimate (EBSCO)
3. Accounting, Tax & Banking Collection (ProQuest)
4. ACM Digital Library
5. ACS Publications (American Chemical Society)
6. African American Biographical Database
7. AgeLine (EBSCO)
8. American Periodicals (ProQuest)
9. Art and Architecture Archive (ProQuest)
10. Arts & Humanities Database (ProQuest)
11. Asian American Drama (Alexander Street)
12. Asian & European Business Collection (ProQuest)
13. Australia & New Zealand Database (ProQuest)
14. AWOL—The Ancient World Online
15. Black Abolitionist Papers
16. Black Studies Center
17. Black Thought and Culture (Alexander Street)
18. Biological Science Database (ProQuest)
19. BioMed Central
20. BMJ Journals
21. BNF (British National Formulary)
22. British and Irish Women's Letters and Diaries (Alexander Street)
23. British Architectural Library Catalogue (RIBA)
24. British Periodicals (ProQuest)
25. Business Market Research Collection (ProQuest)
26. Canadian Business & Current Affairs Database (ProQuest)
27. Canadian Newsstream (ProQuest)
28. Career & Technical Education Database (ProQuest)
29. Cecil Papers (ProQuest)
30. ChemSpider
31. CINAHL Complete (EBSCO)
32. Cochrane Central Register of Controlled Trials (EBSCO)
33. Cochrane Clinical Answers (EBSCO)
34. Cochrane Database of Systematic Reviews (EBSCO)
35. Cochrane Methodology Register (EBSCO)
36. Communication & Mass Media Complete (EBSCO)
37. Computer Science Database (ProQuest)
38. Contemporary World Drama (Alexander Street)
39. Continental Europe Database (ProQuest)
40. Consumer Health Database (ProQuest)
41. Criminology Collection (ProQuest)
42. Dance Online: Dance Studies Collection (Alexander Street)
43. DeJure

44. Digital Theatre Plus
45. Directory of Open Access Journals (DOAJ)
46. Disability in the Modern World: History of a Social Movement (Alexander Street)
47. Drama Online
48. DynaMed Plus
49. Early Encounters in North America (Alexander Street)
50. Early English Books Online
51. Earth, Atmospheric & Aquatic Science Database (ProQuest)
52. East & South Asia Database (ProQuest)
53. East Europe, Central Europe Database (ProQuest)
54. Education Collection (ProQuest)
55. Education Magazine Archive (ProQuest)
56. E-Journals (EBSCO)
57. Emerald Insight
58. Entertainment Industry Magazine Archive (ProQuest)
59. Environment Complete (EBSCO)
60. ERIC (USDE)
61. Ethnologue: Languages of the World
62. Europa World Year Book
63. European Union Legal Database (EUR-Lex)
64. FIAF International Index to Film Periodicals (ProQuest)
65. Film & Television Literature Index with Full-Text (EBSCO)
66. Food Studies Online (Alexander Street)
67. Frost & Sullivan
68. GeoRef (ProQuest)
69. Gerritsen Collection of Aletta H. Jacobs
70. Global Breaking Newswires (ProQuest)
71. GreenFILE (EBSCO)
72. Grove Music Online
73. Health & Medical Collection (ProQuest)
74. Healthcare Administration Database (ProQuest)
75. HeinOnline Academic Core Collection
76. Historical Abstracts with Full Text (EBSCO)
77. HistoryMakers
78. Human Rights Studies Online (Alexander Street)
79. IBSS: International Bibliography of the Social Sciences
80. ICE Virtual Library
81. IEEE Xplore
82. India Database (ProQuest)
83. Inspec (EBSCO)
84. International Encyclopedia of Education (3rd edition)
85. International Newsstream (ProQuest)
86. International Pharmaceutical Abstracts (ProQuest)
87. IOPscience
88. Journals@Ovid Full Text

89. JSTOR
90. Karger
91. Latin America & Iberia Database (ProQuest)
92. Lexis 360 (To access Lexis 360, follow these instructions)
93. Lexis Library
94. LGBT Thought and Culture (Alexander Street)
95. Library & Information Science Collection (ProQuest)
96. Library, Information Science & Technology Abstracts (EBSCO)
97. Linguistics Collection (ProQuest)
98. MarketLine (see how to access this database)
99. MathSciNet (American Mathematical Society)
100. Max Planck Encyclopedia of Public International Law
101. MEDLINE (ProQuest)
102. MEDLINE Complete (EBSCO)
103. Middle East & Africa Database (ProQuest)
104. Military Database (ProQuest)
105. MLA Directory of Periodicals (EBSCO)
106. MLA International Bibliography (EBSCO)
107. Music Online: Music Periodicals of the 19th Century (Alexander Street)
108. National Agricultural Library
109. National Theatre Collection (Alexander Street)
110. Nature.com
111. News, Policy & Politics Magazine Archive (ProQuest)
112. North American Immigrant Letters Diaries and Oral Histories (Alexander Street)
113. North American Women's Letters and Diaries (Alexander Street)
114. Nursing & Allied Health Database (ProQuest)
115. Oxford Academic Journals
116. Oxford Dictionary of National Biography
117. Oxford English Dictionary
118. Oxford History of Western Music
119. Oxford Research Encyclopedia of Linguistics
120. Performing Arts Periodicals Database (ProQuest)
121. Periodicals Archive Online (ProQuest)
122. Persée
123. Philosopher's Index with Full-Text (EBSCO)
124. PLOS
125. Politics Collection (ProQuest)
126. Project Muse
127. ProQuest Academic Complete
128. ProQuest Central
129. ProQuest One Academic
130. PsycINFO (EBSCO)
131. Psychology Database (ProQuest)
132. PTSDpubs (ProQuest)
133. PubChem

134. Public Health Database (ProQuest)
135. Publicly Available Content Database (ProQuest)
136. PubMed
137. PubMed Central
138. Reaxys
139. Rehabilitation Reference Center (EBSCO)
140. Religion Database (ProQuest)
141. Research Library (ProQuest)
142. RILM Abstracts of Music Literature (EBSCO)
143. Routledge Performance Archive
144. SAGE Journals
145. SAGE Knowledge Complete Books and Reference Collection
146. SAGE Research Methods
147. Science Database (ProQuest)
148. ScienceDirect
149. Scopus
150. Shanghai Library
151. Social Science Database (ProQuest)
152. Social Work Online (Alexander Street)
153. Sociology Collection (ProQuest)
154. SpringerLink
155. SSRN—Social Science Research Network
156. Taylor & Francis Online
157. Telecommunications Database (ProQuest)
158. The Europa World of Learning
159. Trench Journals and Unit Magazines of the First World War (ProQuest)
160. Turkey Database (ProQuest)
161. Twentieth Century North American Drama (Alexander Street)
162. UK & Ireland Database (ProQuest)
163. Ulrichsweb: Global Serials Directory
164. US Newsstream (ProQuest)
165. Visible Body Human Anatomy Atlas 2020
166. Vogue Archive (ProQuest)
167. Web of Science
168. Westlaw UK (Access to this database requires VPN)
169. Wiley Online Library
170. Women and Social Movements, International: 1840 to Present (Alexander Street)
171. World Bank Open Knowledge Depository
172. World's Who's Who
173. Zoological Record (EBSCO)

Funding This research is funded by the Tertiary Education Scholarships Scheme (TESS). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Declarations

Conflict of interest The authors have no conflict of interest.

References

Alcock, I., White, M. P., Pahl, S., Duarte-Davidson, R., & Fleming, L. E. (2020). Associations between proenvironmental behaviour and neighbourhood nature, nature visit frequency and nature appreciation: Evidence from a nationally representative survey in England. *Environment International, 136*, 105441. https://doi.org/10.1016/j.envint.2019.105441

Anderson, S. K. (2017). *Bringing school to life: Place-based education across the curriculum*. Rowman & Littlefield Publishers.

Baró, F., Camacho, D. A., Pérez Del Pulgar, C., Triguero-Mas, M., & Anguelovski, I. (2021). School greening: Right or privilege? Examining urban nature within and around primary schools through an equity lens. *Landscape and Urban Planning, 208*, 104019. https://doi.org/10.1016/j.landurbplan.2020.104019

Barrable, A., & Booth, D. (2022). Disconnected: What can we learn from individuals with very low nature connection? *International Journal of Environmental Research and Public Health, 19*(13), Article13. https://doi.org/10.3390/ijerph19138021

Camasso, M. J., & Jagannathan, R. (2018). Improving academic outcomes in poor urban schools through nature-based learning. *Cambridge Journal of Education, 48*(2), 263–277. https://doi.org/10.1080/0305764X.2017.1324020

Chawla, L. (2018). Nature-based learning for student achievement and ecological citizenship. *Curriculum and Teaching Dialogue, 20*(1–2), R25-176.

Chawla, L., & Gould, R. (2020). Childhood nature connection and constructive hope: A review of research on connecting with nature and coping with environmental loss. *People and Nature (Hoboken, N.J.), 2*(3), 619–642. https://doi.org/10.1002/Pan3.10128

Cleary, A., Fielding, K. S., Murray, Z., & Roiko, A. (2020). Predictors of nature connection qmong urban residents: Assessing the role of childhood and adult nature experiences. *Environment and Behavior, 52*(6), 579–610. https://doi.org/10.1177/0013916518811431

Collado, S., & Evans, G. W. (2019). Outcome expectancy: A key factor to understanding childhood exposure to nature and children's pro-environmental behavior. *Journal of Environmental Psychology, 61*, 30–36. https://doi.org/10.1016/j.Jenvp.2018.12.001

Collins English Dictionary. (2023). Nature definition and meaning | Collins English Dictionary. https://www.collinsdictionary.com/dictionary/english/nature

Cortés Loyola, C., Adlerstein Grimberg, C., & Bravo Colomer, U. (2020). Early childhood teachers making multiliterate learning environments: The emergence of a spatial design thinking process. *Thinking Skills and Creativity, 36*(2020), 100655.

Danks, S. (2010). *Asphalt to ecosystems: Design ideas for schoolyard transformation*. New Village Press.

Dyment, J. E. (2005). Green school grounds as sites for outdoor learning: Barriers and opportunities. *International Research in Geographical and Environmental Education, 14*(1), 28–45. https://doi.org/10.1080/09500790508668328

European Commission. (n.d.). Nature-based solutions. European Commission - European Commission. Retrieved December 26, 2021, from https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en.

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

Faber Taylor, A., & Kuo, F. E. (2011). Could exposure to everyday green spaces help treat ADHD? Evidence from children's play settings. *Applied Psychology : Health and Well-Being, 3*(3), 281–303. https://doi.org/10.1111/j.1758-0854.2011.01052.x

Fernández, I. C., Pérez-Silva, R., & Villalobos-Araya, E. (2022). Vegetation cover within and around schools in Santiago de Chile: Are schools helping to mitigate urban vegetation inequalities? *Urban Forestry & Urban Greening, 70*, 127520. https://doi.org/10.1016/j.ufug.2022.127520

Ferreira, A. P. (2014). Vygotsky and Piaget: Scientific concepts. *Psychology in Russia: State of the Art, 7*(3), 24–34.

Gámez-Virués, S., Perović, D. J., Gossner, M. M., Börschig, C., Blüthgen, N., de Jong, H., Simons, N. K., Klein, A.-M., Krauss, J., Maier, G., Scherber, C., Steckel, J., Rothenwöhrer, C., Steffan-Dewenter, I., Weiner, C. N., Weisser, W., Werner, M., Tscharntke, T., & Westphal, C. (2015). Landscape simplification filters species traits and drives biotic homogenization. *Nature Communications, 6*(1), 8568–8568. https://doi.org/10.1038/ncomms9568

Geng, L., Xu, J., Ye, L., Zhou, W., & Zhou, K. (2015). Connections with nature and environmental behaviors. *PloS One, 10*(5), e0127247–e0127247. https://doi.org/10.1371/journal.pone.0127247

Gerl, T., Randler, C., & Jana Neuhaus, B. (2021). Vertebrate species knowledge: An important skill is threatened by extinction. *International Journal of Science Education, 43*(6), 928–948. https://doi.org/10.1080/09500693.2021.1892232

Gibson, J. (2015). The Ecological Approach to Visual Perception. Taylor & Franci. New York. USA Available from Https://Yzhu.Io/Courses/Core/Reading/02.Gibson.Pdf.

Grant & Booth. (2009). A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Information & Libraries Journal, 26*, 91–108. https://doi.org/10.1111/j.1471-1842.2009.00848.x

Gredler, M. E. (2012). Understanding Vygotsky for the classroom: Is it too late? *Educational Psychology Review, 24*(1), 113–131. https://doi.org/10.1007/S10648-011-9183-6

Green, M., & Rayner, M. (2020). School ground pedagogies for enriching children's outdoor learning. *Education 3–13, 50*(2), 238–2251.

Green, M., & Rayner, M. (2022). Ground pedagogies for enriching children's outdoor learning. *Education 3-13, 50*(2), 238–251.

Grietēna, A. (2015). Harmony in Indoor/outdoor context of architecture. *Research for Rural Development*, 231.

Ives, C. D., Giusti, M., Fischer, J., Abson, D. J., Klaniecki, K., Dorninger, C., Laudan, J., Barthel, S., Abernethy, P., Martín-López, B., Raymond, C. M., Kendal, D., & von Wehrden, H. (2017). Human–nature connection: A multidisciplinary review. *Current Opinion in Environmental Sustainability, 26–27*, 106–113. https://doi.org/10.1016/j.cosust.2017.05.005

Jansson, M., & Mårtensson, F. (2012). Green school grounds: A collaborative development and research project in Malmö, Sweden. *Children, Youth and Environments, 22*(1), 260–269.

Jordan, C., & Chawla, L. (2019). A coordinated research agenda for nature-based learning. *Frontiers in Psychology, 10*, 766–766. https://doi.org/10.3389/fpsyg.2019.00766

Kals, E., Schumacher, D., & Montada, L. (1999). Emotional affinity toward nature as a motivational basis to protect nature. *Environment and Behavior, 31*(2), 178–202. https://doi.org/10.1177/00139169921972056

Kesebir, S., & Kesebir, P. (2017). A growing disconnection from nature is evident in cultural products. *Perspectives on Psychological Science, 12*(2), 258–269.

Khan, M., McGeown, S. P., & Islam, M. Z. (2019). There is no better way to study science than to collect and analyse data in your own yard: Outdoor classrooms and primary school children in Bangladesh. *Children's Geographies, 17*(2), 217–230. https://doi.org/10.1080/14733285.2018.1490007

Khan, M., McGeown, S., & Bell, S. (2020). Can an outdoor learning environment improve children's academic attainment? A quasi-experimental mixed methods study in Bangladesh. *Environment and Behavior, 52*(10), 1079–1104.

Kollmuss, A., & Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research, 8*(3), 239–260. https://doi.org/10.1080/13504620220145401

Krettenauer, T., Wang, W., Jia, F., & Yao, Y. (2020). Connectedness with nature and the decline of pro-environmental behavior in adolescence: A comparison of Canada and China. *Journal of Environmental Psychology, 71*, 101348.

Leather, M. (2018). A critique of forest school or something lost in translation. *Journal of Outdoor and Environmental Education, 21*(1), 5–18. https://doi.org/10.1007/s42322-017-0006-1

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

Liu, P., Teng, M., & Han, C. (2020). How does environmental knowledge translate into pro-environmental behaviors? The mediating role of environmental attitudes and behavioral intentions. *Science of the Total Environment, 728*, 138126. https://doi.org/10.1016/j.scitotenv.2020.138126

Loureiro, J., & Dal-Farra, A. (2018). Botany and environmental education in elementary school in Brazil: Articulating knowledge, values, and procedures. *Environmental Education Research, 24*(12), 1655–1668.

MacQuarrie, S. (2018). Everyday teaching and outdoor learning: Developing an integrated approach to support school-based provision. *Education 3-13, 46*(3), 345–361. https://doi.org/10.1080/03004279.2016.1263968

Mann, J., Gray, T., Truong, S., Sahlberg, P., Bentsen, P., Passy, R., ... & Cowper, R. (2021). A systematic review protocol to identify the key benefits and efficacy of nature-based learning in outdoor educational settings. *International Journal of Environmental Research and Public Health*, *18*(3), 1199. https://doi.org/10.3390/ijerph18031199.

Martin, C., & Czellar, S. (2017). Where do biospheric values come from? A connectedness to nature perspective. *Journal of Environmental Psychology, 52*, 56–68. https://doi.org/10.1016/j.jenvp.2017.04.009

McBride, B., Brewer, C., Berkowirz, A., & Borrie, W. (2013). Environmental literacy, ecological literacy, ecoliteracy: What do we mean and how did we get here? *Ecosphere, 4*(5), 67. https://doi.org/10.1890/ES13-00075.1

McCormick, R. (2017). Does access to green space impact the mental well-being of children: A systematic review. *Journal of Pediatric Nursing, 37*, 3–7. https://doi.org/10.1016/j.pedn.2017.08.027

Miller, N. C., Kumar, S., Pearce, K. L., & Badlock, K. L. (2021). The outcomes of nature-based learning for primary school aged children: A systematic review of quantitative research. *Environmental Education Research, 27*(8), 1115–1140. https://doi.org/10.1080/13504622.2021.1921117

Molinario, E., Lorenzi, C., Bartoccioni, F., Perucchini, P., Bobeth, S., Colléony, A., Diniz, R., Eklund, A., Jaeger, C., Kibbe, A., Richter, I., Ruepert, A., Sloot, D., Udall, A. M., & Bonaiuto, M. (2020). From childhood nature experiences to adult pro-environmental behaviors: An explanatory model of sustainable food consumption. *Environmental Education*.

Monsur, M. (2013). *Transitional Space and Preschool Children's Play & Learning Behavior in Childcare Environment. ARCC 2013: The Visibility of Research, Charlotte, United States*. Available at https://www.arccjournal.org/index.php/repository/article/view/193

Müller, M., Kals, E., & Pansa, R. (2009). Adolescents' emotional affinity toward nature: a cross-societal study. *Journal of Developmental Processes, 4*.

Mygind, L., Kurtzhals, M., Nowell, C., Melby, P. S., Stevenson, M. P., Nieuwenhuijsen, M., ... & Enticott, P. G. (2021). Landscapes of becoming social: A systematic review of evidence for associations and pathways between interactions with nature and socioemotional development in children. *Environment International*, *146*, 106238.

Oberle, E., Zeni, M., Munday, F., & Brussoni, M. (2021). Support factors and barriers for outdoor learning in elementary schools: A systemic perspective. *American Journal of Health Education, 52*(5), 251–265.

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

Paddle, E., & Gilliland, J. (2016). Orange is the new green: Exploring the restorative capacity of seasonal foliage in schoolyard trees. *International Journal of Environmental Research and Public Health, 13*(5), 497.

Page, M. J., Moher, D., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & McKenzie, J. E. (2021). PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ*, *372*.

Palmberg, I., & Kuru, J. (2000). Outdoor Activities as a Basis for Environmental Responsibility. *The Journal of Environmental Education, 31*(4), 32–36.

Pinder, J., Fielding, K. S., Fuller, R. A., & Birch, J. (2020). Conservation concern among Australian undergraduates is associated with childhood socio-cultural experiences. *People and Nature (Hoboken, N.J.), 2*(4), 1158–1171. https://doi.org/10.1002/Pan3.10145

Puhakka, R., Rantala, O., Roslund, M., Rajaniemi, J., Laitinen, O., & Sinkhonen, A. (2019). Greening of Daycare Yards with Biodiverse Materials Affords Well-Being, Play and Environmental Relationships. *International Journal of Environmental Research and Public Health, 16*(16), 2948.

Pyle, R. M. (2002). Eden in a vacant lot: Special places, species, and kids in the neighborhood of life. In P. H. Jr Kahn & S. R. Kellert (Eds.), Children and nature: Psychology, sociocultural and evolutionary investigations (pp. 305–328). Cambridge, MA/London: MIT Press.

Raith, A. (2017). Children on Green Schoolyards: Nature Experience, Preferences, and Behavior. *Children, Youth and Environments, 27*(1), 91–111. https://doi.org/10.7721/chilyoutenvi.27.1.0091

Restall, B., & Conrad, E. (2015). A literature review of connectedness to nature and its potential for environmental management. *Journal of Environmental Management, 159*, 264–278. https://doi.org/10.1016/j.Jenvman.2015.05.022

Rickinson, M., Dillon, J., Teamey, K., Morris, M., Chol, M. Y., Sanders, D., & et al. (2004). A Review of Research on Outdoor Learning. *Slough: National* Foundation for Educational Research and King's College London.

Rosa, C. D., Profice, C. C., & Collado, S. (2018). Nature experiences and adults' self-reported pro-environmental behaviors: The role of connectedness to nature and childhood nature experiences. *Frontiers in Psychology, 9*, 1055–1055. https://doi.org/10.3389/fpsyg.2018.01055

Sedawi, W., Ben Zvi Assaraf, O., & Reiss, M. J. (2021). Challenges in measuring "connectedness to nature" among indigenous children: Lessons from the Negev Bedouin. *Cultural Studies of Science Education, 16*(1), 193–229. https://doi.org/10.1007/s11422-020-09995-3

Sharma-Brymer, V., Davids, K., Brymer, E., & Bland, D. (2018). Affordances in nature: Australian primary school children identify learning opportunities. *Curriculum Perspectives, 38*(2), 175–180. https://doi.org/10.1007/S41297-018-0052-z

Sivarajah, S., Smith, S., & Thomas, S. (2018). Tree cover and species composition effects on academic performance of primary school students. *PLoS One, 13*(2), E0193254.

Smith, G. A. (2002). Place-based education: Learning to Be Where We Are. *Phi Delta Kappan, 83*(8), 584–594. https://doi.org/10.1177/003172170208300806

Sobel, D. (1999). *Beyond ecophobia: Reclaiming the heart in nature education* (2nd edition). Orion Society.

Sobel, D. (2008). *Childhood and nature: Design principles for educators*. Stenhouse Publishers.

Soga, M., & Gaston, K. J. (2022). Towards a unified understanding of human–nature interactions. *Nature Sustainability, 5*(5), Article 5. https://doi.org/10.1038/s41893-021-00818-z

Soga, M., Gaston, K. J., 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.

Stevenson, K. T., Moore, R., Cosco, N., Floyd, M. F., Sullivan, W., Brink, L., Gerstein, D., Jordan, C., & Zapalatosch, J. (2020). A national research agenda supporting green schoolyard development and equitable access to nature. *Elementa (Washington, D.C.), 8*(1), 10. https://doi.org/10.1525/Elementa.406

Tamashiro, S., Silveira, J., Merlo, E., & Ghisi, M. (2013). The relationship between ecological knowledge, ecological concern, ecological affection, subjective norms, and the green purchase behavior in Brazil. *African Journal of Business Management, 7*, 3297–3314. https://doi.org/10.5897/AJBM12.1270

Tucker, R., & Izadpanahi, P. (2017). Live green, think green: Sustainable school architecture and children's environmental attitudes and behaviors. *Journal of Environmental Psychology, 51*, 209–216.

UNESCO Institute for Statistics. (2004). Global education digest 2004: Comparing education statistics across the world. Available from: https://uis.unesco.org/sites/default/files/documents/global-education-digest-2004-comparing-education-statistics-across-the-world-en_0.pdf

United Nations. (2018). World Urbanization Prospects The 2018 Revision. Available from: https://www.un.org/en/desa/2018-revision-world-urbanization-prospects#:~:text=Today%2C%2055%25%20of%20the%20world's,increase%20to%2068%25%20by%202050.

Van Velzen, C., & Helbich, M. (2023). Green school outdoor environments, greater equity? Assessing environmental justice in green spaces around Dutch primary schools. *Landscape and Urban Planning, 232*, 104687. https://doi.org/10.1016/j.landurbplan.2023.104687

Van Dijk-Wesselius, J. E., Vandenberg, Maas, J., & Hovinga, D. (2020). Green schoolyards as outdoor learning environments: Barriers and solutions as experienced by primary school teachers. *Frontiers in Psychology, 10*, 2919–2919. https://doi.org/10.3389/Fpsyg.2019.02919

Wallace, H. D. (2019). Transdisciplinary learning in a kitchen garden: Connecting to nature and constructing a path to ecoliteracy? *International Research in Geographical and Environmental Education, 28*(4), 309–323.

Wells, N. M., & Lekies, K. R. (2006). Nature and the Life Course: Pathways from Childhood Nature Experiences to Adult Environmentalism. *Children, Youth and Environments, 16*(1), 1–24.

Whitburn, J., Linklater, W., & Abrahamse, W. (2020). Meta-analysis of human connection to nature and proenvironmental behavior. *Conservation Biology, 34*(1), 180–193. https://doi.org/10.1111/cobi.13381

White, R. L., Eberstein, K., & Scott, D. M. (2018). Birds in the playground: Evaluating the effectiveness of an urban environmental education project in enhancing school children's awareness, knowledge and attitudes towards local wildlife. *PLoS One, 13*(3), E0193993–E0193993. https://doi.org/10.1371/Journal.Pone.0193993

Wyse, D., Hayward, L., Higgins, S., & Livingston, K. (2018). Traditional school subjects versus progressive pedagogy. *The Curriculum Journal, 29*(3), 295–297. https://doi.org/10.1080/09585176.2018.1487668

Yang, Y., Hu, J., Jing, F., & Nguyen, B. (2018). From awe to ecological behavior: the mediating role of connectedness to nature. *Sustainability, 10*(7), 2477. https://doi.org/10.3390/su10072477

Zaballa, I., Merino, M., & Villaroel, J. D. (2021). Children's pictorial expression of plant life and its connection to school-based greenness. *Sustainability (basel, Switzerland), 13*(9), 4999.