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Systematic literature review of nature-based Early Learning and Childcare on children's health, wellbeing and development

CHILDREN, EDUCATION AND SKILLS

social research

Systematic literature review of nature-based Early Learning and Childcare on children's health, wellbeing and development

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Contents

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Funder: Early Learning and Childcare Directorate, Scottish Government

Short title: Nature-based ELC on children's health, wellbeing and development

Summary

What we already know

Evidence on the impact of the **outdoors** and **nature** on children's physical, cognitive, social and emotional health, wellbeing and development is more established compared to **nature-based Early Learning and Childcare** (ELC). For, example, consistent research tells us that when children are outdoors, they engage in higher levels of physical activity which is important for reducing negative health outcomes, such as obesity, cancer, cardiovascular disease, and depression among other outcomes. Similarly, in older children and adolescents (5-18 years), non-educational nature-based settings has a positive impact across a number of outcomes. Nature appears to be particularly beneficial for physical activity and outcomes related to mental health. Less evidence exists on whether nature can enhance children's cognitive and learning outcomes, but these can be improved through increased levels of physical activity.

What this review adds

To our knowledge, this is the first systematic review to synthesise global evidence on the role of **nature-based ELC** on children's health, wellbeing and development. The evidence thus far, as described above, exists primarily in conceptually similar research fields (outdoors and nature more broadly) and in older children and adolescents (5-18 years). This means that we cannot be certain that the benefits older children and adolescents gain from being in nature will be similar to the benefits of nature-based ELC on younger children.

Overview of methodology

The purpose of this systematic review was to understand the extent to which nature-based ELC influences children's (2-7 years) physical, cognitive, social and emotional, and environmental outcomes.

A search for literature was conducted in 9 databases and websites to find relevant global evidence. Studies were included in this review if a) children were in ELC and had not started primary school, and b) the ELC settings provided children with exposure to nature, and c) included child-level outcomes related to health, wellbeing and development.

To provide a level of scientific trust in our studies and subsequent evidence, we conducted two assessments:

I. Assessment of the **quality of the studies**
II. Assessment of the **certainty of the evidence**

To understand the **quality** of eligible studies, we used the Effective Public Health Practice Project (EPHPP) tool (quantitative) and Dixon-Woods checklist (qualitative). This assessment aids in the interpretation of findings from each study.

For example, if a study was rated weak then we should interpret its findings with caution.

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework was used to assess the **certainty** of the evidence for a single outcome which has been reported in more than one study. This assessment provides a rating that enables us to draw conclusions about the findings reported at an outcome level. For example, if the certainty of evidence is low for a specific outcome, we need to be cautious in our interpretation of the findings and subsequently the recommendations.

To present the findings for quantitative evidence, studies with the same exposure and reported on similar outcomes were grouped and summaries provided based on whether evidence favoured nature (i.e. nature-based ELC) or favoured the comparison (traditional ELC). A narrative synthesis was conducted to report on findings grouped by outcome domains with the better-quality evidence prioritised in any conclusions drawn. For qualitative studies, a thematic analysis of reported themes was conducted, grouping them into lower and higher order themes.

Key Findings

Overview of the included studies:

The findings presented in this report are based on 59 unique studies (representing 65 articles). Most of the studies were published in the USA, Australia and Norway. Only 3 studies were published in the UK, of which, one study included data from Scotland. For the quality of the included studies, the majority were rated as weak. Studies were generally given a poor rating because participants were unlikely to be representative (selection bias), it was unclear whether the researchers or outcome assessors were aware of the research questions (blinding) and withdrawals and dropouts were not reported or was high (in before and after studies only). Study designs were also rated weak because most were controlled cross-sectional and cross-sectional studies. Outcomes of cross-sectional studies were assessed at a single timepoint only and so permits drawing conclusions about the causal link between nature exposures in ELC and health and wellbeing outcomes in children. **Given the large number of weak studies, it is important to interpret study findings with caution because it is difficult to know for certain if any possible benefits are as a result of attending nature-based ELC and not any other influencing factor.**

Findings for child-level outcomes:

The **quantitative** element of the review reported generally favourable findings on the role of nature-based ELC on children's physical, cognitive, social, emotional and environmental development compared with traditional ELC. The findings reported are dived into 3 categories:

i) **likely positive association** – positive health outcomes with most studies associated with nature-based ELC;

ii) **likely negative association** – negative health outcome with most studies associated with nature-based ELC; and
iii) **inconsistent findings**– unclear whether these studies favoured nature-based ELC or traditional ELC (i.e. not enough evidence).

The evidence suggested that there were no harms associated with attending nature-based ELC.

Based on very low and moderate evidence, playgrounds which included grassed areas, vegetation, natural elements, rocks, hills or shaded areas were **positively associated** with increased **total physical activity**, **moderate-to-vigorous physical activity (MVPA)** and **step counts** and **decreased sedentary time** during ELC.

Based on low and moderate evidence, compared to traditional ELC, nature-based ELC was **positively** associated with:

- **balance**
- **self-regulation** (ability to understand and manage behaviour)
- **nature relatedness** (or biophilia)
- **play interactions**

Based on moderate evidence, compared to traditional ELC, nature-based ELC was **negatively** associated with children's **speed and agility.**

Based on very low, low and moderate evidence, compared to traditional ELC, nature-based ELC had **inconsistent** findings on the following outcomes:

- object control skills
- attention
- social skills
- social and emotional development
- attachment
- initiative
- awareness of nature
- environmentally responsible behaviour
- illnesses
- behavioural problems (such as temper tantrums or hyperactivity)
- play disruption (aggressive and antisocial behaviours in play) and disconnection (withdrawn behaviour and nonparticipation in play)

Similarly, the **qualitative** (e.g. practitioner reported feedback) element of the review reported generally positive findings:

- Nature affords many more opportunities for children to be active, diversify their play, engage in risky play, interact with peers and teachers, increase their creativity and enable child-initiated learning compared to traditional settings.
- Nature-based ELC affords opportunities for children to be physically active, to engage in diverse types of play and interact with peers. This combination is likely to have an impact on a range of physical, cognitive, and social emotional and environmental outcomes
- Children prefer settings which integrate some nature: either a full naturalised playground or a mixed area. A small number of studies indicated that movement and risky play were similar no matter the setting type.

Summary

In summary, evidence suggested that specific natural elements: grass, hills, vegetation, or rocks had a positive association with **MVPA**, **total physical activity** and reduction in **sedentary time** during the ELC day, whereas trees may limit physical activity levels. Findings for motor competence were mixed: generally, **balance** was better in children who attended nature-based ELC, but they performed worse in a test of **speed and agility** compared to children from traditional ELC. Findings for **object control skills** and **illnesses** were inconsistent. For the cognitive domain, children who attended nature ELC also demonstrated better levels of **self-regulation** (ability to understand and manage behaviour) compared to typical ELC settings. However, findings for **attention** were inconsistent. For emotional outcomes, findings were inconsistent for **social skills, social and emotional development, attachment, initiative and behavioural problems.** For environmental outcomes, **nature relatedness** was higher in children who attended nature-based ELC compared to traditional ELC. However, findings were also inconsistent for **awareness of nature** and **environmentally responsible behaviour**. There was also an indication that **play interaction** was higher in children who attended nature ELC compared to traditional ELC. Findings for **play disruption** and **disconnection** were inconsistent.

Findings from the qualitative evidence suggests that compared to traditional settings, the natural environment affords many more opportunities for children to be physically active, play and interact with their peers. Children also prefer settings which integrate some nature either a full naturalised playground or a mixed area.

Suggested Recommendations

The evidence base in the present report makes it difficult to provide strong recommendations. The evidence is predominately weak and outcomes were assessed over a short period of time meaning that we could not fully understand the mechanisms by which any improvements may have occurred. However, based on the available evidence, there are **three** suggested recommendations:

1. Ensure that ELCs have a rich and varied environment that includes a combination of grassed areas, vegetation, natural elements, rocks, hills and/or shaded areas. These appear particularly important for encouraging physical activity, diversifying play types and enabling human interactions which are all important for childhood development.

2. Ensure that all children can access nature across all setting types: outdoor; indoor/outdoor; satellite. In studies where there was a likely association, evidence from this review suggested that both indoor/outdoor and satellite approaches provided children with high exposure to nature. Therefore, it is

important to understand **how much and how regularly** (daily, weekly, etc) children are exposed to/engage with nature across each setting.

3. To aide future policy development in Scotland, it is important that researchers work collaboratively with practitioners and policy makers to establish **what** child and ELC level outcomes should be measured and **how** we can best collect data on these. By embedding robust evaluation practices, we can generate stronger evidence on the impact of nature-based ELC in Scotland.

Structure of Report

The introduction will provide an overview of the impact of nature on children's health, wellbeing and development before introducing the research questions. The methodology used will then be described and results will be presented. The results will provide an overview of the eligible studies and findings will be broken down into three outcome domains: (i) **physical**, (ii) **cognitive**, and (iii) **social, emotional and environmental** development. Outcomes will be presented for different types of nature exposures within ELC settings. The present report will conclude with a discussion of the findings, key recommendations for policy, practice and research followed by references and appendices.

Introduction

Emerging evidence suggests that childhood physical, cognitive, and social and emotional health and wellbeing is worsening across low and high-income counties (1, 2). Globally, an estimated 41 million infants and young children (0-5 years) are living with overweight or obesity (1) and 10-20% of children and adolescents experience mental disorders (2). In Scotland, a similar pattern is evident with 22.4% of children living with overweight or obesity when starting primary school (3). As children mature into adolescence and adulthood, these negative health outcomes continue and exacerbate related conditions, including type 2 diabetes, cardiovascular disease, cancer and chronic depression (1, 2). Excess weight and poor mental health are also likely to affect behaviour in childhood and key cognitive outcomes important for educational attainment (4, 5). These negative health outcomes are influenced by complex and interrelated political, environmental, social and individual factors. These have caused children to live increasingly sedentary lifestyles dominated by screen use and low levels of physical activity which begin to decline around the age children start primary school (6, 7).

Providing young children with opportunities outdoors, particularly in nature, could potentially offer an effective strategy for enhancing children's physical, cognitive, and social and emotional wellbeing (8, 9). When children are outdoors, they engage in higher levels of physical activity (10-12); important for improving overweight and obesity, bone and skeletal health, motor skills, and cognitive development (13, 14). Experiences in nature, which can include trees, vegetation, grass, hills, water, sand and other elements may provide additional affordances beyond the benefits of the outdoors alone (15, 16). These natural elements allow children to diversify their play, develop their motor skills and engage in physical activity through climbing and navigating varied surfaces (17, 18). Two separate systematic reviews have suggested that exposure to nature improves emotional wellbeing, overall mental health, resilience, self-esteem and reduced stress in children and adolescents aged 0-18 years (8, 9). There is less evidence on the effect of nature on learning and cognitive outcomes (8).

Key evidence missing that this review addresses:

Evidence primarily exists in older children and adolescents and looks beyond just educational settings. This means that it is not known what specific benefits nature-based early learning and childcare (ELC) provide children and the mechanisms by which potential benefits may occur. To our knowledge, no high-quality evidence synthesis exists that looks at the effect of nature-based ELC on young children's (2-7 years) health, wellbeing and development.

The early years are an important time to intervene as children are rapidly developing across a range of physical, cognitive, and social and emotional outcomes (19). Furthermore, the majority of children aged 3-5 years attend ELC (98%; n= 96,375) in Scotland in 2019 highlighting that educational settings offer a potentially cost-effective and sustainable solution to ensuring that children are provided with opportunities to improve health outcomes (14).

Currently, the Scottish Government is committed to increasing free ELC entitlement for all 3- and 4-year olds (and eligible 2-year-olds) from 600 hours to 1140 hours (20). To achieve this progressive policy, the ELC Directorate has made a substantial investment in the workforce, infrastructure and new, innovative models of delivery. Scotland has looked to Norway, Denmark and Finland to explore increasing full day outdoor nature-based ELC, indoor/outdoor[1] and satellite settings[2]. These models aim to promote high-quality, accessible, and affordable nature-based experiences for young children attending ELC and enhance their health, wellbeing and development (21). This has seen Scotland become the UK and a global leader in promoting nature-based experiences in early years education.

With increased nature-based provision in ELC, it is important to understand what the possible benefits and harms are to children's health, wellbeing and development and the process by which they occur. Therefore, the ELC Directorate has commissioned researchers at the MRC/CSO Social and Public Health Sciences, University of Glasgow to conduct a novel and timely systematic review to look at the existing global evidence on nature-based ELC on children's physical, cognitive, social, emotional and environmental development. This will inform future policy, planning, and practice recommendations for their ELC as outdoor, nature-based provision increases. The relevance and timeliness of this report have also increased with the emerging interest of outdoor education on limiting the spread of COVID-19.

Review aim and research questions

The aim of this systematic review is to synthesise existing global literature to answer the following research questions:

1. To what extent does attending nature-based ELC influence children's physical, cognitive, social, emotional and environmental outcomes?
2. What are children's, parent's and/ or practitioner's perceptions of nature-based ELC on children's physical, cognitive, social, emotional and environmental outcomes?
3. What are the potential mechanisms by which nature-based ELC improve children's physical, cognitive, social, emotional and environmental outcomes?

Methods

Step 1: Searching the literature

To ensure transparency and scientific rigour, the methodology of the present review was registered to the International Prospective Register of Systematic Reviews (CRD42019152582) on 2nd October 2019 prior to the commencement of the

[1] Indoor/outdoor settings allow children to move safely and freely from their classroom via a door to the playground

[2] Satellite settings provide children with nature-experiences by taking them to another setting (such as a park or woodland area) for one or two days per week.

literature search. The planned methodology has also been peer-reviewed and published in a scientific journal (22).

This comprehensive systematic review aimed to gather global evidence on the effect of nature-based ELC on children's health, wellbeing and development from both scientific and non-scientific sources:

Scientific sources: nine relevant electronic databases were searched:
1) Education Research Information Centre (ERIC) – (EBSCOhost),
2) Australian Education Index – (Proquest),
3) British Education Index – (EBSCOhost),
4) Child Development and Adolescent Studies – (EBSCOhost),
5) Applied Social Sciences Index and Abstracts – (Proquest),
6) PsycINFO – (EBSCOhost),
7) MEDLINE – (EBSCOhost),
8) SportDiscus – (EBSCOhost) and
9) Scopus (Elsevier).

Search strategies used for the nine electronic databases were constructed by the review team (VW, AM and AJ) and an example search strategy for the ERIC database can be found in Appendix A which was adapted for the other eight databases. To capture as much relevant evidence as possible, the searches were not restricted by year of publication or publication language.

To capture non-peer reviewed evidence, such as dissertations and reports, Open Grey (www.opengrey.eu), Dissertation and Theses Database (ProQuest) and Directory of Open Access Journals (www.doaj.org) were searched. Researchers in the field of children, nature and play were contacted directly to highlight articles. Finally, the first 10 pages of Google Scholar were checked. Literature citing of studies published from 2019 onwards were screened to identify recently published evidence that may have been missed in the initial searches.

Non-scientific sources: Relevant organisations and practitioners in the field were contacted via Twitter and email to obtain additional evidence. Websites of relevant organisations, professional bodies and other groups involved in outdoor education and outdoor play were also searched.

Step 2: Defining the inclusion and exclusion criteria

We followed the PI(E)COS framework for defining the eligibility criteria. PI(E)COS stands for Population, Intervention or Exposure, Comparison, Outcomes and Study design. This provides a systematic approach to capturing evidence relating to the research question.

Population: Children attending ELC settings (i.e. nurseries, preschool) who have not started primary school education were included. The age children start primary (or elementary school as it is known in other countries) varies globally and as this is a review of international evidence, children in eligible studies had to be between 2-7 years. **Studies which included children younger than 2 years or older than 7**

years were excluded because this age group would not typically attend ELC settings. Studies which included solely a child population with disease conditions (for example, autism, physical disability, attention deficit hyperactivity disorder) were excluded.

Exposure/Intervention: The exposure of interest was nature-based ELC which is an umbrella term that encompasses different types of international early years education types, including nature-based preschool, kindergarten and daycare (23). These can vary depending on country context, approach used, level of nature, and duration (half day, full day), but are related through their integration of nature in their curriculum and/or environment. This means to be eligible for inclusion in this review, studies had to include nature-based ELC; that is interventions that provided children with nature-based experiences or explored specific natural elements (e.g. hills, trees, water, snow etc.). ELC settings where they did not integrate nature into their curriculum and/or environment were excluded. For example, studies where settings utilised a more traditional indoor approach or where the playground was predominately concrete and features manmade structures (swings, slide, climbing frame etc.) were excluded.

Comparison: Attendance of traditional, indoor ELC (preschool, daycare) where children's outdoor opportunities were less and in an environment which was predominately concrete and consisted of manmade elements such as swings, slide, and climbing frames.

Outcomes: To capture the possible wide-ranging outcomes of nature-based ELC, any child-level outcome related to health, wellbeing and development were included. Specifically, this included outcomes related to children's physical (e.g. physical activity, motor development), cognitive (e.g. executive functions, attention), social (e.g. prosocial behaviour), emotional (e.g. stress reduction) and environmental (connectedness to nature) health, wellbeing and development. Studies were excluded if they included outcomes which were not child-level. Studies which assessed outcomes using unvalidated questionnaires were also excluded (for both quantitative and qualitative designs).

Study designs: Both quantitative and qualitative designs were eligible. Qualitative studies that explored perceptions (from parent, practitioner or child) at a time when the child was attending nature-based ELC were included. All quantitative study designs, including: cross-sectional and case-control studies measured when the child was attending nature-based ELC; longitudinal, quasi-experimental and experimental studies with at least two time points, and; retrospective studies if outcomes were assessed at a time when the child attended nature-based ELC were included. Studies were excluded where the timepoint of outcome measurement could not be readily associated with the exposure; for example, if studies measured effect once the child had left the nature-based ELC or case studies reviewing only one child. Qualitative studies were also excluded if they did not have a comparator (exposure, control group or pre/post).

Step 3: Selecting the studies

Only studies that met the above criteria were included. References from the nine electronic databases and other searches were imported to the referencing software, Endnote, and one reviewer (AJ) removed duplicates. Titles and abstracts were screened once (AJ, PM, RC, IF, SI, FL, BJ, VW) and 10% were screened in duplicate independently (AM). Two researchers independently screened full text articles in duplicate. A third reviewer was brought in to discuss and resolve any disagreement. Multiple publications for the same study were combined and reported as a single study.

Step 4: Extracting the data

Quantitative Data: Data from eligible studies was extracted by one reviewer (AJ) with another reviewer cross-checking all extracted data (AM, PM). The following information was extracted:

- Study ID (authors, year of publication)
- Country
- Study design (cross-sectional, controlled cross-sectional, controlled before and after etc.)
- Participants (age, gender, socioeconomic status, sample size etc.)
- Intervention/ exposure type and duration (nature-based ELC, naturalised playgrounds etc.). Details on what any possible comparator groups received were also detailed (for example, characteristics of traditional preschool).
- Outcome measures (type, assessment tool, unit and time point of assessment etc.)
- Outcomes and results (effect estimates, standard deviation, confidence intervals etc.)

Qualitative Data: One reviewer read through each eligible qualitative study (AJ) and provided a summary of the main themes as reported by the study author and any other relevant information. A second reviewer read the study and summary provided by reviewer one and added any additional information (HT, PM). The following information was extracted:

- Study ID (authors, year of publication)
- Country
- Participants (i.e. gender, socioeconomic status, sample size etc.)
- Intervention/ exposure type
- Intervention/exposure duration
- Research aims
- Outcome measures (interviews, focus groups etc.)
- Outcomes and results (summary of key themes).

Step 5: Assessing the quality of the studies

The quality of all included studies was assessed by two reviewers independently (AJ/PM, AJ/AM), cross-checked and disagreement resolved through discussion with a third reviewer.

The quality of quantitative studies was assessed using the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool (24). This assesses six components of study quality: selection bias; study design; confounders; blinding; data collection methods; withdrawals and drop-outs (in before and after studies only). Each component was rated 1–3 to give a total global rating of weak, moderate, or strong quality.

Why assess the quality of studies?

Assessing the quality of studies is important because it guides the interpretation of findings. For example, if a study demonstrates a significant positive health impact, but it is of weak design then we would interpret findings with caution. This might be because bias has been brought into the study through a small number of children from one or two schools only and/or the data collection methods used are not valid or reliable.

When we assess the quality of the evidence, we can make judgements on confounding. Confounding relates to other factors which may influence the findings of the study, for example, the child's age, gender or socioeconomic status. It is important in any study that these are considered in the design (the group receiving nature-based ELC are matched to a control group with the same characteristics) or in the statistical analysis. If confounding has been considered, then we can have more confidence in the findings presented.

Finally, the type of study design is also factored in. Studies which assess outcomes at baseline in an intervention group and control group and then assess outcomes again at follow-up (before and after studies) are generally of stronger design and we can have more confidence in the findings. However, before and after studies can still be rated weak if there is bias or confounding has not been considered. Cross-sectional studies have a weaker design. This is because they only assess outcomes at one timepoint and we cannot be sure that findings reported are a result of attending nature-based ELC.

For qualitative data, the trustworthiness of the study was assessed using the Dixon-Woods (2004) checklist (25). This tool assesses whether research questions are clear and suited to qualitative enquiry, whether sampling, data collection and analysis are described and appropriate, if claims are supported by sufficient evidence and whether data is integrated, and whether the study makes a useful contribution to the review question(s). Qualitative studies were excluded if the research questions were not suited to qualitative inquiry or if the paper did not make a useful contribution to the review question.

See Appendix B for the EPHPP and Dixon-Woods quality assessment tool.

Step 6: Synthesising the data

Synthesis Without Meta-analysis (SWiM) was followed for reporting findings (26). For synthesising the findings, studies with the same exposure and reported on

similar outcomes were grouped and presented in summary tables. Outcomes were grouped into similar outcome domains (physical, cognitive, social emotional and environmental) and sub domains. SWiM aims to provide a summary of the effect direction and address whether evidence had favoured nature or favoured the comparison. A narrative synthesis was conducted to report on findings grouped by outcome domains with the better quality evidence prioritised in any conclusions drawn.

For qualitative studies, a thematic analysis of reported themes was conducted, grouping them into lower and higher order themes.

A logic model was created to summarise the findings of the qualitative and quantitative studies. The purpose of the logic model is to present a testable theory of change that will allow comparison and examination of how the different data types relate to each other and to enable readers to identify gaps for future research.

Step 7: Assessing the certainty of evidence

Assessing the certainty of evidence for each outcome allows to draw conclusions about our confidence that the observed findings reflect true associations and effects, and that future research is unlikely to change the results. The Grading of Recommendations, Assessment, Development and Evaluation (GRADE) framework was used to assess the certainty of the evidence for each of the assessed outcomes by judging the study quality, precision, consistency, and directness across studies (27). Risk of bias relates to the quality of all studies that assessed the same outcome and exposure. Precision refers to the range around an effect estimate where a small range indicates high precision. Consistency takes into account as to whether studies suggested conflicting results or not. GRADE was applied when there were two or more studies reported on the same outcome and exposure. The certainty of evidence was rated up or down depending on the risk of bias, precision and consistency across studies to provide an overall rating for the certainty of the evidence for each outcome: very low (true effect different from estimated effect, very likely to change with new evidence emerging), low, moderate and high (true effect is similar to estimated effect; unlikely to change with new evidence emerging) (27).

Quality of studies versus certainty of evidence:

Assessing the **quality of the studies** (see Step 5) relates to the design and conduct of the study. Judgements are made on selection bias, study design, confounders, blinding, data collection methods, withdrawals and drop-outs on each eligible quantitative study.

Whereas the **certainty of evidence** looks at a single outcome which has been reported in more than one study. Study quality (above and Step 5), precision, consistency, and directness are assessed across studies and provides a rating that enables us to draw conclusions about the findings reported. For example, if the certainty of evidence is low for a specific outcome, we need to be cautious in our interpretation of the findings and subsequently the recommendations.

Results

Results of the literature search

The results of the systematic literature search are summarised in Figure 1. In total, the search yielded 40,348 records, of which, 9,250 duplicates were removed. Of the remaining 31,098 articles, 29,729 irrelevant titles and abstracts were removed leaving 1,370 full text articles to be screened. 1,224 irrelevant articles were excluded (reasons detailed in Figure 1). Two potentially eligible papers were excluded because they could not be adequately translated (28, 29). 70 qualitative studies with no comparator (i.e. exposure, control group, pre/post) were excluded as were a further 11 after having their quality assessed. This left a total of 59 unique studies (representing 65 individual papers), of which 49 were included in the narrative synthesis (quantitative) and 9 were included in the thematic analysis (qualitative) and one study was included in both.

Figure 1. Results from the literature search

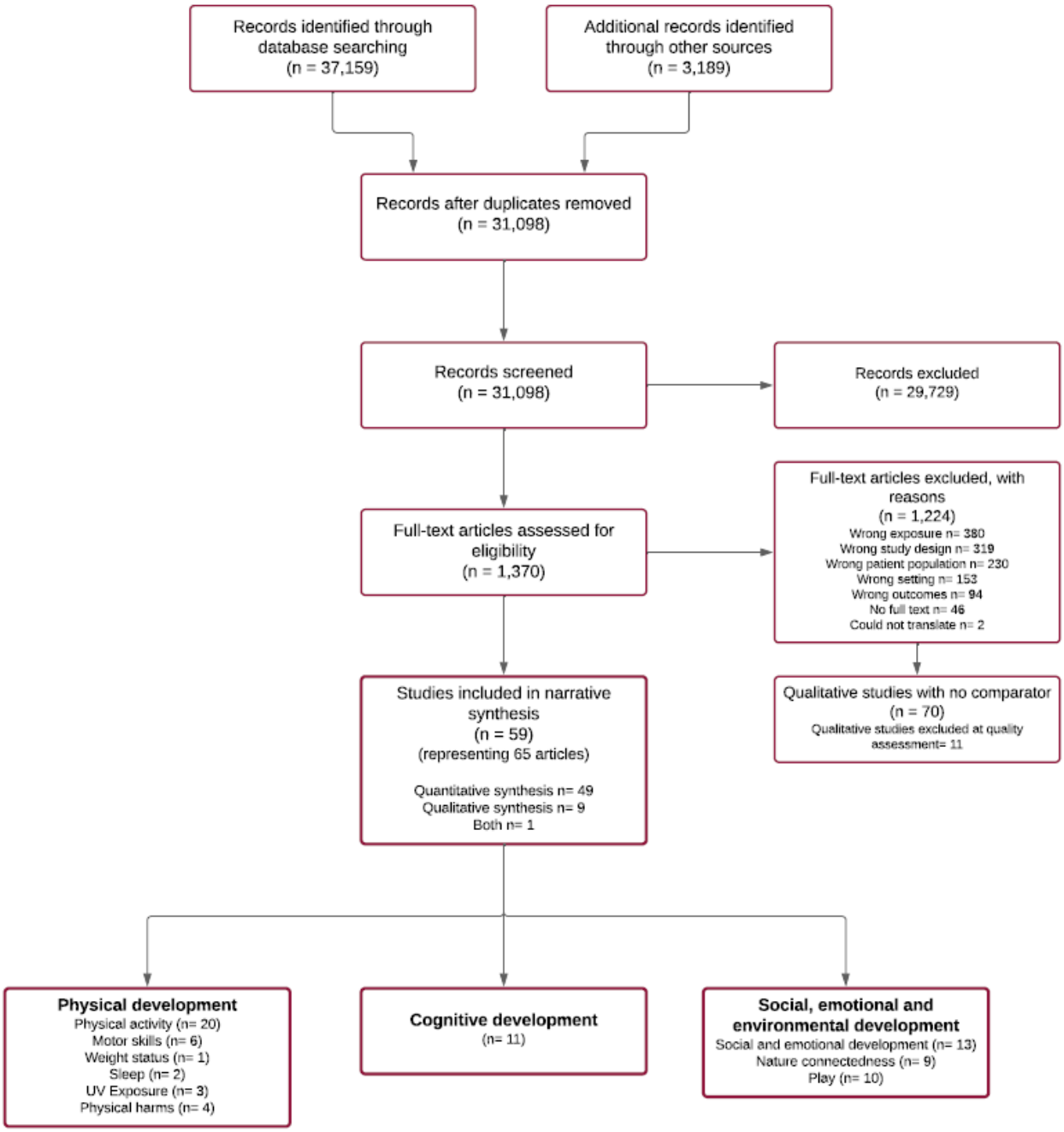
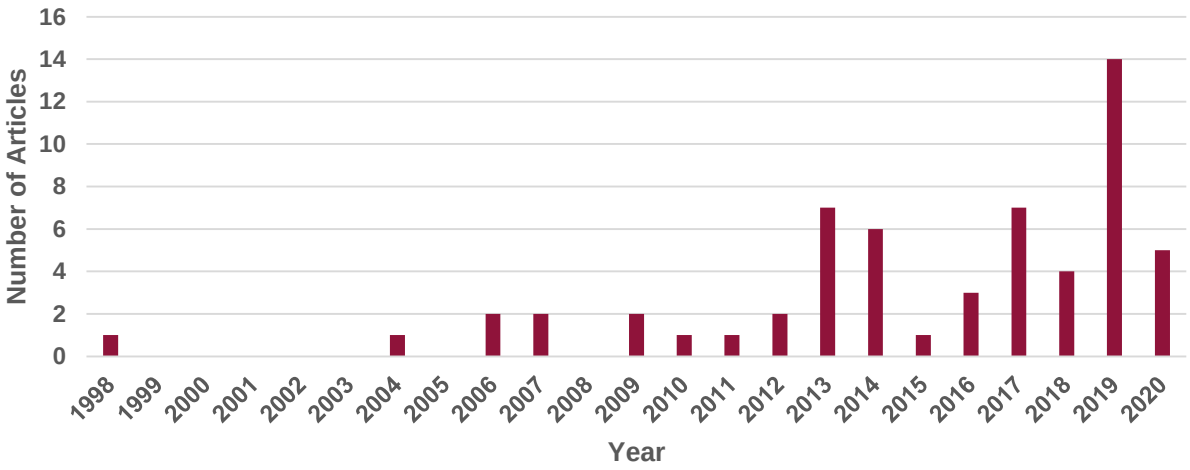


Figure 2 presents the year of publication for the 59 unique studies. Few studies were published between 1998-2012. Since 2013, there has been an increase in publications on this topic.

Figure 2. Year of publication per included study

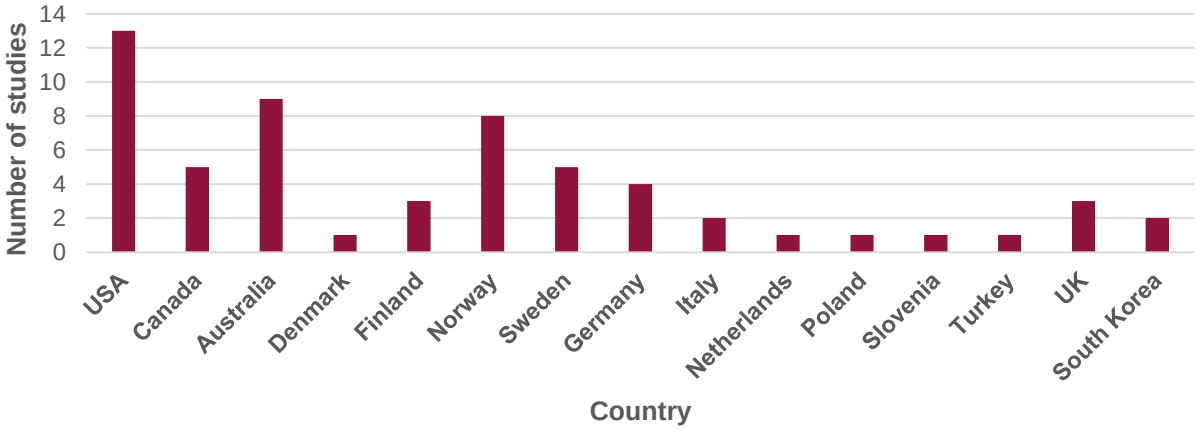


Characteristics of the eligible studies

Geographical location

Most of the studies were published in the USA (n=13), Australia (n=9) and Norway (n= 8). Only 3 studies were published in the UK, of which one study included data from Scotland. Figure 3 presents the number of studies included from each country.

Figure 3. Publication by country



Study designs

Of the quantitative studies, the majority were cross-sectional (n= 22) and controlled cross-sectional (n= 13). Fewer were uncontrolled before and after (n= 6) and controlled before and after (n= 9). Of the cross-sectional studies, one was a mixed-methods and included in both the quantitative narrative synthesis (n=50 unique studies) and the qualitative thematic analysis.

Exposure – Nature

Studies were categorised into four main exposures: nature-based ELC (29 studies), naturalised playgrounds (13 studies), types of nature elements (15 studies) and garden-based interventions (2 studies). Table 1 presents an overview of these categories and their features.

Table 1. Overview of the exposure categories

Nature-based ELC	The ELC curriculum and environment have a strong emphasis on nature where children spend most of their time outdoors in naturalised areas such as woods, forest and/ or naturalised playgrounds. Educators are usually present and may lead on structured educational activities.
Naturalised playgrounds	Interventions which have enhanced the nature in the playground or studies which compare natural playgrounds to traditional playgrounds. Children would not typically spend as much time outdoors in these studies.
Types of natural elements	Studies which looked at the impact of specific natural elements, such as trees, vegetation, hills, grass etc., or specific features or quality of the playground. These studies tended to be controlled cross-sectional or cross-sectional in design.
Garden-based interventions	Studies which include an intervention predicated by a garden component within the ELC setting.

Exposure – Comparison

When studies included a comparison exposure (controlled before and after and controlled cross-sectional study designs only), it tended to be traditional ELC where children would spend less time outdoors and the outdoor playground environment included predominately manmade structures (slide, climbing frame, swings). In some instances, the comparison group may have included some nature through teacher-led eco interventions, or the playground may have included some nature (limited grass and trees). However, the comparison exposure was less than the experimental group.

Sample size and participant characteristics

For sample size and participant characteristics of each study, see Appendix C. Total sample size of the eligible quantitative and qualitative studies was 10,067. Sample sizes were generally small, the majority of controlled and uncontrolled before and after studies had fewer than 100 participants. Controlled cross-sectional and cross-sectional studies also tended to have small sample sizes, but there was a much larger range with one study including 1700 children (experimental n= 506; control n= 1201) (30) and another had less than 20 children (31). Sample size in the qualitative studies ranged from 75 (32) to 12 (33).

As per inclusion criteria, mean age of participants was always 2-7 years. One study assessed girls only (34), all other studies included both genders. Socioeconomic

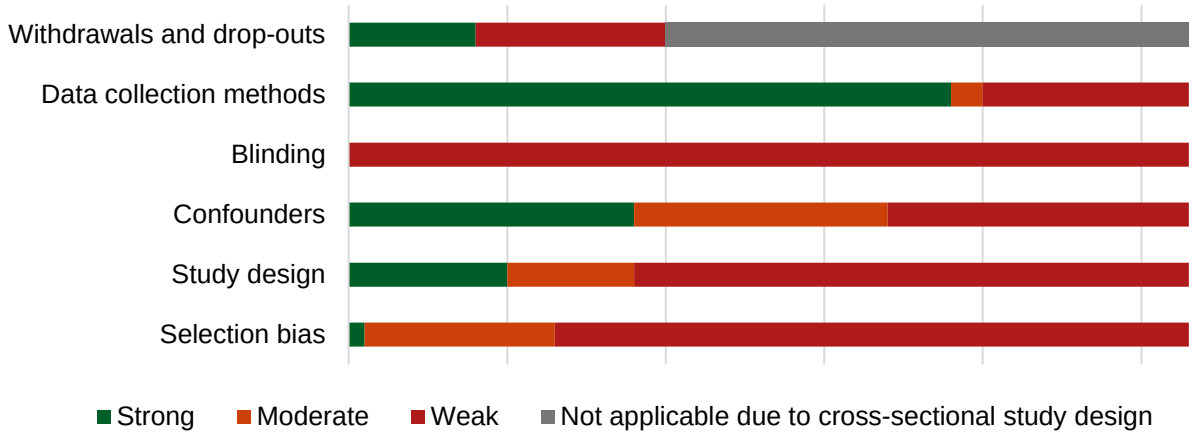
status (SES) was infrequently reported in the eligible studies, in instances when it was reported, SES was generally moderate to high (35-41).

Quality of included studies

Only four studies were of moderate quality (2= nature-based ELC settings, 1= naturalised playgrounds, 1= Types of natural elements) (36, 42-44) and the remaining were rated weak. Figure 4 presents the quality across all studies by assessment item. Studies were generally given a poor rating because participants were unlikely to be representative (selection bias), it was unclear whether the researchers or outcome assessors were aware of the research questions (blinding) and withdrawals and dropouts were not reported or was high (in before and after studies only). Study designs were also rated weak because most were controlled cross-sectional and cross-sectional studies. A weak rating is given to these types of studies because outcomes are assessed at a single timepoint only and so permits drawing conclusions about the causal link between nature exposures in ELC and health and wellbeing outcomes in children. Given the large amount of weak studies, it is important to interpret study findings with caution because it is difficult to know for certain if any possible benefits are as a result of attending nature-based ELC and not any other influencing factor.

See Appendix D for the quality of each quantitative study as assessed by the EPHPP tool.

Figure 4. Quality across all studies by assessment item



Main findings – Quantitative

Outcomes reported in eligible studies were grouped into three domains: physical development, cognitive development, and social, emotional and environmental development. Of these three higher level categories, we derived 9 sub-domains. Table 3 presents an overview of these (sub)domains and number of studies reporting on each outcome.

Table 3. Outcome domains and sub-domains (number of studies in bracket)

Physical development	Cognitive development	Social, emotional and environmental development
Physical activity (20)	Cognition and learning (11)	Social and emotional development (13)
Motor skills (6)		Nature connectedness (9)
Weight status (1)		Play (10)
Sleep (2)		
UV exposure (3)		
Physical harms (4)		

Before presenting findings for each outcome domain, a combined summary of the evidence will be presented first. Table 4 presents findings where outcomes were reported in more than one study for **nature-based ELC.** Similarly, Table 5 presents findings where outcomes were reported in more than one study for **Types of Natural Elements.** These tables report the certainty of evidence for each outcome, the number of studies grouped for each outcome and how many studies favoured the comparison and how many favoured nature. One colour block equates to one study (*unless the study favours neither nature or the comparison), dark green highlights the study favours nature and statistical significance (p<.05); light green favours nature, but no statistical significance; light red/pink favours comparison no statistical significance; and dark red favours comparison and statistical significance (p<.05).

Table 4. Nature-based ELC vs traditional ELC on Physical, Cognitive, and Social, Emotional and Environmental outcomes

Outcome	N of studies	Certainty of evidence	Favours comparison	Favours nature
Physical				
Sedentary time (mins/ ELC day	2	Moderate	O	G
MVPA (mins/ ELC day)	2	Moderate	O	G
Balance	3	Moderate	O	DG DG
Object Control	2	Moderate	O	G
Speed and agility	3	Moderate	R R O	
Illness	2	Very low	O	G
Cognitive				
Attention	3	Moderate	O	G G
Self-regulation / control	3	Low		G DG DG

Social, emotional and cognitive										
Social skills	3	Moderate				O	G	DG		
Social and emotional development	3	Moderate				O	G	G		
Attachment	2	Low				O	G			
Initiative	2	Low				O	DG			
Behavioural Problems	3	Moderate			R	O	G			
Nature Relatedness / biophilia	6*	Moderate					G	DG	DG	DG	DG
Environmentally responsible behaviour	3	Moderate			O	O	DG			
Awareness of nature	2	Low					G	G		
Play interaction	3	Moderate				O	DG	DG		
Play disruption	2	Moderate				R	DG			
Play disconnection	2	Moderate				R	DG			

Abbreviations: E= experimental; C= comparison; N= number; MVPA= moderate-to-vigorous physical activity; ELC= Early learning and childcare.

One colour block = one study.

* denotes where a study favours neither nature or comparison and is therefore not counted.

■ (dark green – DG) = favours nature and statistical significance (p<.05); ■ (green – G) = favours nature; ■ (orange – O) = favours comparison; ■ (red – R) = favours comparison and statistical significance (p<.05).

Table 5. Types of natural elements physical outcomes

Outcome	N of studies	Certainty of evidence	Favours comparison	Favours nature
Physical				
Sedentary time (mins/ ELC day	2	Very low	O	DG
MVPA (mins/ ELC day)	4*	Moderate	O	G G
Total PA (mins/ ELC day)	4*	Moderate		G G G
Step counts/ ELC day	2	Very low		G DG

Abbreviations: E= experimental; C= comparison; N= number; MVPA= moderate-to-vigorous physical activity; PA= physical activity ELC= Early learning and childcare.

One colour block = one study.

* denotes where a study favours neither nature or comparison and is therefore not counted.

■ (dark green – DG) = favours nature and statistical significance (p<.05); ■ (green – G) = favours nature; ■ (orange – O) = favours comparison.

The **quantitative** element of the review reported generally favourable findings on the role of nature-based ELC on children's physical, cognitive, social, emotional and environmental development compared with traditional ELC. The findings reported are dived into 3 categories:

i) **likely positive association** – positive health outcomes with most studies associated with nature-based ELC;
ii) **likely negative association** – negative health outcome with most studies associated with nature-based ELC; and
iii) **inconsistent** – unclear whether these studies favoured nature-based ELC or traditional ELC (i.e. not enough evidence).

The evidence suggested that there were no harms associated with attending nature-based ELC.

Based on very low and moderate evidence, playgrounds which included grassed areas, vegetation, natural elements, rocks, hills or shaded areas were **positively associated** with increased **total physical activity**, **moderate-to-vigorous physical activity (MVPA)** and **step counts** and **decreased sedentary time** during ELC.

Based on low and moderate evidence, compared to traditional ELC, nature-based ELC was **positively** associated with:

- **balance**
- **self-regulation** (ability to understand and manage behaviour)
- **nature relatedness** (or biophilia)
- **play interactions**

Based on moderate evidence, compared to traditional ELC, nature-based ELC was **negatively** associated with children's **speed and agility.**

Based on very low, low and moderate evidence, compared to traditional ELC, nature-based ELC had **inconsistent** findings on the following outcomes:

- object control skills
- attention
- social skills
- social and emotional development
- attachment
- initiative
- awareness of nature
- environmentally responsible behaviour
- illnesses
- behavioural problems (such as temper tantrums or hyperactivity)
- play disruption (aggressive and antisocial behaviours in play) and disconnection (withdrawn behaviour and nonparticipation in play)

Further analysis of the finding for each outcome domain will now be presented.

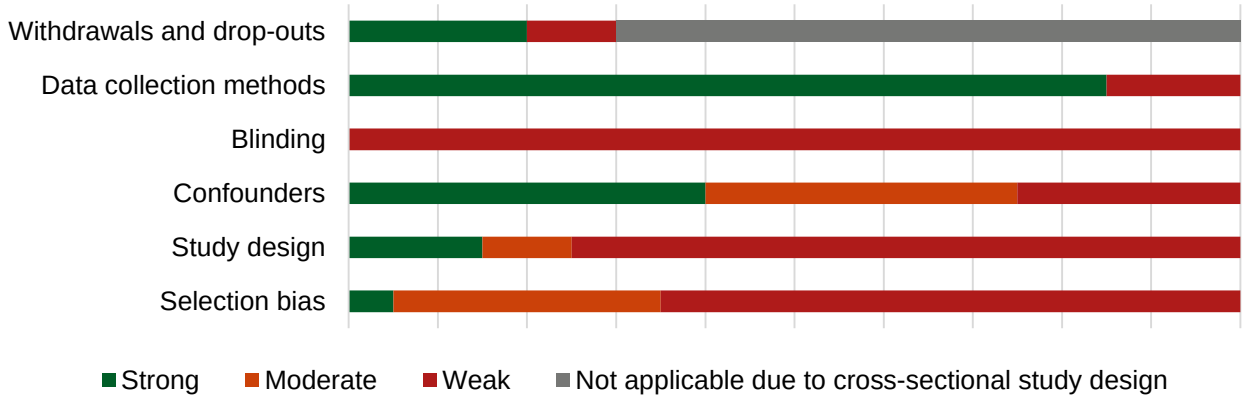
Outcome Domain 1 - Physical development

The physical development domain presents six related sub-domains: physical activity, motor competence, weight status, sleep, UV exposure and physical harms.

1. Physical Activity

Of the 20 articles reporting on physical activity, 15 studies used device-measured methods to record children's physical activity levels and sedentary time. The ActiGraph accelerometer was used in 12 studies (31, 39-42, 44-49), pedometers were used in two (50, 51) and Global Positioning System (GPS) devices were used once (52). The remaining 5 eligible studies used direct observational methods such as the Observational System for Recording Physical Activity in Children-Preschool (OSRAC-P) or Children's Activity Rating Scale (CARS) which codes varying physical activity intensities (38, 53-56) (see Appendix E). The methodological quality across the 20 studies that assessed physical activity is shown in Figure 5.

Figure 5. Quality across studies: Physical activity



1.1. Nature-based ELC settings

Table 5 presents the results from device-measured sedentary time (mins/ ELC day) and MVPA (mins/ ELC day) in eligible studies where these outcomes were reported in more than one study. Findings indicated that there was a positive health impact on sedentary time (mins/ ELC day) between children attending nature-based ELC and children attending traditional ELC (45), the other study demonstrated a negative health impact (46). Similarly, there were conflicting findings for time spent in MVPA (mins/ ELC day) with one study reporting 6 minutes more MVPA (mins/ ELC day) in children who attended nature-based ELC (45) and the other showing 15.5 minutes less MVPA (mins/ ELC day) compared to children attending a typical ELC (46).

Table 5. Nature-based ELC and types of natural elements on physical activity

Study ID	Study Design	Sample size (E/C)	Favours comparison	Favours nature
Nature-based ELC				
Sedentary time (mins/ ELC day)				
Müller et al (2017)[45]	Controlled before & after	43 / 45		G
Fyfe-Johnson et al (2019)[46]	Controlled cross-sectional	20 / 13	O	
MVPA (mins/ ELC day)				
Müller et al (2017)[45]	Controlled before & after	43 / 45		G
Fyfe-Johnson et al (2019)[46]	Controlled cross-sectional	20 / 13	O	
Types of Natural Elements				
Sedentary time (mins/ ELC day)				
Määttä et al (2019b)[41]	Cross-sectional	655		DG
Sugiyama et al (2012)[49]	Cross-sectional	89	O	
MVPA (mins/ ELC day)				

Ng et al (2020)[44]	Controlled before & after	159 / 138	/ /
Christian et al (2019)[39]	Cross-sectional	678	G
deWeger (2017)[47]	Cross-sectional	274	G
Sugiyama et al (2012)[49]	Cross-sectional	89	O
Total PA (mins/ ELC day)			
Ng et al (2020)[44]	Controlled before & after	159 / 138	/ /
Christian et al (2019)[39]	Cross-sectional	678	G
deWeger (2017)[47]	Cross-sectional	274	G
Määttä et al (2019)[40]	Cross-sectional	864	G
Step counts/ ELC day			
Boldemann et al (2006)[50]	Cross-sectional	199	DG
deWeger (2017)[47]	Cross-sectional	274	G

Abbreviations: E= experimental; C= comparison; N= number; MVPA= moderate-to-vigorous physical activity; PA= physical activity; ELC= Early learning and childcare.

One colour block = one study.

■ (dark green – DG) = favours nature and statistical significance (p<.05); ■ (green – G) = favours nature; ■ (orange – O) = favours comparison; ■ (grey – //) = favours neither nature or control, or statistics not presented.

Controlled before & after studies – difference between experimental and control group at follow-up (unless stated). Uncontrolled before & after studies – change since baseline (unless stated). Controlled cross sectional – difference between experimental and control (unless stated). Cross-sectional – positive, negative or no association.

For outcomes that could not be grouped together in the effect direction plot, findings of one weak study suggested children who attended nature ELC engaged in less habitual (mins/day) light physical activity and MVPA and more sedentary time compared to the control across the full week, weekday and weekend (46). The two studies using direct observational methods to assess physical activity in nature ELC found that children in the nature kindergarten were less stationary and engaged in more slow-easy and moderate physical activity compared to the control (38, 53).

1.2. Naturalised playgrounds

Studies for this exposure could not be grouped together because a single outcome was not reported in more than one study. Findings of one intervention study where the playground was enhanced to include more natural elements indicated a positive impact on MVPA and a statistically significant impact on PA and non-sedentary PA

assessed using direct observation (54). In another intervention study, device measured MVPA significantly decreased from baseline to follow-up by 1.32 minutes (42). The other three cross-sectional studies found CPM (a measure of total PA) were similar across a natural and traditional playgrounds (31) and gait/cycles (similar to step counts) were lower in a nature playground (51), but children covered a greater distance (km) (52).

1.3. Types of natural elements

Table 5 presents the results from device-measured sedentary time (mins/ ELC day), MVPA (mins/ ELC day), total physical activity (mins/ ELC day) and step counts (ELC day) in eligible studies where these outcomes were reported in more than one study. Four studies looked at device measured MVPA (mins/ ELC day), of which one study reported non-significant difference for natural elements between the experimental and control groups (44), two studies favoured nature (39, 47) and one study showed no association (49). Grassed areas were positively and significantly associated with MVPA (44). Higher vegetation (height in metres) (39), natural elements (47), gradient and shade had a positive, but non-significant, association with MVPA (49). In another study, natural surfaces were found to be significantly associated with less MVPA, and vegetation did not have a favourable association with MVPA (49).

In the four studies that looked at total device measured physical activity (mins/ ELC day), three favoured the respective types of natural elements and one study reported non-significant differences for natural elements between the experimental and control groups (44). Grassed areas were positively and significantly associated with total physical activity (44). Vegetation, natural elements, grass, and rocks had a positive association with total PA, but these were non-significant (39, 40, 47). Forest and trees were negatively associated with total physical activity (mins/ ELC day) (40).

Higher frequency of nature trips was significantly associated with lower levels of sedentary time (mins/ ELC day) (41). Similarly, gradient (such as hills) and shade showed an association with lower levels of sedentary time (mins/ outdoor time), but “mostly natural surfaces” and vegetation were associated with increased sedentary time (all non-significant) (49).

Step counts were found to be significantly associated with high environment score (playgrounds which had a large outdoor area, trees and shrubbery, and integrated play areas with vegetation) (50) and natural elements (47).

Additional findings (not presented in Table 5), indicated that natural elements were significantly and positively associated with a reduction in percent time spent in habitual sedentary time, and increased MVPA and CPM (57). Vegetation and hilly landscape were significantly associated with a reduced percent time in MVPA (ELC day) (48). Hilly landscape was also associated with reduced percent time in MVPA, but this was non-significant (48). There was a positive, but non-significant association with nature and PA assessed using direct observation (55) . Finally,

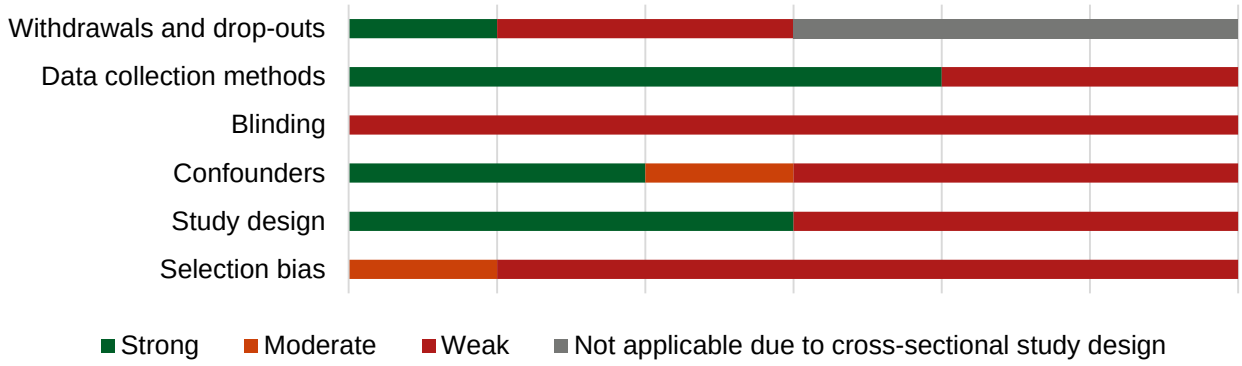
there was no association between nature and observations of high wellbeing and PA assessed using direct observation (56).

Full results for physical activity can be found in Appendix E.

2. Motor competence

Motor competence refers to the child's ability to perform a range of movement skills, such as running, jumping, catching and throwing. These are important as they enable children to engage in physical activity throughout their life course. Six studies assessed outcomes related to motor competence and all examined the effect or association of nature-based ELC on outcomes related to children's motor competence (18, 45, 58-63). Figure 6 presents the quality of studies assessing motor competence by assessment item for methodological quality.

Figure 6. Quality across studies: Motor competence



2.1. Nature-based ELC Settings

Studies explored a range of outcomes related to motor competence. Three studies assessed a range of motor or fundamental movement skills, such as jumping, running, balance and strength (18, 59-62). Motor competence was reported more broadly in three studies (45, 58, 61). Practitioner perspectives of children's physical development was reported in one study (63).

Table 6 presents the results from motor competence (balance, object control skills, and speed and agility) in eligible studies where these outcomes were reported in more than one study. Findings suggested that in two studies, balance was significantly better in children who attended nature ELC compared to children who attended traditional settings (18, 59, 60, 62). Whereas, one study found that children who attended traditional settings performed better (61). There were mixed findings for object control skills (catching, throwing, dribbling) (45, 61) and children in nature ELC performed worse in the shuttle run test (test of speed and agility) in all three studies (two significant, one non-significant) (18, 59-62).

Additional findings reported that body function, gross motor skills and fine motor skills were better in children who attended nature ELC compared to the control, but

these differences were non-significant (58). Similarly, locomotor skills (running, skipping, hopping) were significantly better in nature ELC compared to traditional ELC (45). However, how children perceive their own motor competence was marginally lower in children who attended nature ELC compared to the comparison (45). One study indicated that total motor competence (manual dexterity, ball skills and balance) was worse in children who attended nature ELC compared to children who attended traditional ELC (61), but this difference was not statistically significant.

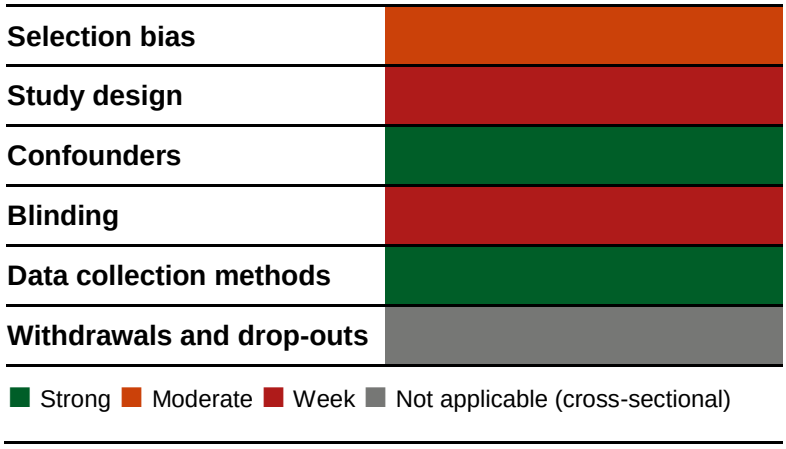
Children who attended nature ELC also performed better across a number of skills. At follow-up, children performed significantly better at skipping compared to children who attended a traditional setting (18, 59, 60). In another study, children from nature ELC performed significantly better at hanging on a pull up bar (strength), jumping left/right and one-leg jump (left foot only) compared to urban and rural children who attended traditional ELC (62). However, total motor fitness scores were found to be significantly lower in children who attended nature ELC compared to control schools (61).

Full results for motor competence can be found in Appendix E.

3. Weight status

Weight status was assessed in only one cross-sectional study which compared BMI and waist circumference in children from schools with high environment quality (i.e. large space, vegetation, tress etc.) compared to low environment quality (64). Figure 7 presents the quality of the study assessing weight status by assessment item for methodological quality.

Figure 7. Quality across studies: Weight status



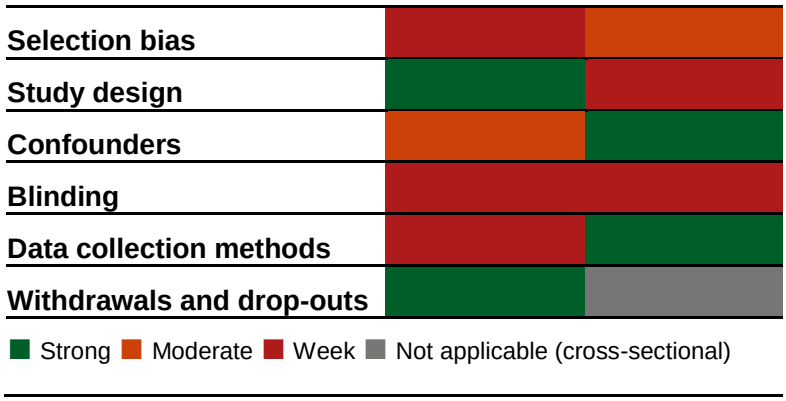
3.1. Types of natural elements

Findings from this study suggested that outdoor environment quality was not significantly associated with BMI or waist circumference (64). However, prevalence of overweight and waist circumference were lower in the higher environment quality group compared to the lower quality (64).

4. Sleep

Sleep was assessed in two studies, of which one was a controlled before and after which compared sleep time and quality in children from a nature-based ELC compared to a traditional ELC (36). The other study was cross-sectional and compared sleep duration in high quality versus low quality outdoor environments (64). These studies could not be combined and presented in a summary table because the exposures and study designs were different. Figure 8 presents the quality of studies assessing sleep by assessment item for methodological quality.

Figure 8. Quality across studies: Sleep



4.1. Nature-based ELC Settings

In the controlled before and after study, sleep was assessed using the Children's Sleep Habits Questionnaire (CSHQ) which assesses eight sleep domains: bedtime resistance, sleep onset delay, sleep duration, sleep anxiety, night wakings, parasomnia, sleep-disordered breathing, and daytime sleepiness (36). Total sleep time was also reported. Findings indicated that Total CSHQ score, sleep disordered breathing and daytime sleepiness was significantly better in the children who attended nature-based ELC compared to traditional. All other domains were better but statistically non-significant. Total sleep time was also higher in children who attended nature-based ELC (10.5 hours ± 1.0 vs 10.4 ± 0.9) (36).

4.2. Types of natural elements

Mean sleep time (minutes) was also reported to be higher in ELC settings which had a higher environment score (658 minutes ± 44) compared to a lower environment score (642 ± 32) and this association was also significant. High environment scores relate to playgrounds which have a large space, trees, vegetation, hilly terrain and integrate natural elements with play structures.

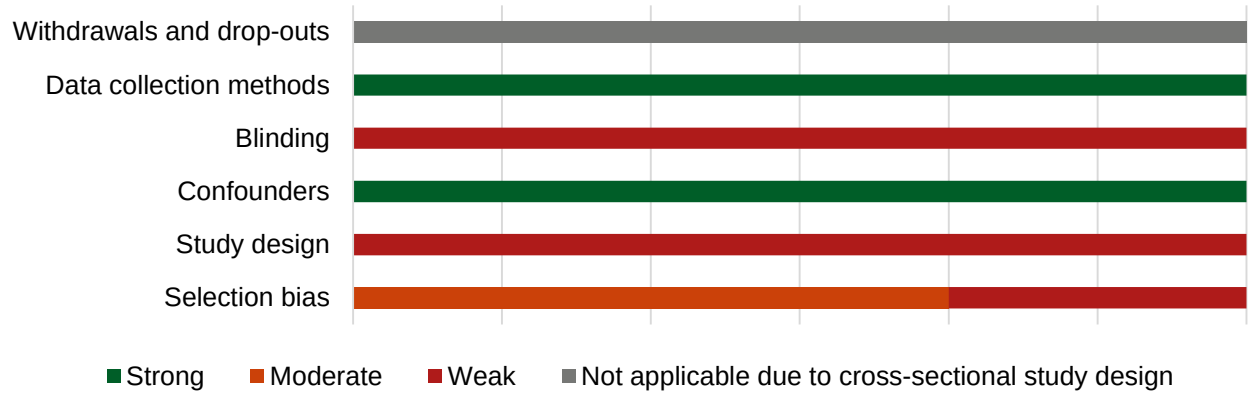
5. UV Exposure

5.1. Types of natural elements.

UV Exposure was assessed in three cross-sectional studies, of which two were conducted in Sweden and one in Australia (39, 50, 65). These studies examined

the association between high environmental quality (i.e. large space, vegetation, tress etc.) versus low quality. All three studies found UV exposure was lower and significantly associated with environmental quality (39, 50, 65). UV exposure was lower in areas where vegetation and trees were more integrated into the playground. Figure 9 presents the quality of studies assessing UV exposure by assessment item for methodological quality.

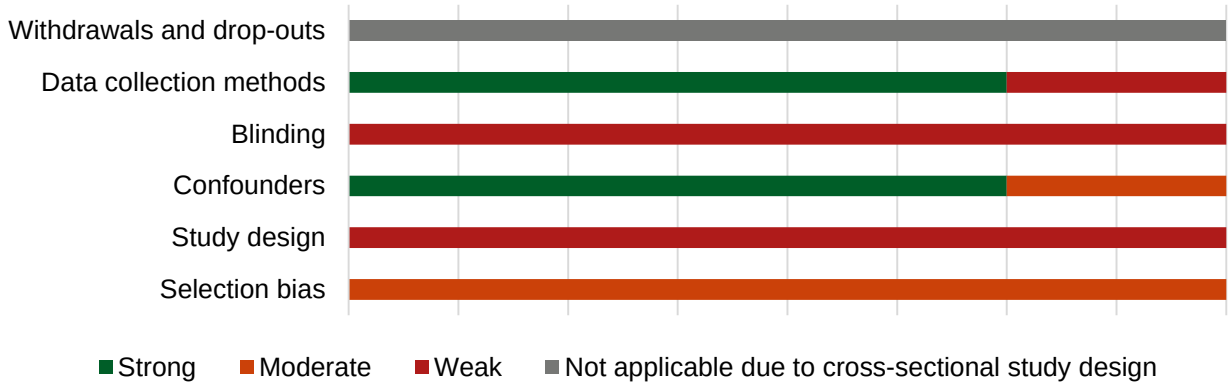
Figure 9. Quality across studies: UV exposure



6. Harms

Possible harms and negative consequences of nature-based ELC was assessed in three controlled cross-sectional studies (30, 37, 66), and the association between environment quality was assessed in one cross-sectional study (64). The quality across the four studies reporting harms is shown in Figure 10.

Figure 10. Quality across studies: Harms



6.1. Nature-based ELC settings

Table 6 presents the results from illness and sickness in eligible studies where these outcomes were reported in more than one study in nature ELC compared to traditional ELC (37, 66). **Illnesses and sickness absenteeism** were reported as the number of days the child was absent from school as reported by their teacher or parent (37, 66). One study reported fewer illness episodes in the nature-based ELC compared to the traditional ELC (non-significant) (37). The other found that

sickness absenteeism was lower in regular ELC compared to nature-based ELC, but again this was non-significant (66).

Total **minor injuries** (wound/cut, sprain, bite) were also explored, and differences were found between genders. Boys in nature ELC had less (non-significant) minor injuries compared to boys who attended traditional ELC (37). Whereas girls who attended nature ELC had significantly higher minor injuries than girls who attended traditional education (37). **Tick bites and borreliosis** (or Lyme's Disease) were also significantly more prevalent in nature ELC in Germany compared to traditional ELC (30). 73% of children who attended nature-based ELC reported presence of at least one tick bite versus 27% in the control (30). Similarly, 2% of children who attended nature-based ELC reported presence of Lyme Disease versus 0.4% of control children (30). It is likely that children in nature-based ELC spend more time outdoors and so have greater exposure to ticks.

6.2. Types of natural elements

Another study explored the association between **illness symptoms** (runny nose, cough fever, respiratory problems etc.) and high quality versus low quality environment. There was no association between environment quality and symptoms (64).

Table 6. Nature-based ELC vs traditional ELC on motor competence and physical harms

Study ID	Study Design	Sample size (E/C)	Favours comparison	Favours nature
Balance				
Ene-Voiculescu & Ene-Voiculescu (2015)[18, 59, 60]	Controlled before & after	46 / 29		DG
Lysklett et al (2019)[61]	Controlled cross sectional	43 / 49	O	
Scholz & Krombholz (2007)[62]	Controlled cross-sectional	45 / 84		DG
Object Control				
Müller et al (2017)[45]	Controlled before & after	43 / 45		G
Lysklett et al (2019)[61]	Controlled cross sectional	43 / 49	O	
Speed and agility				
Ene-Voiculescu & Ene-Voiculescu (2015)[18, 59, 60]	Controlled before & after	46 / 29	O	
Lysklett et al (2019)[61]	Controlled cross sectional	43 / 49	R	
Scholz & Krombholz (2007)[62]	Controlled cross-sectional	45 / 84	R	
Illness				
Frenkel et al (2019)[37]	Controlled cross-sectional	71 / 70		G

Moen et al (2007)[66]	Controlled cross-sectional	267 / 264		O	

Abbreviations: E= experimental; C= comparison; N= number; ELC= Early learning and childcare.

One colour block = one study.

■ (dark green – DG) = favours nature and statistical significance (p<.05); ■ (green – G) = favours nature; ■ (orange – O) = favours comparison; ■ (red – R) = favours comparison and statistical significance (p<.05).

Controlled before & after studies – difference between experimental and control group at follow-up (unless stated). Uncontrolled before & after studies – change since baseline (unless stated). Controlled cross sectional – difference between experimental and control (unless stated). Cross-sectional – positive, negative or no association.

Summary of physical domain

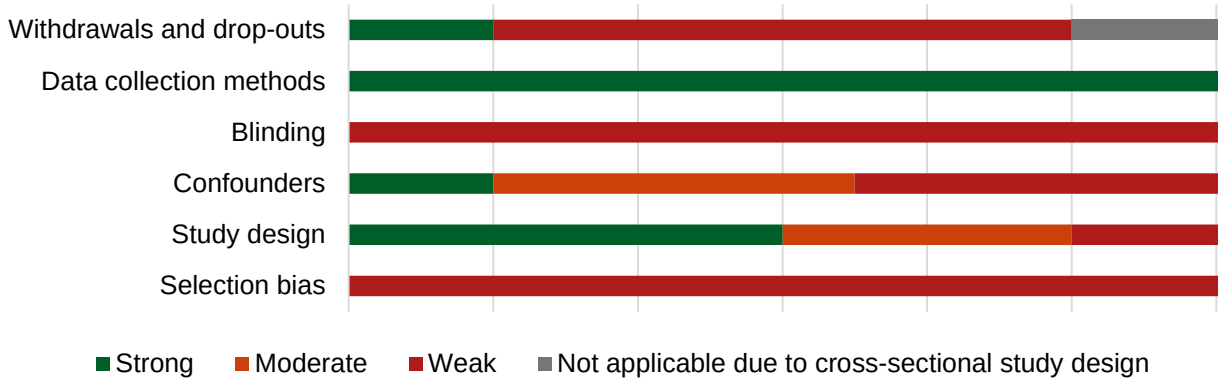
In summary, it is unclear whether nature-based ELC have a positive effect on children's **sedentary time** and **moderate-to-vigorous physical activity (MVPA)** during the ELC day. However, evidence suggested that specific natural elements: grass, hills, vegetation and rocks had a positive association with ELC day **MVPA**, **total physical activity** and reduction in **sedentary time**, whereas trees may limit physical activity levels. Findings for motor competence were mixed: generally **balance** was better in children who attended nature ELC, but they performed worse in a test of **speed and agility** compared to children from traditional ELC. Findings for **object control skills** and **illnesses** were inconsistent.

Outcome Domain 2 - Cognitive development

7. Cognition and learning

A total of 11 studies (representing fifteen papers) included a cognitive or learning related outcome. Seven studies looked at the associations of nature ELC (34, 35, 45, 46, 58, 63, 67-71). Only one cross-sectional study had a naturalised playground exposure which compared outdoor green spaces to indoors (72), one study looked at high environment versus low environment (natural elements) (73) and two utilised garden-based interventions (74, 75). The quality across the studies reporting on cognition and learning is shown in Figure 11.

Figure 11. Quality across studies: Cognition and learning



7.1. Nature-based ELC settings

Table 7 presents the results for cognitive development in eligible studies where these outcomes were reported in more than one study. Two studies found a favourable association with children's attention in nature-based ELC compared to traditional ELC (45, 46, 67, 68). There was a positive trend for self-regulation (ability to understand and manage behaviour) across three studies, with two studies reporting significantly higher scores in children who attended nature ELC compared to children who attended traditional settings (35, 45, 67, 70).

Table 7. Nature-based ELC vs traditional ELC on cognitive and learning outcomes

Study ID	Study Design	Sample size (E/C)	Favours comparison	Favours nature
Attention				
Burgess & Ernst (2020)[67, 68]	Controlled before & after	84 / 24		G
Müller et al (2017)[45]	Controlled before & after	43 / 45	O	
Fyfe-Johnson et al (2019)[46]	Controlled cross-sectional	20 / 13		G
Self-regulation / control				
Cooper (2018)[35]	Controlled before & after	13 / 11		G
Müller et al (2017)[45]	Controlled before & after	43 / 45		DG
Ernst et al (2019)[67, 70]	Uncontrolled before & after	78		DG

Abbreviations: E= experimental; C= comparison; N= number; ELC= Early learning and childcare.

One colour block = one study.

■ (dark green – DG) = favours nature and statistical significance (p<.05); ■ (green – G) = favours nature;

■ (orange – O) = favours comparison

Controlled before & after studies – difference between experimental and control group at follow-up (unless stated). Uncontrolled before & after studies – change since baseline (unless stated). Controlled cross

sectional – difference between experimental and control (unless stated). Cross-sectional – positive, negative or no association.

Two of the included studies looked at the association between nature ELC and executive functions of which one examined three domains: working memory, attention (presented above) and inhibition (45) and the other study tested overall executive function (cognitive flexibility, inhibitory control and working memory) (67, 69). Findings indicated there were small improvements in working memory and association with inhibition (45). Overall executive function score was higher in the nature ELC compared to the control, but this was non-significant (67, 69). In another study, cognitive development was lower in nature- based ELC and teacher perception of language development was higher; however, these differences were non-significant (58). There was also no significant differences in the nature ELC compared to the control for communication (35). Total learning behaviours - assessed across three dimensions: attention, competence motivation and attitudes - was measured in another study (67, 68). Children who attended nature ELC had a higher total score compared to traditional ELC, indicating better learning behaviours but this was non-significant. However, kindergarten readiness (counting, rhyming, recognition) was lower in children who attended nature ELC than those who attended a traditional setting (34). There were marginal differences in curiosity scores in children who attended nature ELC compared to the control group (67). Finally, there were significant improvements in areas of creativity (fluency originality and imagination in children who attended nature ELC.

See appendix E for full findings related to the cognitive domain.

7.2. Naturalised playgrounds

The one eligible study utilised a visual spatial task (an indicator of children's direct attention) to determine if there was a difference in children who had been exposed to playground green spaces for free play compared to children who were indoors (72). Findings suggested that children who had been exposed to free play in green space gained higher visual spatial accuracy scores compared to children in the indoors setting (72).

7.3. Types of natural elements

One eligible study looked at attention in relation to ELC which had a high-quality environment (i.e. large space, vegetation, tress etc.) to those which had a low-quality environment (73). Findings indicated that the two domains of attention: hyperactivity and inattention were lower in schools with high quality environments and inattention was significantly associated (73).

7.4. Garden-based interventions

The two eligible garden-based intervention studies assessed varying outcomes. One study looked at scientific attitudes and abilities (74) and the other study

assessed delay gratification (self-regulation) and visual motor integration (hand-eye coordination) (75). All subcategories of scientific attitudes and abilities significantly improved from baseline to follow-up (measured one week after a 24 week intervention) (74). Delay gratification (self-regulation) and visual motor integration did not significantly improve from baseline to follow-up (75).

Summary of cognitive domain

Findings indicated that for **attention,** two studies demonstrated positive health impacts and one study showed a negative health impact. More evidence supported **self-regulation** (ability to understand and manage behaviour) with three studies demonstrating a positive health impact for children attending nature-based ELC compared to children attending traditional ELC.

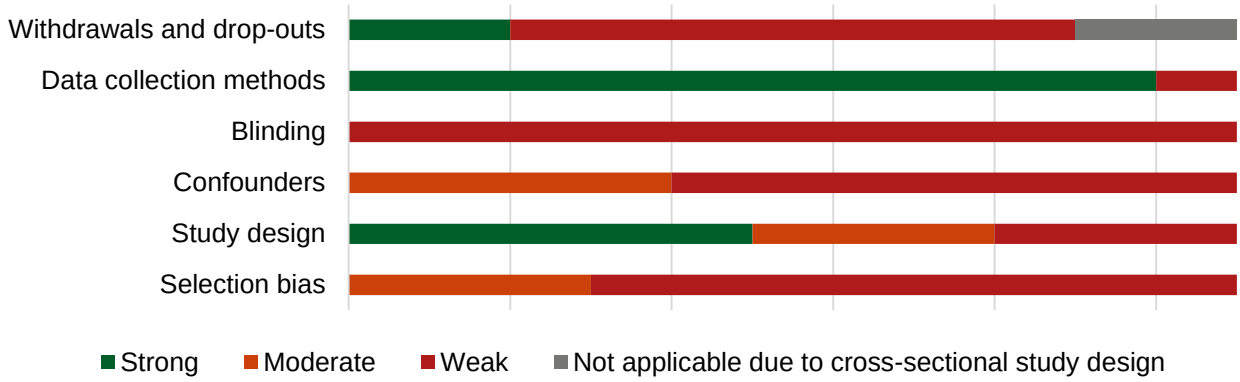
Outcome Domain 3 - Social, emotional and environmental development

The social, emotional and environmental development domain presents three related outcomes: social and emotional, nature connectedness and play.

8. Social and emotional outcomes

A total of thirteen studies included an outcome related to social and emotional development, of which four studies were controlled before and after (34, 35, 45, 58), four were uncontrolled before and after (42, 54, 70, 74), one was a controlled cross-sectional (46) and the remaining four were cross-sectional (55, 63, 64, 72). The quality across the thirteen studies reporting on social and emotional outcomes is shown in Figure 12.

Figure 12. Quality across studies: Social and emotional development



8.1. Nature-based ELC settings

Table 8 presents the results for social and emotional outcomes in eligible studies where these were reported in more than one study. This included social skills, social and emotional development, attachment (child's ability to promote and maintain positive connections with others), initiative (child's ability to use independent thought and action), and behavioural problems. For social skills

(including prosocial behaviour, social responsibility), two of the three studies reported higher scores in children who attended nature ELC (34, 45, 46). Similarly, social and emotional development was higher (all non-significant) in children who attended nature ELC compared to traditional ELC in two studies (35, 46, 58). Findings for attachment and initiative were mixed across two studies (35, 67). Children from nature ELC also exhibited higher behavioural problems across two studies (34, 45) and another study suggesting behavioural problems were lower in children who attended nature ELC (46).

In addition, resilience was assessed in one study, which found that total protective factors as reported by the parent and teacher significantly improved from baseline to follow-up (67, 70).

Table 8. Nature-based ELC vs traditional ELC on social and emotional outcomes

Study ID	Study Design	Sample size (E/C)	Favours comparison	Favours nature
Social skills				
Cordiano et al (2019)[34]	Controlled before & after	12 / 14	O	
Müller et al (2017)[45]	Controlled before & after	43 / 45		DG
Fyfe-Johnson et al (2019)[46]	Controlled cross-sectional	20 / 13		G
Social and emotional development				
Agostini et al (2018)[58]	Controlled before & after	41 / 52		G
Cooper (2018)[35]	Controlled before & after	13 / 11	O	
Fyfe-Johnson et al (2019)[46]	Controlled cross-sectional	20 / 13		G
Attachment				
Cooper (2018)[35]	Controlled before & after	13 / 11	O	
Ernst et al (2019)[67, 70]	Uncontrolled before & after	78		G
Initiative				
Cooper (2018)[35]	Controlled before & after	13 / 11	O	
Ernst et al (2019)[67, 70]	Uncontrolled before & after	78		DG
Lower behavioural problems				
Cordiano et al (2019)[34]	Controlled before & after	12 / 14	R	
Müller et al (2017)[45]	Controlled before & after	43 / 45	O	
Fyfe-Johnson et al (2019)[46]	Controlled cross-sectional	20 / 13		G

Abbreviations: E= experimental; C= comparison; N= number; ELC= Early learning and childcare.

One colour block = one study.

■ (dark green – DG) = favours nature and statistical significance (p<.05); ■ (green – G) = favours nature; ■ (orange – O) = favours comparison; ■ (red – R) = favours comparison and statistical significance (p<.05).

Controlled before & after studies – difference between experimental and control group at follow-up (unless stated). Uncontrolled before & after studies – change since baseline (unless stated). Controlled cross sectional – difference between experimental and control (unless stated). Cross-sectional – positive, negative or no association.

8.2. Naturalised playgrounds

Three studies with naturalised playgrounds included outcomes related to children's social and emotional wellbeing. Two studies implemented interventions aimed at enhancing the nature in the playground (42, 54) and the other compared free play in ELC green spaces compared to indoors (72). All studies assessed social skills and interactions, of which one found an improvement from baseline to follow-up and the other found positive associations between social interactions and free play in nature playgrounds (42, 72). However, another study reported significantly more negative teacher and children interactions (54). Children's strengths and difficulties, as measured using the strengths and difficulties questionnaire, improved from baseline to follow-up (42) and stress was lower in free play in nature playgrounds compared to free play indoors (72).

8.3. Types of natural elements

Two studies assessed whether nature was associated with aspects of social and emotional wellbeing. One study assessed whether nature was related to children's emotional wellbeing as assessed by the Leuven Well-being Scale (55). It was found that nature was a statistically significant predictor of emotional wellbeing (55). The other study assessed stress by measuring cortisol levels and found that higher quality environments (i.e. large space, vegetation, tress etc.) increased children's stress levels compared to low quality environments (64).

8.4. Garden-based interventions

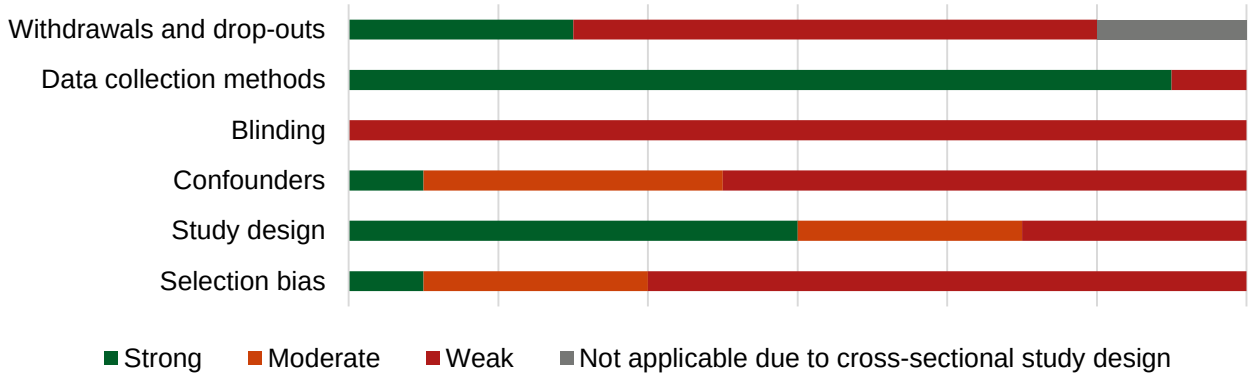
This study aimed to determine the effects of a horticulture intervention on emotional intelligence and prosocial behaviour (74). There was a significant and positive effect of the intervention on both of these outcomes from baseline to follow-up (74).

See appendix E for full results on social and emotional wellbeing.

9. Nature connectedness

Nine studies looked at the impact of attending nature ELC on nature connectedness, of which three studies were controlled before and after (43, 45, 58), two were uncontrolled before and after (76, 77), three were controlled cross-sectional (78-80) and one was cross-sectional (63). The quality across the nine studies reporting on nature connectedness outcomes is shown in Figure 13.

Figure 13. Quality across studies: Nature connectedness



9.1. Nature-based ELC settings

Table 9 presents the results for nature connectedness in eligible studies where these outcomes were reported in more than one study. Six studies assessed nature relatedness (or biophilia) and five studies reported higher scores in children who attended nature ELC, of which four studies were significant (43, 45, 77-79). One study showed no difference (80). For environmentally responsible behaviour, two studies showed a negative health impact (43, 45), although differences between children who attended nature-based ELC and traditional ELC were marginal (43, 45). One study also reported higher scores in children who attended nature ELC (78). Finally, in two studies, awareness of environment was higher in children who attended nature ELC compared to traditional settings (58, 78).

There were also improvements in knowledge and skills of nature in children who attended an educational intervention (76) and awareness of the surrounding environment was higher children who attended nature ELC (58).

Table 9. Nature-based ELC vs traditional ELC on nature connectedness

Study ID	Study Design	Sample size (E/C)	Favours comparison	Favours nature
Nature Relatedness / biophilia				
Elliot et al (2014)[43]	Controlled before & after	21 / 22		DG
Müller et al (2017)[45]	Controlled before & after	43 / 45		G
Yilmaz et al (2020)[77]	Uncontrolled before & after	40		DG
Barrable et al (2020)[78]	Controlled cross-sectional	141 / 110		DG
Giusti et al (2014)[79]	Controlled cross-sectional	11 / 16		DG
Rice & Torquati (2013)[80]	Controlled cross-sectional	68 / 46	/	/
Environmentally responsible behaviour				
Elliot et al (2014)[43]	Controlled before & after	21 / 22	O	
Müller et al (2017)[45]	Controlled before & after	43 / 45	O	

Barrable et al (2020)[78]	Controlled cross-sectional	141 / 110		DG	
Awareness of nature / environment					
Agostini et al (2018)[58]	Controlled before & after	41 / 52		G	
Barrable et al (2020)[78]	Controlled cross-sectional	141 / 110		G	

Abbreviations: E= experimental; C= comparison; N= number; ELC= Early learning and childcare.

One colour block = one study.

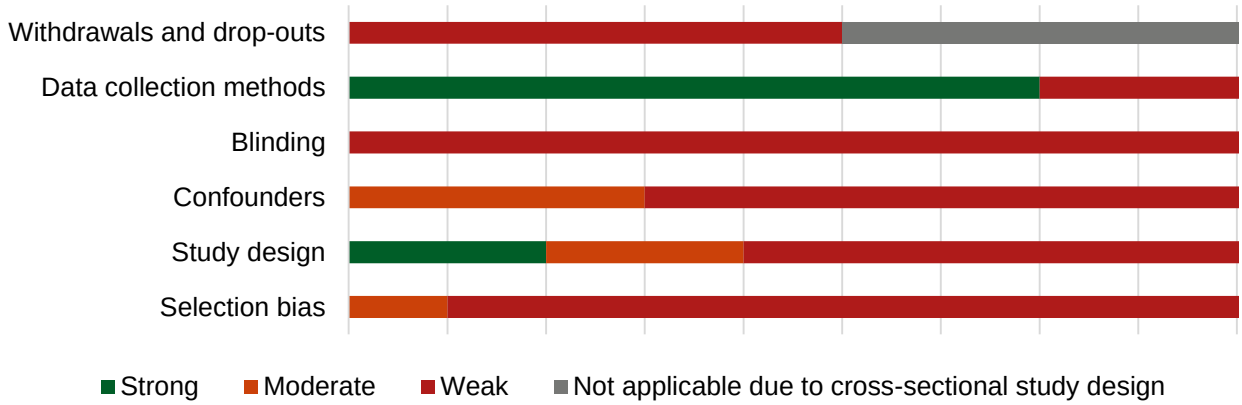
■ (dark green – DG) = favours nature and statistical significance (p<.05); ■ (green – G) = favours nature; ■ (orange – O) = favours comparison; ■ (grey – //) = favours neither nature or control, or statistics not presented.

Controlled before & after studies – difference between experimental and control group at follow-up (unless stated). Uncontrolled before & after studies – change since baseline (unless stated). Controlled cross sectional – difference between experimental and control (unless stated). Cross-sectional – positive, negative or no association.

10. Play behaviour

A total of ten studies included an outcome related to children's play behaviour, of which three studies were controlled before and after (34, 58, 67, 68), one was uncontrolled before and after (42), three were controlled cross-sectional (81-83) and three were cross-sectional (84-86). The quality across the ten studies reporting on play behaviour outcomes is shown in Figure 14.

Figure 14. Quality across studies: Play behaviour



10.1. Nature-based ELC settings

Table 10 presents the results for play behaviour in eligible studies where these outcomes were reported in more than one study. Three studies assessed play interaction, two demonstrated significantly higher play interactions in children who attended nature ELC and one showed less (34, 67, 68, 81). Findings for play disconnection and disruption were mixed (34, 67, 68).

Overall play development and pretend play was higher in nature ELC compared to traditional settings (34, 58).

Table 10. Nature-based ELC vs traditional ELC on play behaviour

Study ID	Study Design	Sample size (E/C)	Favours comparison	Favours nature
Play interaction				
Cordiano et al (2019)[34]	Controlled before & after	12 / 14	O	
Burgess & Ernst (2020)[67, 68]	Controlled before & after	84 / 24		DG
Robertson et al (2020)[81]	Controlled cross-sectional	15 / 15		DG
Play disruption				
Cordiano et al (2019)[34]	Controlled before & after	12 / 14	R	
Burgess & Ernst (2020)[67, 68]	Controlled before & after	84 / 24		DG
Play disconnection				
Cordiano et al (2019)[34]	Controlled before & after	12 / 14	R	
Burgess & Ernst (2020)[67, 68]	Controlled before & after	84 / 24		DG

Abbreviations: E= experimental; C= comparison; N= number; ELC= Early learning and childcare.

One colour block = one study.

■ (dark green – DG) = favours nature and statistical significance (p<.05); ■ (green – G) = favours nature; ■ (orange – O) = favours comparison; ■ (red – R) = favours comparison and statistical significance (p<.05).

Controlled before & after studies – difference between experimental and control group at follow-up (unless stated). Uncontrolled before & after studies – change since baseline (unless stated). Controlled cross sectional – difference between experimental and control (unless stated). Cross-sectional – positive, negative or no association.

10.2. Naturalised playgrounds

Five studies with naturalised playgrounds included outcomes related to children's play behaviours. One study was an intervention where children were measured prior to their playgrounds being modified to include more nature and again once the renovations were completed (42). The other studies compared play in natural versus traditional playgrounds (82-85). The intervention study found significant improvements in playing with natural elements from baseline to follow-up (42). There was also more risky play, solitary play and more prosocial and less antisocial behaviours observed in their play (42). There was also evidence across studies to indicate that children engaged in more creative and imaginative play. Dramatic play was significantly higher in natural playgrounds compared to manufactured ones (82). In another study, in the natural playground children engaged in longer

episodes of sociodramatic play episodes compared to children from the traditional playground and were more likely to engage in object substitutions, explicit metacommunication (nonverbal cues such as tone of voice, body language etc.) imaginative transformations (85). Functional and constructive play was also higher, but creative and imaginative play was low across playgrounds with natural areas and those with no natural areas (84). However, another study demonstrated that functional and imaginative play tended to be higher in traditional playground compared to natural ones (83).

10.3. Types of natural elements

One study looked at cognitive play (functional, constructive, exploratory, dramatic, games with rules) across natural, mixed and manufactured zones in playgrounds. Compared to the mixed and traditional zones, the natural area afforded greater dramatic, exploratory and constructive play (86).

Summary of social, emotional and environmental development

In summary, across a small number of studies, findings were inconsistent for **social skills, social and emotional development, attachment, initiative** and **behavioural problems.** Evidence for the environmental domain indicated positive associations with **nature relatedness**. Findings for **awareness of nature** and **environmentally responsible behaviour** were inconsistent. There was also an indication that **play interaction** was higher in children who attended nature ELC compared to traditional ELC. Findings for **play disruption** and **disconnection** were inconsistent.

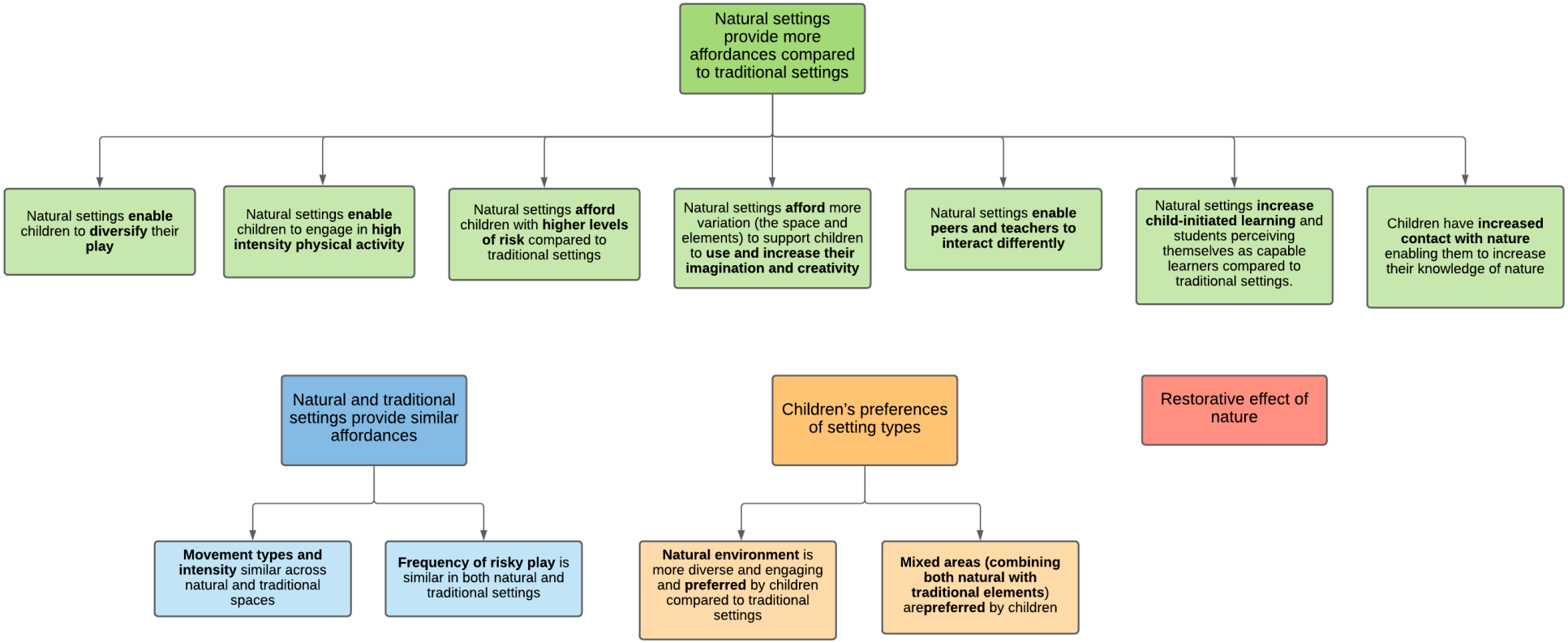
Main findings – Qualitative research studies

There were ten studies included in the thematic analysis (see Appendix C and E for characteristics and findings of included studies), of which, six studies involved nature-based ELC, three studies were naturalised playgrounds and one study included natural elements. A combination of direct observation and interviews (predominately with educators) were the most commonly used methods to collect data.

Findings from the thematic analysis indicated four main themes (presented in Figure 15):

1. Natural ELC settings provide more affordances compared to traditional ELC settings
2. Natural and traditional ELC settings provide similar affordances
3. Children’s preferences of setting types
4. Restorative effect of nature

Figure 15. Overview of the four main themes from the thematic analysis



Theme 1: Natural ELC settings provide more affordances compared to traditional ELC settings

This theme included a number of sub-themes all relating to the different affordances that nature provides compared to traditional settings, including: diversifying play; high intensity physical activity; risk; increased imagination and creativity; peer and teacher interactions; child-initiated learning and perception of learning, and increase their knowledge of nature.

The majority of studies (n=7) indicated that nature afforded children with the opportunity to engage in a range of play types (32, 33, 86-90). This is important for movement and physical activity but also supports social interaction and creativity. Related to diversifying play, two studies reported that nature enables children to engage in high intensity physical activity (89, 91). Similarly, two studies suggested that nature setting afford higher levels of risk (90, 92), but not necessarily higher frequency of risky play (see Theme 2).

> *"High physical-motor levels are created, the children jump down and run back up. They talk, shout and laugh. Three of the girls jump together and try to land in differing ways. They hold hands and try to jump together from the small knoll. There is laughter. They are eager and enduring. The small knoll has many opportunities for variation, in height and width, which invite challenges suitable for each child's resources. The children have visual, verbal and physical contact with each other. The top of the knoll provides an overview. Some find it scary the first time they try, but together they challenge each other, supporting and encouraging each other. The children decide how much they will participate and how they jump, and how they wish to solve the challenges offered by the knoll" (91).*

> *"I like playing in the fallen logs and trees on the playground; it is so much fun, but a bit scary too! I like the big pile of sticks and logs that we made – it is for another fort that is going to be really high off the ground." (92).*

Findings from this theme also indicated the importance of the natural environment for increasing imagination and creativity (86, 88, 92), increasing contact with nature (33, 88, 89) and enabling children to interact with peers and teachers differently (33, 88, 91, 92). Another theme noted that natural settings increase child-initiated learning and student perceiving them as capable learners (33, 86, 93).

> *"[CogG] has poor concentration, sees herself as the baby, finds it difficult to sit and listen to story. She is extremely lacking in confidence … shy … she won't look at you indoors. With child-led learning she is totally engrossed and remains on task. Outside is the best learning environment for her … she remains on task. When outside she will come over and say 'I like this' and 'I like doing that', 'this is my favourite place." (93)*

Theme 2: Natural and traditional settings provide similar affordances

This theme included two sub-themes a) movement types and intensity are similar across natural and traditional spaces and b) frequency of risky play is similar in both natural and traditional settings. This theme indicated that two related outcomes: physical activity and risky play are similar no matter the playground type (nature or traditional). Sandseter (2009) noted that children will always seek risk no matter the playground type, but natural areas provide the opportunity for greater risk (see Theme 1) (90). Similarly, in another study movement types and intensity did not vary in natural playgrounds compared to traditional playgrounds (32). However, this was found it one study only. Theme 1 indicated that natural settings enable children to engage in high intensity physical activity and to diversify their play.

Theme 3: Children's preferences of setting types

This theme included two sub-themes a) natural environment is more diverse and engaging and preferred by children compared to traditional settings and b) mixed areas (combining both natural with traditional elements) are preferred by children.

Two studies indicated that children preferred the natural environment compared to the traditional (91, 92) and one indicated they preferred mixed-areas (86). Based on the three studies, it appears that children at minimum prefer their playground somewhat naturalised.

> *"I like going outside and playing! I like playing with my friends, Sydney and Megan. We play hide and seek on the playground and hide in the forest in the logs and trees. I like outside [in nature] because it's so fun and I really like to play. Sometimes I play with my sister too; I like all the colours outside and all the space." (92)*

Theme 4: Restorative effect of nature

Two studies indicated the benefits of the natural environment for having a restorative effect on children (88). The experiences and exposure to nature enabled children to be energetic and engage in a variety of play types, but it was noted that these experiences supported them to sleep easier and restore their energy levels.

> *"Now it's become very difficult to finish playing. They would rather continue, and those who need to take a nap, they've had a nice, long time outdoors and nice games so they fall asleep more easily, and it affects their energy in the afternoon. Some children have very long days here. They come in the morning and stay until five o'clock; they seem to be somehow energetic and lively in the yard. This is new for us. The contrast to the previous yard is so great that the effects can be seen here very quickly." (89)*

Summary of qualitative evidence

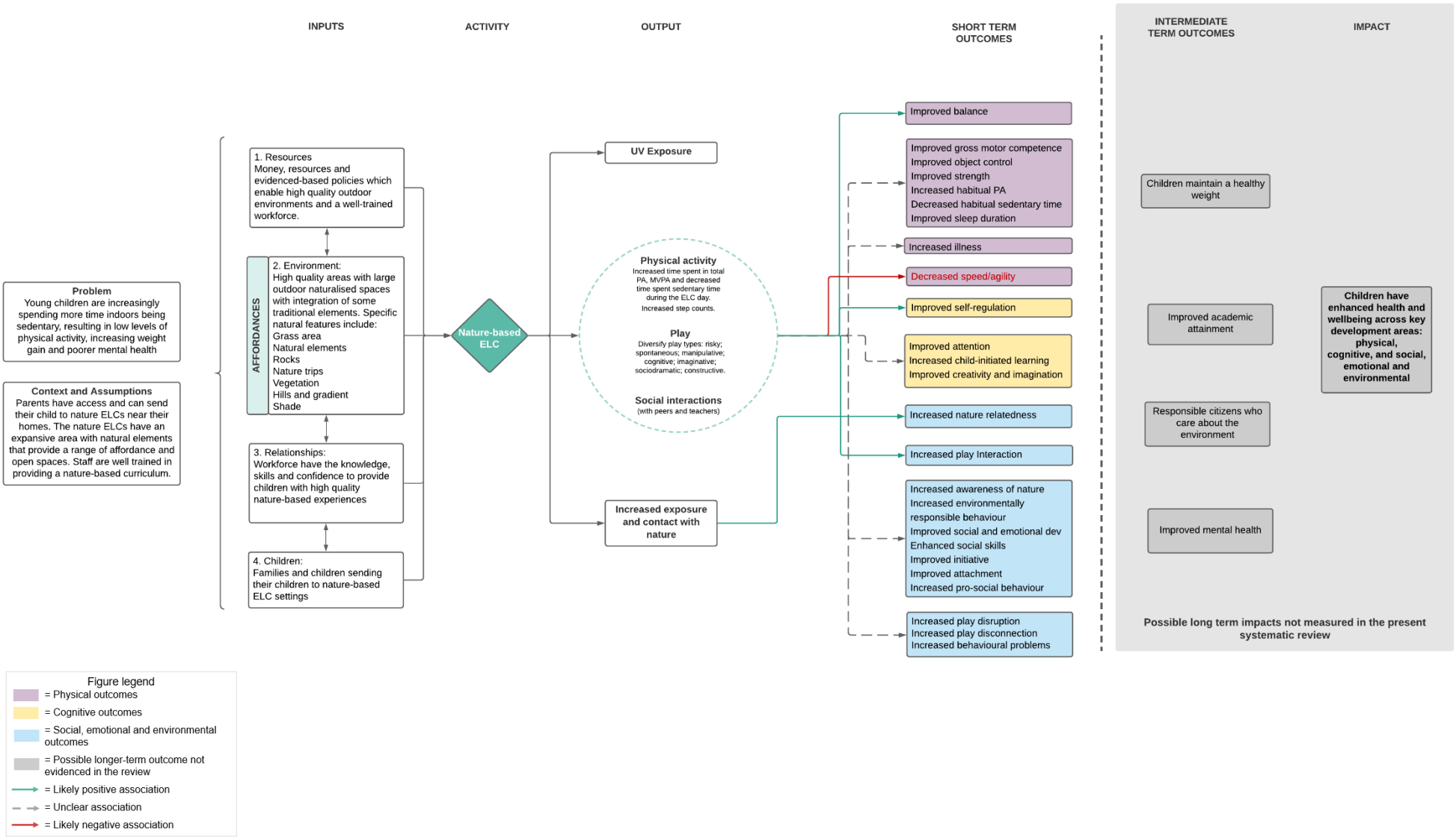
Findings from the qualitative evidence suggests that compared to traditional settings, the natural environment affords many more opportunities for children to be physically active, play and interact with their peers. Natural settings are also important for providing restoration for children. Children also prefer settings which integrate some nature either a full naturalised playground or a mixed area. A small number of studies indicated that movement and risky play were similar no matter the setting type.

Logic model

Figure 16 presents a logic model of the combined quantitative and qualitative evidence. The purpose of this logic model is to present what is required for a nature-based ELC to function (the **inputs**), what are the direct environmental and child level **outputs** and what the possible short and intermediate term **outcomes** might be for children.

We could only draw conclusions on short term outcomes because studies did not assess the longer term impacts of nature-based ELC. We propose what the longer-term outcomes and impact (grey box) might be based on other evidence (detailed in the discussion). Based on the evidence we could not draw specific conclusions on what the possible causal pathways might be, but this logic model can act as a hypothesis of what the benefits are for children and what has caused these benefits.

Figure 16. Logic model from the combined quantitative and qualitative evidence



Discussion

This systematic review aimed to synthesise existing global literature to examine whether attending nature-based ELC influenced children's physical, cognitive, and social and emotional development. This was a comprehensive review of a large body of both quantitative and qualitative evidence.

Key findings

Findings from the **quantitative** evidence suggested predominately positive associations across a number of outcome domains and sub-domains. These are summarised below.

Based on very low and moderate evidence, playgrounds which included grassed areas, vegetation, natural elements, rocks, hills or shaded areas were **positively associated** with increased **total physical activity**, **moderate-to-vigorous physical activity (MVPA)** and **step counts** and **decreased sedentary time** during ELC.

Based on low and moderate evidence, compared to traditional ELC, nature-based ELC was **positively** associated with:

- **balance**
- **self-regulation** (ability to understand and manage behaviour)
- **nature relatedness** (or biophilia)
- **play interactions**

Based on moderate evidence, compared to traditional ELC, nature-based ELC was **negatively** associated with children's **speed and agility.**

Based on very low, low and moderate evidence, compared to traditional ELC, nature-based ELC had **inconsistent** findings on the following outcomes:

- object control skills
- attention
- social skills
- social and emotional development
- attachment
- initiative
- awareness of nature
- environmentally responsible behaviour
- illnesses
- behavioural problems (such as temper tantrums or hyperactivity)
- play disruption (aggressive and antisocial behaviours in play) and disconnection (withdrawn behaviour and nonparticipation in play)

Findings from the **qualitative** (e.g. practitioner reported feedback) element of the review also generally reported positive findings:

- Nature affords many more opportunities for children to be active, diversify their play, engage in risky play, interact with peers and teachers, increase their creativity and enable child-initiated learning compared to traditional settings.
- Nature-based ELC affords opportunities for children to be physical activity, to engage in diverse types of play and interact with peers. This combination is likely to have an impact on a range of physical, cognitive, and social and emotional outcomes (logic model).
- Children prefer settings which integrate some nature either a full naturalised playground or a mixed area. A small number of studies indicated that movement and risky play were similar no matter the setting type.

Strengths and limitations of the review process & evidence

This was a comprehensive review of global **quantitative** and **qualitative** evidence on the impact nature-based ELC on children's health, wellbeing and development. The review was guided by a steering group which consisted of experts in this area from research, policy and practice. These experts were involved throughout the project to ensure relevancy across disciplines. The review also involved international co-authors who supported data screening, translation of papers and providing important country specific contexts to ensure all global evidence was captured. A total of nine databases were searched and not restricted by publication year or language. Searches extended to websites and non-published research, and

experts from policy, practice and research were contacted to provide evidence. We included all study designs and not just the “gold standard” to ensure this review provided an overview of the best available evidence to date. The review was registered to PROSPERO, an online systematic review registry, and a protocol published to BMC Systematic Reviews (22). Strict systematic review procedures were followed ensuring rigour at each step. Full text articles were screen and study quality were assessed independently by two reviewers.

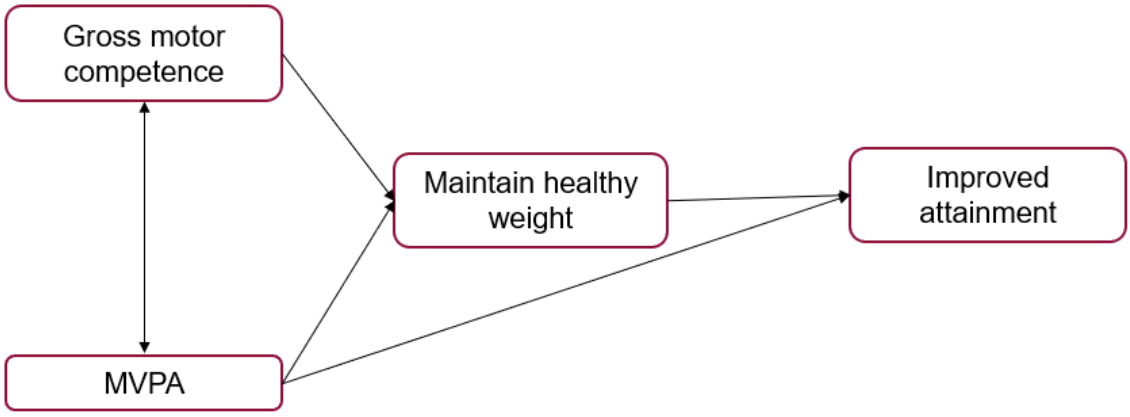
However, we were unable to screen titles and abstracts or extract data in duplicate. This was mitigated by screening 10% of the titles and abstracts, and data were checked by a second reviewer. The EPHPP tool used to assess quality was modified slightly to ensure relevancy for the present review, but this may have reduced the validity and reliability of the tool. Strength and limitations of the evidence - 59 unique studies (representing 65 articles) were included in this review, of which, nine were controlled before and after designs. Eligible studies were conducted across 15 countries ensuring global relevancy of the report. Studies also tended to use reliable and valid methods for assessing the outcomes which gives greater confidence in the findings presented. However, the majority of these studies were cross-sectional or controlled cross-sectional with small sample sizes meaning that we cannot be certain that any results found were because of the exposure. Studies were predominately rated weak because the children and ELC settings were unlikely to be representative, it was unclear whether the researchers or outcome assessors were aware of the research questions (potentially introducing bias into the study) and withdrawals and dropouts were not reported or was high.

Implications for future research

To enhance the evidence base, future research should focus on well-designed controlled studies with larger sample sizes and robust valid and reliable measures for assessing a range of physical, cognitive, social, emotional, and environmental outcomes. This would help to understand whether benefits and possible harms are a result of attending nature-based ELC and not any other factor.

The studies included in the review only explored the short-term impacts of attending nature-based ELC (see logic model) meaning that we were unable to draw specific conclusions about possible longer-term benefits. However, we know from other literature how pathways may be drawn between the short and intermediate-term outcomes. For example (see Figure 17), previous systematic reviews have suggested that gross motor competence (movements which require the whole body such as running or jumping) is positively associated with physical activity levels in childhood and adolescence (94, 95). This relationship is bi-directional as physical activity is also associated with better motor competence (14). Young children who engage in higher levels of physical activity, particularly MVPA, are more likely to have a healthy weight (14); and obesity is both a cause and consequence of low levels of MVPA (96). Finally, evidence is suggestive of MVPA being positively associated with academic attainment (97) and higher levels of obesity being associated with lower attainment (98). This is just one example, but similar pathways exist for other short and intermediate-term goals.

Figure 17. Example of a pathway between short and intermediate-term outcomes



Longitudinal studies that explore the impact of attending nature-based ELC over a longer period, e.g. into primary school, would a) enable us to understand the longer-term impacts and b) support continuity of policy in primary school education to ensure children continue to receive outdoor natural experiences. This is important because in Scotland the majority of children who attend nature-based ELC settings will transition into a traditional primary school setting that may offer predominately indoor and more sedentary education. This may result in children who attended nature-based ELC finding the transition more difficult, with any possible improvements gained from the nature-based experiences potentially diminishing over time.

Finally, the evidence base in the UK is limited. Only three studies were included in this review, of which, only one collected data in Scotland. As nature-based ELC increases in Scotland, it is important that more robust evidence (as described above) is collected to understand the impacts on children's health, wellbeing and development. Although evidence from other counties can be informative, each country has different policy, environmental and cultural contexts which may not translate. Examples include the weather, funding structure and country specific cultures (for example, aversion to being outdoors in poor weather or pervasive use of screen time). Most of the studies included in the review were conducted in the US or Australia where the climate is not comparable to Scotland. Similarly, many were also conducted in Norway which has a strong cultural emphasis on being outdoors in nature – the term "Friluftsliv" (translated "free air life") relates to the strong connection Norwegians have to nature (99). Finally, understanding the specific funding structure in Scotland is also an important factor. Many nature-based ELCs are still private meaning there is not equitable access for all children, although nature-based approaches are increasing through satellite and indoor/outdoor approaches in local authority ELCs.

Summary – Identified research gaps:

1. The evidence base is compounded by studies which have small sample sizes, are not controlled and use weak study designs (cross-sectional). This limits the conclusions we can draw from the evidence. Future research

should be higher quality with stronger controlled designs and larger sample sizes to enable us to draw stronger conclusions on the impact of nature-based ELC on children's health, wellbeing and development.

2. None of the studies included assessed the longer-term impact of nature-based ELC on children's physical, cognitive, social, emotional and environmental development. By conducting longitudinal research, we will be able to understand more about the possible impacts of nature-based ELC and the mechanisms by which improvements occur.
3. The evidence base in Scotland and the UK is limited – only one study in the review was conducted in Scotland. Given the current focus on expanding nature-based ELC provision, it is important that more high quality research is conducted in Scotland to understand specific contexts (policy, environment and culture) and benefits (or harms) to children.

Implication for policy and practice

Based on very low to moderate quality evidence (with low number of children and studies across different outcomes), findings are supportive of nature-based approaches in ELC settings, with no findings suggesting harms to children. Across most outcomes, the findings generally favour nature compared to the comparison (traditional ELC). Only one outcome, **speed and agility**, was negatively associated, and this was across a small number of studies. **Balance**, **self-regulation**, **nature relatedness** and **play interactions** were positively associated with nature-based ELC compared to traditional ELC.

In Scotland there are three delivery models: outdoor (or nature-based ELC); indoor/outdoor (children move freely from indoors to outdoors); and satellite (taken to another setting for nature-based experiences). Table 11 presents the type of ELC provided per study for each outcome category where there were positive associations. The majority of studies used an outdoor approach, five studies used a satellite approach and one indoor/outdoor. It is important to highlight that irrespective of approach, in studies with favourable outcomes, children were exposed to large amounts of nature on almost a daily basis. For example, for studies that used a satellite approach, children had daily trips (18, 43, 59, 60, 79) meaning children spent most of their time outdoors in nature. Similarly in the study with the indoor/outdoor approach (35), children were allowed outdoors when they wanted but also participated in a weekly forest programme. It is important to highlight that these studies were conducted in countries which may have a better climate than Scotland meaning that it is perceived to be easier to be outdoors daily. However, across indoor/outdoor and satellite settings in Scotland, with support from the practitioners, it might be useful to quantify how regularly children are outdoors in nature to understand whether this can be improved. Findings from this report are important in providing evidence for expansion of free ELC entitlement; however, if nature-based approaches continue to increase in Scotland, these should be supported by robust research (as detailed in the previous section) to understand more about the impacts and any possible causal pathways.

Table 11. Positive outcomes grouped by type of nature-based ELC provision.

Outcome	Study	Description of nature-based ELC	Scottish ELC category	Discussions and implications
Balance	Ene-Voiculescu & Ene-Voiculescu (2015), Norway [18, 59, 60]	Children used the forest next to the ELCs every day for 1-2 hours throughout the year when they attended kindergarten. The small forest (7.7 hectares) consisted of mixed woodland vegetation, some open spaces of rocks and open fields and meadows in between. Occasionally they used the outdoor playground inside the ELCs.	Satellite	Nature-based ELC was significantly positively associated with balance in two out of three studies. All three studies used highly naturalised settings which are likely to afford opportunities for children to develop their balance (rocks, logs etc). It was unclear why the third study (Lysklett) was not positively associated with balance given the exposure was similar across these studies.
	Scholz & Krombholz (2007), Germany [62]	Forest kindergarten.	Outdoor	
	Lysklett et al (2019), Norway [61]	Nature-based ELCs located close to a large recreational area, with woods, lakes and tracks just outside the city centre. They used the nearby nature area for hiking and playing least three times, per week	Satellite	
Self-regulation	Cooper (2018), England [35]	Forest school sessions run by two trained leaders which operate for 10 week cycles on Tuesday AM and PM (2 hours each). Children attend either the AM or PM session. The forest school consists of trees and vegetation, a seating area made from logs, a mud kitchen using old crates and a tyre, a greenhouse and pond. The forest school is located on site and when children do not have forest school sessions outdoors, they have a " free flow" environment where children are allowed outside when they want.	Indoor/ outdoor	Nature-based ELC was positively associated with self-regulation in three studies (significant in two). All three studies had a high exposure to nature where children spend the majority of their time outdoors.
	Ernst et al (2019), USA [68, 70]	The ELCs utilised a combination of wild natural settings spaces that were minimally managed and natural playscapes designed specifically for nature play. The majority of time spent was in free play outdoors in unmaintained or minimally maintained natural settings regardless of weather conditions (approximately four to five hours per day). Children at both groups had one to two hours of daily outdoor playtime (weather permitting) in a maintained outdoor space that contained playground equipment.	Outdoor	
	Müller et al (2017), Canada [45]	Nature kindergarten.	Outdoor	
Nature relatedness	Müller et al (2017), Canada [45]	Nature kindergarten.	Outdoor	Nature-based ELC was positively associated with nature relatedness in

	Elliot et al (2014), Canada [43]	A two-year pilot project in which 22 students would spend the mornings from 9:00 to 11:45 outside their school, exploring their local natural environment.	Satellite	three studies (significant in four). These studies used a combination of outdoor and satellite sessions, indicating that any increased exposure to nature may improve nature relatedness. One study (Rice & Torquati) found neither favourable nor unfavourable associations.
	Yilmaz et al (2020), Turkey [77]	Children visited a natural, unstructured area for one day in a week for four consecutive weeks. The education programme consisted of 12 semi-structured activities (3 per week). In addition, children also had 30 minutes' walk near a natural pond when they visit the setting each week and each week, children had 30 minutes unstructured free play time to discover the natural environment.	Satellite	
	Barrable et al (2020), UK (England, Scotland, Wales) [78]	ELCs that have a continuous outdoor provision, with no permanent indoor access and children are outdoors for the whole duration of the ELC day.	Outdoor	
	Giusti et al (2014), Sweden [79]	ELCs were assessed on their frequency of natural experiences. Each ELCs was ranked according to the highest frequency of use of the greatest variety of nature experiences in its surroundings. This included ten ELC's with the most frequent use of all nature experiences.	Satellite	
	Rice & Torquati (2013), USA [80]	The nature ELCs featured: vegetation, gardens, areas for digging in soil, sand, and "loose parts" (sticks, seeds, pinecones etc) and other naturally occurring objects that children used in their play. Climbing structures and pretend play structures such as a boat or a playhouse were also included.	Outdoor	
Play interactions	Burgess & Ernst (2020), USA [67, 68]	See Ernst et al (2019)	Outdoor	Nature-based ELC was significantly positively associated with play interaction in two studies. These settings are highly naturalised where children spend most of their time outdoors. One study found a negative association (Cordiano); however, in this study children also spend most of their time outdoors in nature.,
	Robertson et al (2020), Australia [81]	ELC located in a rural area and consisted of a small traditional playground area (sand pit, obstacle course etc.) and a larger open ended nature area consisting of trees, shrubbery, grass, natural loose-parts). It has a highly naturalised area towards the rear that was rich in natural elements including small and large shrubbery, and larger tree and vegetation	Outdoor	
	Cordiano et al (2019), USA [34]	Outdoor ELC programme involved children spending five mornings per week at the school's outdoor campus. The children were outdoors in the forest for 90% of the school day.	Outdoor	

There are key environmental features that appear particularly important for increasing total PA and MVPA, reducing sedentary time, supporting risky play and diversifying play types, enabling different human interactions and supporting creativity. These tend to be a combination of grassed areas, vegetation, natural elements, grass, rocks, hills and shaded areas. It is important, where possible, that ELC settings afford these natural features, possibly with a combination of traditional elements (such as open space) which may enhance other outcomes. Furthermore, some qualitative evidence highlighted that children may prefer playgrounds with a mixture of nature and traditional spaces. This evidence builds on the Scottish Government's "Out to Play - creating outdoor play experiences for children: practical guidance" (20) and could support a future revised version of this document.

The majority of studies included in the review did not look at the role of the practitioner specifically. However, the evidence suggests that nature is likely to afford opportunities for children to interact differently with their peers and practitioners. Practitioners are likely to influence the experiences children have in nature-based ELC by ensuring that children have opportunity to be outdoors in nature to enable them to play, be physically active and interact with each other. It is important that practitioners understand the importance of promoting being outdoors in nature and related benefits possibly through targeting training and removing barriers.

Suggested recommendations

1. Ensure that ELCs have a rich and varied environment that includes a combination of grassed areas, vegetation, natural elements, rocks, hills and/ or shaded areas. These appear particularly important for encouraging physical activity, diversifying play types and enabling human interactions which are important for childhood development.

2. Ensure that all children can access nature across all setting types: outdoor; indoor/outdoor; satellite. In studies where there was a likely association, evidence from this review suggested that both indoor/outdoor and satellite approaches provided children with high exposure to nature. Therefore, it is important to understand **how much and how regularly** (daily, weekly, etc) children are exposed to/engage with nature across each setting.

3. To aide future policy development in Scotland, it is important that researchers work collaboratively with practitioners and policy makers to establish **what** child and ELC level outcomes should be measured and **how** we can best collect data on these. By embedding robust evaluation practices, we can generate stronger evidence on the impact of nature-based ELC in Scotland.

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List of abbreviations

BMI = Body mass index
CARS = Children's Activity Rating Scale
CPM = Counts per minute
EPHPP = Effective Public Health Practice Project
GRADE = Grading of Recommendations, Assessment, Development and Evaluation
ELC = Early learning and childcare
ERIC = Education Research Information Centre
Mins = Minutes
MVPA = Moderate to vigorous physical activity
OSRAC-P = Observational System for Recording Physical Activity in Children-Preschool
PA = Physical activity
PI(E)COS = Population, Intervention or Exposure, Comparison, Outcome, Study design
Study ID = Study identifier
SWiM = Synthesis without Meta-analysis
UV = Ultraviolet

Glossary

Term	Definition
Randomized control trial (RCT)	A study in which a number of similar people are randomly assigned to 2 (or more) groups to test a specific drug, treatment or other intervention. One group (the experimental group) has the 'intervention' being tested (e.g., nature-based ELC), the other (the comparison or control group) has an alternative intervention, a dummy intervention (placebo) or no intervention at all (i.e. usual practice such as traditional ELC). The groups are followed up to see how effective the experimental intervention was. Outcomes are measured at specific times and any difference in response between the groups is assessed statistically.

Randomisation	Assigning people in a research study to different groups without taking any similarities or differences between them into account. For example, it could involve using a random numbers table or a computer-generated random sequence. It means that each individual (or each group in specific types of designs) has the same chance of having each intervention. This is a very important step to reduce bias in the cause-effect relationship by distributing measured and unmeasured participant characteristics randomly between groups.
Controlled Before & After study (CBA)	The allocation of participants to the intervention or control group is not randomised. The key outcome is assessed among the same study population before and after receipt of the intervention. The change in outcome is compared with the same outcome measurements and changes in a suitable comparison group acting as a control group who have not received the intervention. The key outcome is assessed at the same time points in the intervention and the control group. This design may be referred to as a non-randomised controlled trial or quasi-experimental study
Uncontrolled Before & After Study	Similar to the CBA design but with one major difference: no control group is included to act as a comparator for those who received the 'intervention'.
Longitudinal study	A study of the same group of people at different times. This contrasts with a cross-sectional study, which observes a group of people at one point in time.
Retrospective study	A research study that focuses on the past and present. The study examines past exposure to suspected risk factors for the disease or condition. Unlike prospective studies, it does not cover events that occur after the study group is selected.
Cross-sectional study	A 'snapshot' observation of a group of people at one time point. Can be a study that examines the relationship between an exposure (e.g. nature-based ELC or natural elements) and outcomes of interest (e.g. health indicator) at one time point.
Controlled cross-sectional study	A study that examines the relationship between the exposure and outcomes of interest at one time point in two or more groups (e.g. naturalised playground and traditional playground).
Statistical Significance	A statistically significant result is one that is assessed as being due to a true effect rather than random chance. See P value.
P-value	The p value is a statistical measure that indicates whether or not an effect is statistically significant. For example, if a study comparing 2 treatments (e.g. nature-based ELC vs traditional ELC) found that 1 seems to be more effective than the other, the p value is the probability of obtaining these results by chance. By convention, if the p value is below 0.05 (that is, there is less than a 5% probability that the results occurred by chance), it is considered that there probably is a real difference between treatments. If the p value is 0.001 or less (less than a 0.1% probability that the results occurred by chance), the result is seen as highly significant. However, a statistically significant difference is not necessarily practically significant. For example, nature-based ELC might increase children's levels of physical activity statistically significantly more than traditional ELC. But, if the difference in the average time spent in physical activity is 1 minute, it may not be practically significant. If the p value shows that there is likely to be a difference between treatments, the confidence interval describes how big the difference in effect might be.

[1] available from https://www.nice.org.uk/Glossary

Appendices

Appendix A. Example search strategy – ERIC

S1	DE "Preschool Children"
S2	TI child* OR AB child*
S3	TI (boy* OR girl*) or AB (boy* OR girl*)
S4	TI toddler OR AB toddler
S5	TI young N1 child* OR AB young N1 child*
S6	TI early N1 child* OR AB early N1 child*
S7	TI early N1 year* OR AB early N1 year*
S8	TI “pre-primary” or AB “pre-primary”
S9	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8
S10	DE "Nursery Schools" OR DE "Preschool Education" OR DE "Outdoor Education" OR DE "Adventure Education"
S11	TI nurser* OR AB nurser*
S12	DE "learning" OR TI early N1 learning OR AB early N1 learning
S13	TI (“preschool” or “pre-school”) OR AB (“preschool” or “pre-school”)
S14	TI kindergarten OR AB kindergarten
S15	TI (childcare OR child N1 care) OR AB (childcare OR child N1 care)
S16	TI (daycare OR day N1 care) OR AB (daycare OR day N1 care)
S17	TI education OR AB education
S18	DE "Play" OR TI (Play OR “play-based learning”) OR AB (Play OR “play-based learning”)
S19	TX (Waldkindergartens OR udeskole OR friluftsliv OR peuterspeelzaal OR kinderopvang OR bush N1 kinder*) OR TI (forest N1 kindergarten* OR forest N1 school*) OR AB (forest N1 kindergarten* OR forest N1 school*)
S20	S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19
S21	TI outdoor* OR AB outdoor*
S22	TI (nature OR “nature-based”) OR AB (“nature-based”)
S23	TI environment* OR TI outdoor N1 environment* OR AB outdoor N1 environment*
S24	TI (forest* OR wood* OR park* OR recreation* OR landscape* OR tree* OR hill* OR garden* OR beach* OR eco)
S25	AB (forest* OR wood* OR park* OR recreation* OR landscape* OR tree* OR hill* OR garden* OR beach* OR eco)
S26	TI (green OR greenspace or green N1 space) OR AB (green OR greenspace or green N1 space)
S27	TI (loose N1 parts OR “loose-parts”) OR AB (loose N1 parts OR “loose-parts”)
S28	TI (adventure* OR wild OR “open-air”) OR AB (adventure* OR wild OR “open-air”)
S29	S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28
S30	S9 AND S20 AND S29

Appendix B. Modified quality appraisal tools
EPHPP Quality Assessment Tool

Modifications in bold red

A) SELECTION BIAS
(Q1) Are the individuals selected to participate in the study likely to be representative of the target population? **(i.e. children aged 2-7 years not in formal education yet)**

1. Very likely
2. Somewhat likely
3. Not likely
4. Can't tell

(Q2) What percentage of selected individuals **consented to the research?**

1. 80 - 100% agreement
2. 60 – 79% agreement
3. less than 60% agreement
4. Not applicable
5. Can't tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

B) STUDY DESIGN
Indicate the study design:

1. Randomized controlled trial
2. Controlled clinical trial
3. Cohort analytic (two group pre + post)
4. Case-control
5. Cohort (one group pre + post (before and after))
6. Interrupted time series
7. Other specify _____
8. Can't tell

Was the study described as randomized? If NO, go to Component C.
No **Yes**

If Yes, was the method of randomization described? (See dictionary)
No **Yes**

If Yes, was the method appropriate? (See dictionary)
No **Yes**

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

C) CONFOUNDERS
(Q1) Were there important differences between groups prior to the intervention?

1. Yes
2. No
3. Can't tell

The following are examples of confounders:

1. **Gender**
2. **Age**
3. **Socio economic status (SES – e.g. Parental education, deprivation status)**

(Q2) If yes, indicate the percentage of relevant confounders that were controlled (either in the design (e.g. stratification, matching) or analysis)?

1. **All confounders**

2. **Two confounders**
3. **One confounder**
4. Can't Tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

D) BLINDING
(Q1) Was (were) the outcome assessor(s) **and/or analysists** aware of the intervention or exposure status of participants?
1. Yes
2. No
3. Can't tell

(Q2) **Were outcome assessors aware of the research question?**
1. Yes
2. No
3. Can't tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

E) DATA COLLECTION METHODS
(Q1) Were data collection tools shown to be valid?
1. Yes
2. No
3. Can't tell

(Q2) Were data collection tools shown to be reliable?
1. Yes
2. No
3. Can't tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

F) WITHDRAWALS AND DROP-OUTS
(Q1) Were withdrawals and drop-outs reported in terms of numbers and/or reasons per group?
1. Yes
2. No
3. Can't tell
4. Not Applicable (i.e. one time surveys or interviews)

(Q2) Indicate the percentage of participants completing the study. (If the percentage differs by groups, record the lowest).
1. 80 -100%
2. 60 - 79%
3. less than 60%
4. Can't tell
5. Not Applicable (i.e. Retrospective case-control)

RATE THIS SECTION	STRONG	MODERATE	WEAK

See dictionary	1	2	3

COMPONENT RATINGS
Please transcribe the information from the grey boxes on pages 1-3 onto this page. See dictionary on how to rate this section.

A	**SELECTION BIAS**	**STRONG**	**MODERATE**	**WEAK**
		1	2	3
B	**STUDY DESIGN**	**STRONG**	**MODERATE**	**WEAK**
		1	2	3
C	**CONFOUNDERS**	**STRONG**	**MODERATE**	**WEAK**
		1	2	3
D	**BLINDING**	**STRONG**	**MODERATE**	**WEAK**
		1	2	3
E	**DATA COLLECTION METHOD**	**STRONG**	**MODERATE**	**WEAK**
		1	2	3
F	**WITHDRAWALS AND DROPOUTS**	**STRONG**	**MODERATE**	**WEAK**
		1	2	3

Overall Grade (based on above six criteria):

Scored 1 for study design (i.e. controlled studies); AND **Scored 1 or 2 in at least three other important components, including:** **selection bias** **confounders** **blinding** **withdrawals and drop-outs.**	**STRONG** **1**
Scored 1 for study design; AND **Scored 1 or 2 in two other important components, including:** **selection bias** **confounders** **blinding** **withdrawals and drop-outs.**	**MODERATE** **2**

OR **Scored 2 for study design; AND** **Scored 1 or 2 in at least three other important components, including:** **selection bias** **confounders** **blinding** **withdrawals and drop-outs.**	
Scored 1 for study design; AND **Scored 3 in more than <u>two</u> other important components, including:** **selection bias** **confounders** **blinding** **withdrawals and drop-outs.** **OR** **Scored 2 for study design; AND** **Scored 3 in more than <u>one</u> other important components, including:** **selection bias** **confounders** **blinding** **withdrawals and drop-outs.** **OR** **Scored 3 for study design**	**WEAK** **3**

Dixon-Woods (2004) checklist

Question 1	Are the research questions clear?
Question 2	Are the research questions suited to qualitative inquiry
Question 3	Are the following clearly described? - Sampling - Data collection - Analysis
Question 4	Are the following appropriate to the research question? - Sampling - Data collection - Analysis
Question 5	Are the claims made supported by sufficient evidence?
Question 6	Are the data, interpretations, and conclusions clearly integrated?
Question 7	Does the paper make a useful contribution **to the review question**?

Appendix C. Characteristics of included studies

Table 1. Characteristics of included quantitative studies						
Author, year and country	**Study design**	**Age (range or mean ± SD), sex (n or % m/f), SES.**	**Exposure and comparison**	**Follow-up time point**	**Outcome(s)**	**Data analysis**
Nature-based ELC						
Agostini et al (2018), Italy. E: 41 children / 7 teachers / 1 school C: 52 children / 13 teachers / 1 school	Controlled before & after	E: Age: 47.2 months ± 6.52 Gender: 13m/28f C: Age: 46.75 months ± 6.95 Gender: 29m/23f SES not reported.	E: Teachers underwent special training in outdoor education over one year including (15 days). ELC consisted of a green park with some centuries-old trees (e.g., firs, willows, maples), plants and flowers, and without any play structures. C: ELC contained grass and cement without larger plants, trees, and play structures.	T1= Jan 2014 T2= May 2014 T3= Oct 2014 T4= May 2015 (16 months from baselines)	Motor skills Cognitive Social and Emotional Nature Connectedness Play	Mixed-Model Repeated Measures analysis of variance (ANOVA)
Cooper (2018), United Kingdom (England). E: 13 children C: 11 children Children from the same school	Controlled before & after	E: Age: 47 months (range 45-48) Gender: 7m/4f C: Age: 44 months (range 41-47) Gender: 7m/4f SES was noted as being “generally above average" for both groups.	E: Forest school sessions run by two trained leaders which operate for 10 week cycles on Tuesday AM and PM (2 hours each). Children attend either the AM or PM session. The forest school consists of trees and vegetation, a seating area made from logs, a mud kitchen using old crates and a tyre, a greenhouse and pond. The forest school is located on site and when children do not have forest school sessions outdoors, they have a “ free flow” environment where children are allowed outside when they want. C: Usual nursery practice which also involves a large amount of outdoor exploration. Children also participated	10- weeks	Cognitive Social and Emotional	Wilcoxon Signed-Rank Test; Mann-Whitney U test.

			in a one hour per week nature play session which incorporated elements of the forest school and included gardening, litter picking and PA. Staff have created an engaging multi-sensory outdoor environment for children which includes a sand pit area, water features and climbing apparatus. The nursery has an allotment system for children to plant fruit trees.			
Cordiano et al (2019), USA. E: 12 children / 1 ELC class. C: 14 children / 1 class. Children from the same school.	Controlled before & after study	Age: 51.5 months (4.3 years) Gender: 26f SES: 46% of students attending the ELC receive financial assistance	E: Outdoor pre-primary programme involved children spending five mornings per week at the school's outdoor campus. The children were outdoors in the forest for 90% of the school day. C: Traditional prekindergarten programme involved children spending five mornings per week at the school's main campus. This involves an Eco!Wonder curriculum that teaches all children about nature and sustainability. Children also visited the outdoor campus one morning per week and spent one immersion week at the outdoor campus in the spring. The remainder of their outdoor time was spent in built environments.	8 months	Cognitive Social and Emotional Play	Mixed-model analysis of covariance (ANCOVA) Covariates: age
Choi et al (2014), South Korea. E: 18 children / 1 ELC C: 19 children / ELC	Controlled before & after	E: Age: 4.2 ± 1.1 Gender: 11m/7f SES: all middle class C: Age: 4.0 ± 1.1	E: Children attend forest kindergarten 5 days per week, year-round, regardless of weather conditions. Children are outdoors more than 80% of the day and usually play, walk, run, and observe various things in the forest. C: Regular kindergarten (not described)	8 months	Sleep	Wilcoxon signed rank test.

		Sex: 11m/8f SES: all middle class				
Elliot et al (2014), Canada. E: 21 children / 1 ELC C: 22 children / 2 ELC	Controlled before & after (mixed-methods)	E: Age: 5.3 years (0.5 SD) Gender: 10m/11f SES not reported. C: Age: 5.3 years (0.3 SD) Sex: 7m/15f SES not reported.	E: A two-year pilot project in which 22 students would spend the mornings from 9:00 to 11:45 outside their school, exploring their local natural environment. C: not described	6 months	Nature Connectedness	ANOVA
Ene-Voiculescu & Ene-Voiculescu (2015), Fjortoft (2004), Fjortoft (2001), Norway. E: = 46 children / 1 kindergarten C: 29 children, / 2 kindergartens	Controlled before & after	Age: 6.1 years Gender: 38m/37f SES not reported.	E: Children used the forest every day for 1-2 hours throughout the year when they attended kindergarten. Occasionally they used the outdoor playground inside the kindergarten fence. The small forest (7.7 hectares) consisted of mixed woodland vegetation, some open spaces of rocks and open fields and meadows in between. C: Children used the traditional outdoor playground for 1-2 hours a day and visited natural sites only occasionally.	10 months	Motor skills	T-test.
Ernst & Burcak (2019), USA. E: 34 children / 2 ELC C: 43 children / 2 ELC	Controlled before & after	E: Age: 4 years Sex: 50%m/ 50%f C Age: 4 years	E: The nature-preschools utilised a combination of wild natural settings spaces that were minimally managed and natural playscapes designed specifically for nature play. The majority of time spent was in free play outdoors in unmaintained or minimally	9 months	Cognitive (all 5 papers) Social and emotional (Ernst & Burcak, 2019l Ernst et al., 2019)	GLM Covariates: pre-test scores, age, gender, prior participation

Burgess & Ernst (2020) E: 84 children / 4 ELC C: 24 children / 2 ELC Zamzow & Ernst (2020) E: 78 / 4 ELC C: 44 children / 2 ELC Ernst et al (2019) E: 78 children / 4 ELC Wojciehowski & Ernst (2018) E: 75 children / 4 ELC	Uncontrolled before & after	Sex:64%m/ 36%f SES not reported	maintained natural settings regardless of weather conditions (approximately four to five hours per day). C: Non-nature preschools emphasised child-directed play. The majority of time was spent indoors in free or loosely guided play (four to five hours), with about one hour daily of teacher-led playful learning. Children at both groups had one to two hours of daily outdoor playtime (weather permitting) in a maintained outdoor space that contained playground equipment.		Play (Burgess & Ernst, 2020)	t-test
Müller et al (2017), Canada. E: 43 children / 1 ELC C: 45 children / 1 ELC	Controlled before & after	Age: E: 63.56 months (3.33 SD) C: 64 months (3.56 SD) Gender not reported. SES not reported.	E: “nature kindergarten” C: “traditional kindergarten” Neither are described.	9 months Sep/Oct-May	PA Motor skills Cognitive Social and Emotional Nature Connectedness	Analyses of Covariance (ANCOVA)
Nazaruk & Klim-Klimaszewska (2017), Poland. E: 90 children (50 urban / 40 rural)	Uncontrolled before & after	Age: 6 years Gender not reported. SES not reported.	Teachers arranged trips in the forest, the park, the allotment garden, the meadow, the agritourism farm, animals at the zoo.	6 months	Nature connectedness	Mann-Whitney U test; Pearson Chi test

Yilmaz et al (2020), Turkey. 40 children / 1 ELC	Uncontrolled before & after	Age: 72 months (6 years) Gender: 14m/26 SES not reported.	E: Children visited a natural, unstructured area for one day in a week for four consecutive weeks. The education programme consisted of 12 semi-structured activities (3 per week). In addition, children also had 30 minutes walk near a natural pond when they visit the setting each week and each week, children had 30 minutes unstructured free play time to discover the natural environment.	4 weeks (1 session per week - 1 full day) conducted in spring 2018	Nature connectedness	Paired sample t-test; ANOVA
Barrable et al (2020), UK (England, Scotland, Wales). E: 141 /12 ELC C: 110 children / 6 ELC	Controlled cross-sectional	Age: 4.53 ± 1.39 Gender: 127m/89f SES not reported.	E: ELC's that have a continuous outdoor provision, with no permanent indoor access and children are outdoors for the whole duration of the ELC day. C: ELC's that are predominately indoor and have variable outdoor provision.	N/A	Nature connectedness	GLM with a binomial error distribution Covariates: Parental NC scores, sex, exposure
Frenkel et al (2019), USA. E: 71 children / 5 ELC C: 70 children / 4 ELC	Controlled cross-sectional	Age: 4.3% = 2 years, 29.1% = 3 years, 50.4% = 4 years, 16.3% = 5 years Gender: 82m/59f SES: 103, 036 USD (median zip code Income)	E: All nature ELC sites were located in parks with distinct areas marked off with rocks and other natural features for daily activities. Children were encouraged to play in the natural environment, which included grassy areas, areas with dirt, and tree cover and to play with natural features such as sticks, rocks, and mud. C: Traditional ELC were primarily held indoors and had outdoor play areas built on concrete. children spending less than 1.5 hr outdoors each day.	N/A	Harms	Poisson regression models Covariates: age
Fyfe-Johnson et al (2019), USA.	Controlled cross-sectional	Age: 3-5 years Gender:	E: The nature ELC occurs outdoors in a forested park where most children attend 5 days per week from 9 am to 1	N/A	Physical activity Cognitive Social and emotional	Descriptives only.

E: 20 children / 1 ELC C: 13 children (waitlist control or 2-hour nature-based, outdoor enrichment class provided by experimental ELC		E: 11m/9f C: 9m/4f SES: E: 18 > $90,000 C: 8> $90,000	pm; 2-day and 3-day per week options are available on a limited basis. The physical environment consists of dedicated classroom areas in the forested areas. Children use logs and tree stumps to sit; portable canopies are used during inclement weather. Most of the day is spent hiking and exploring the surrounding forest. No traditional play structures or pre-fabricated playgrounds are utilized. C: 2 hour nature-based outdoor enrichment class was offered once weekly by the same nature ELC the intervention group children attended. Classes were led by a teacher and attended by both child and caregiver. The classes consisted of science-based exploration through outdoor play in a forested park and involved: circle time, station time (learning stations that emphasize sensory and fine motor skills, creativity, and numerical and literacy skills), short stories, and hikes. Others were included in a wait-list control			
Giusti et al (2014), Sweden. E: 11 children / 2 ELC C: 16 children / 5 ELC	Controlled cross-sectional	Age: 5 years Gender not described. SES not reported.	ELC were assessed on their frequency of natural experiences. Each ELC was ranked according to the highest frequency of use of the greatest variety of nature experiences in its surroundings E: The ten ELC with the most frequent use of all nature experiences. C: The ten ELC with the least frequent use of all nature experiences.	N/A	Nature connectedness	t-test
Lysklett et al (2019), Norway.	Controlled cross sectional	Age: 5.1-6 years	Nature-based ELCs located close to a large recreational area, with woods,	N/A	Motor skills	T-test

E: 43 children / 4 ELC C: 49 children / 4 ELC		Gender: 53m/39f SES not reported	lakes and tracks just outside the city centre. Both types of preschools used the nearby nature area for hiking and playing every week E: nature ELC at least three times, per week C: traditional preschools once per week.			
Meyer et al (2017), Canada. E: 46 children / 3 ELC C: n= 35 children / 2 ELC	Controlled cross-sectional	Age: 5-6 years Gender: 39m/42f SES: predominately middle-class children	E: Children spent every morning in nature participating in teacher-directed, nature-based learning activities. The nature kindergartens differed per site but included a beach, unmanaged wooded area, natural playground (trees and vegetation) and artificial playground. C: Children were assessed in their classrooms where they engaged some storytelling, singing, dancing, tai chi, reading, drawing, and art. They also took part in music and computer classes and science fair.	N/A	PA	Descriptives only.
Moen et al (2007), Norway. E: 267 children / 37 ELC C: 264 children / 32 ELC	Controlled cross-sectional	Age: 3-6 years. Gender not reported. SES not reported.	E: had ‘‘outdoor’’ or ‘‘nature’’ as part of their name, or emphasized outdoor pedagogy and children spent an average of 3.5–8 hours/day outdoors in winter. C: children spend on average spend 1.25–4.0 hours/day outdoors.	N/A	Harms	GLM
Rice & Torquati (2013), USA. E: 68 children / 6 ELC C: 46 children /4 ELC	Controlled cross-sectional	Age: 56.4 months (12.8 SD) Gender not reported. SES: 46.5% of participants	E: The nature programme featured: vegetation, gardens, areas for digging in soil, sand, and “loose parts” (sticks, seeds, pinecones etc) and other naturally occurring objects that children used in their play. Climbing structures and pretend play structures such as a	N/A	Nature connectedness	ANOVA and Chi square

		reported an annual income of $85,000 or more.	boat or a playhouse were also included. C: The non-nature programmes consisted of pretend play structures, sand and/or wood chips, and paved surfaces for wheeled toys, and had few natural elements such as trees or grass.			
Robertson et al (2020), Australia. E: 15 children / 1 ELC C: 15 children / 1 ELC	Controlled cross-sectional	Age: 4-5 years Gender not reported. SES not reported.	E: ELC is in a rural area and consisted of a small traditional playground area (sand pit, obstacle course etc.) and a larger open ended nature area consisting of trees, shrubbery, grass, natural loose-parts). It has a highly naturalised area towards the rear that was rich in natural elements including small and large shrubbery, and larger tree and vegetation C: ELC is located in a suburban area and consisted predominately of man-made structures (almost half the space). The playground also consisted of some nature such as trees and vegetable garden.	N/A	Play	Independent samples t-test
Scholz & Krombholz (2007), Germany E: 45 children / 10 forest kindergartens C: Rural = 42 children / 2 ELC; Urban = 42 children / 2 ELC	Controlled cross-sectional	Age: E: 5.5 (SD 0.4) C: Rural= 5.7 (0.4 SD); Urban= 5.7 (0.4 SD) Gender: 71 boys, 58 girls SES not reported.	E: forest kindergarten C: traditional rural and urban kindergarten	N/A	Motor skills	MANOVA Covariates: age

Weisshaar et al (2006), Germany. E: 506 children / 25 ELC C: 1201 children / 28 ELC	Controlled cross-sectional	Age: 4.9 (1.1 SD) Gender: 901m/803f SES not reported.	E: Forest kindergarten located in forested areas where children spend all-season full-time outdoors. C: Conventional kindergartens (not described)	N/A	Harms	Fisher test and logistic regression Covariates: age, sex, skin inspection, and recommended vaccination
Ernst (2014), USA. E: 46 educators	Cross-sectional	Not described.	Outdoor environments that range from relatively natural to wild spaces.	N/A	Motor skills Cognitive Social and emotional Nature connectedness	Multiple regression
Wright (2019), USA. 48 children / 2 ELC	Cross-sectional	Age: 3-5 years Gender not reported. SES not reported.	The 2 sites were located in a forested park/ They both consisted of large space (10,000Sq/ft), log borders, sloping areas, vegetation, large trees, natural loose parts. Manufactured supplies such as shovels, wheelbarrows, books, magnifying glasses were brought in. 4 hours of the school day is spent outdoors.	N/A	Physical activity	Descriptives only
Author, year and country	**Study design**	**Age (range or mean ± SD), sex (n or % m/f), SES.**	**Exposure and comparison**	**Follow-up time point**	**Outcome(s)**	**Data analysis**
Naturalised playgrounds						
Brussoni et al (2017), Canada. E: 48 children / 2 ELC	Uncontrolled before & after (mixed methods)	Age: 4.28 (0.63 SD) Gender: 53% m/47%f SES not reported.	Playgrounds were improved using the Seven Cs which consists of 27 items, rated on a 5-point scale, for a maximum score of 135 Changes predominately involved inclusion of more natural elements such as, vegetation, boulders, rock, loose parts. Seven Cs scores	Data were collected at T2; May-July 2014) two-weeks after playground modification	Physical activity Social and emotional Play	Wilcoxon signed rank tests; General linear modelling. Covariates: age, gender, ELC

			increased from 44 to 97 in ELC A, and 35 to 125 in ELC B.			
Cosco et al (2014), USA. E: 804 / 27 ELC	Uncontrolled before & after	Age: 2-5 years Gender not reported. SES not reported.	Preventing Obesity by Design is an ELC outdoor renovation intervention. Prior to the intervention the space had few structures (slides, swings etc.) in a rectangle space enclosed by a fence. Whereas, post intervention, the space had more natural elements, including trees, garden, vegetation etc.	Not described.	Physical activity Social and emotional	Logistic regression and bivariate correlations Covariates: gender
Cloward Drown et al (2014), USA. E: 24 children / 1 ELC (observed in 2 different playgrounds, natural vs manufactured)	Controlled cross-sectional	Age: 4.5 years Gender: 7m/17f SES not reported.	E: The natural playground was characterised by a majority of natural surfaces (vegetation, boulders, grass etc.) This playground also consists of sandbox, bikes pathway and instruments. C: The manufactured playground is equipment-oriented with hard surfaces. Although it includes some vegetation, the main features are a xylophone, slide, and pit, a ball pit, water play area and concrete ramps leading to a plastic play castle and a spin chair.	N/A	Play	Chi-squared
Luchs, & Fikus (2013), Germany. E: 38 children / 1 ELC C: 21 children / 1 ELC	Controlled cross-sectional	Age: 5-6 years Gender: 33m/26f SES not described	E: the natural playground provides children with wild and natural areas, including trees, grass, flowers etc. There are also sandboxes, dirt, rock and water and mud area. C: the contemporary playground provides traditional man-made structures, such as slide, sandbox, playhouse, water area, seesaw, roundabout etc.	N/A	Play	t-test
Carrus (2012), Italy. E: 16 children / 1 ELC	Cross-sectional	Age: 18-36 months (1.5-3 years). Gender not reported. SES not reported.	Free play in garden and green spaces of the ELC compared to free play indoors.	N/A	Cognitive Social and emotional	mixed model ANOVA with 2-way interactions

Dyment et al (2013), Australia. E: 120 children / 3 ELC C: 40 children / 1 ELC	Cross-sectional	Age: ELC A = older toddlers, young children; ELC B = young children; ELC C = older toddlers, young children, ELC D = 2-5 year olds Sex: 57%m/ 43% f. SES: the 4 centres differed in terms of SES (Centre A = high SES, B= varied SES, C= low SES, D= medium)	E: three centres all of which contained natural areas (trees, rocks, gardens). Two ELC's also has manufactured elements C: one centre which contained no natural areas	N/A	Play	Descriptives only.
Luchs, & Fikus (2018), Germany. E: 17 children / 1 ELC	Cross-sectional	Age: 5.85 ± 0.49 years Gender: 9m/8f SES not reported.	E: the nature playground has large natural space featuring trees, grass, hills, vegetations, water C: the contemporary playground has traditional play structures such as slides and swings. It has some natural elements, including grass and trees.	N/A	Physical activity	Paired sample t-test
Morrissey et al (2017), Australia. E: 28 children / 1 ELC C: 28 children / same school as E.	Cross-sectional	Age: 4-5 years Gender: 28m/28f SES not reported.	E: ELC contained natural structures such as logs, shrubs, rocks etc. It also contains a few manmade elements. C: a traditional space with standard man-made equipment such as swings and climbing frame. It also had some natural elements like trees but much less than the natural playground.	N/A	Play	Chi-square analyses
Storli et al (2010), Norway. E: 16 children / 1 ELC	Cross-sectional	Age: 3-5 years Gender: 9m/7f SES not reported	Nature - gathering loose nature materials, climbing running. Traditional - children engaged in activities such as cycling, digging, climbing	N/A	Physical activity	t-tests

Torkar & Rejc (2017), Slovenia. E: 25 children / 1 ELC	Cross-sectional	Age: 4 and 5 years old Gender: 16m/9f SES not reported.	E: forest playground which contains a forest patch, river and bushes. The space is approx. 500 m^2 C: Traditional playground which contains fixed equipment such as seesaw, roundabout, slide, climbers and playhouse. There is some nature surrounding the playground (trees, bushes). The space is approx. 500 m^2	N/A	Physical activity	Mann Whitney
Author, year and country	**Study design**	**Age (range or mean ± SD), sex (n or % m/f), SES.**	**Exposure and comparison**	**Follow-up time point**	**Outcome(s)**	**Data analysis**
Types of natural elements						
Ng et al (2020), Australia. E: 159 children / 6 ELC C: 138 children / 5 ELC	Controlled before and after	Age: 2 years 10 months (0.82 SD) Gender: 49%m/51%f SES: No significant differences between intervention and control group reported.	Variable of interest was natural elements. Measured using the modified Environment and Policy Assessment and Observation (EPAO) physical environment domain. This tool assesses the prevalence of PA opportunities in the physical environment. There were 5 subscales: Fixed play equipment' and 'Portable play equipment' from the EPAO, 'Total size of playing area', 'Outdoor play spaces', and 'Natural elements'. A number of items per subscale were scored - 1 if present, 0 if not.	6 months	Physical activity	Mulitvariate linear regression Covariates: age, sex, parental education, accelerometer wear time.
Boldemann et al (2004), Sweden. E: 64 children / 2 ELC	Cross-sectional	Age: 1-6 years Gender:26m/38f SES not reported.	E: ELC 1 had play constructions surrounded by trees but exposed to the sun and ELC 2 had attractive play constructions positioned under a canopy of tree crowns. Average time spent outdoors was 207 min at site ELC 1, and 256 min at site 2.	N/A	UV exposure	t-tests
Boldemann et al (2006), Sweden.	Cross-sectional	Age: 4.5-6.5 years Gender: 114m/85f	ELC environment scores and averages dichotomized to (>2 high, <2 low)	N/A	Physical activity UV exposure	Bivariate analysis; Linear

E: 199 children / 11 ELC		SES not reported.	Outdoor environments were assessed on their play potential. They were scored 1, 2, and 3 with respect to size of outdoor area, overgrown surfaces (trees shrubbery) and integration of play structures or other defined play areas with vegetation.			mixed-models.
Christian et al (2019), Australia. E: 678 children / 48 ELC	Cross-sectional	Age: 3.4 ± 0.8 Sex: 53%m/47%f SES: 32% = low, 34% = medium SES and 34% = high SES.	ELC settings were dichotomized to vegetation < 3m in height or vegetation> 3m in height. High-resolution airborne multispectral 4-band images and Geographic Information System (GIS) was used to identify the location, shape and size of ELC outdoor play spaces. Approximately 31% of centres' outdoor play space had vegetation with 23% (20.5 SD) having <3 m in height and 8% (13.7SD) with >3 m hight.	N/A	Physical activity UV exposure	Multilevel linear regression models. Covariates: age, gender, and ELC SES and size.
deWeger (2017), Australia. E: 274 children / 12 ELC	Cross-sectional	Age: 4.2 years (0.5 SD) Gender: 141m/133f SES not reported.	Variable = natural elements The quality of the outdoor learning environment in the ELC's was assessed for 3 hours per day over 2 days using the POEMS instrument. This is grouped into 5 domains: **Physical environment (13 questions),** Interactions (13 questions), Play and Learning Settings (13 questions), Program (9 questions), and Teacher/Caregiver role (8 questions). Scores are them summed to give a total score	N/A	Physical activity	Hierarchical linear modelling (HLM) Covariates: age, gender, BMI-z score and accelerometer wear time (level 1), outdoor environment quality (level 2)
Gubbels et al (2018), Netherlands.	Cross-sectional	Age: 34.14 months (8.97 SD) Gender: 72m/79f	The SB and PA physical environment of each ELC was assessed using a standardized observation protocol, based on the updated Environment	N/A	Physical activity	Multivariate linear regression analyses

E: 151 children / 22 ELC		SES not reported.	and Policy and Assessment Observation (EPAO). The following natural elements were assessed: large trees (2.5 m or taller), small trees (less than 2.5 m tall), trees that children can climb, shrubs, flowering plants, variation in ground (hills, mounds), grass, rocks large enough to climb, a hill for rolling down or climbing up. A sum score of all the types of natural elements that were present was calculated.			
Maartensson et al (2009), Sweden. E: 198 children / 11 ELC	Cross-sectional	Age: 5.26 (0.56 SD) Gender: 113m / 85f SES not reported	The outdoor settings of each preschool were dichotomized into ‘‘high-score’’ and ‘‘low-score’’ environments in analysis The following were assessed: A. Total outdoor area. 1= small (<2000 m^2), 2= medium (2000–6000 m^2), 3= large (46000 m^2) B. Proportion of the area containing shrubbery, trees or hilly terrain: 1= little/non-existent, 2= <half of the area, 3= >half of the area C. Integration between vegetation, open areas and play structures: 1= no integration. 2= either (a) Play structures adjacent to trees and shrubbery or integrated into areas, or (b) The open spaces are located in between play-areas and not in separate parts of the environment. 3= environments fulfilling both 2a and 2b above. Outdoor environments were scored 1, 2 or 3 along three elements. The three scores of each environment were	N/A	Cognitive	Nested mixed model

			summed up and divided by 3, yielding an average score for each environment ranging from 1 to 3.			
Määttä et al (2019), Finland. E: 864 children / 66 ELC	Cross-sectional	Age: 4 years 4 months (10 SD) Gender: 48% girls SES: 29% had mother with high educational background (at least masters)	Observation instrument was designed for the study and consisted of items from the EPAO. ELC physical environments were assessed, of which, surfaces in the preschool grounds (9 items) and terrain in the playground, related to the natural environment (grass, forest, trees, rocks).	N/A	Physical activity	Multilevel linear regressions models Covariates: age, gender, season, municipality, pre-school group cluster
Määttä et al (2019b), Finland. E: 655 children / 66 ELC	Cross-sectional	Age: 4.7years (0.89 SD) Gender: As above SES: As above	Frequency of nature trips (mean/per week): Teachers completed weekly diary of activities which were categorised into 5 groups (1=outdoors, 2=teacher-led sessions, 3=free play, 4=organised PA lessons and 5=mixed sessions). Daily number of each activity was calculated and summed for the week level and then divided by the number of the days (from 3 to 5) to form the average daily amount of each activity. A questionnaire was then completed to determine activities that are close to the ELC and occur regularly (nature visits). Visits were recorded for mean times per week	N/A	Physical activity	Multilevel linear regressions models. Covariates: age, gender, average attendance at preschool and study season
Olesen et al (2013), Denmark. E: 441 children / 42 ELC	Cross-sectional	Age: 5.8 years Gender: 49.5%m/50.5%f SES not reported.	Researchers collected a range of environmental correlates, of which, vegetation and hilly landscape related to nature	N/A	Physical activity	Univariate analyses and multi-level modelling

						Covariates: Gender, rain, preschool type, afternoon hours, location, indoor area, Playground area, playground time, parent education
Sando (2019), Norway. E: 80 children / 8 ELC	Cross-sectional	Age:3.5 (SD=0.5) Gender: 41m/39f SES not reported.	The places and materials in the playground were categorised into nature, pathways, open area and fixed functional equipment. Nature was coded in four of the institutions and ranged from large forest areas (1500 m^2) to smaller areas with trees and natural surfaces.	N/A	Physical activity Social and emotional	A random intercept multilevel model Covariates: age, gender
Sando & Sandseter (2019), Norway. E: 73 / 8 ELC	Cross sectional (mixed-methods)	Age: 4.2 years (0.7 SD) Gender: 36m/37f SES not reported.	ELC settings featuring nature were coded (places). For objects, these were coded when a child was holding, using or interacting with an object and included: sand, water, mud and nature materials The variables for places and objects describe the percentage of time the child is at a place or in which the object was used during each observation.	N/A	Physical activity	Generalized linear latent and mixed models
Söderström at al (2013), Sweden. E: 172 children / 9 ELC	Cross-sectional	Presented per ELC Age: S1: 4.6 (1.0 SD) S2. 4.1 (0.5 SD) S3: 4.3 (0.7 SD) S4: 4.4 (0.8 SD) S5: 4.7 (0.8 SD) S6: 4.6 (0.9 SD)	Outdoor Play Environment Categories (OPEC) scoring tool was used to assess playgrounds on (i) total outdoor area, (ii) amount of trees, shrubbery and hilly terrain and (iii) integration between vegetation, open areas and play structures, each component with a	N/A	Sleep Harms Weight status Social and emotional	ANOVA and MANOVA Covariates: Age, gender, birth Weight, mother SES.

		S7: 4.3 (0.9 SD) S8: 4.6 (0.6 SD) S9: 4.8 (0.7 SD) Gender: % f S1: 29% S2. 41% S3: 50 % S4: 42% S5: 50% S6: 56% S7: 61% S8: 41% S9: 63%	score range of 1–3 (high score = high quality). The OPEC scores were then dichotomized (low OPEC value< 2, high OPEC value >2)			
Sugiyama et al (2012), Australia. E: 89 children / 10 ELC	Cross-sectional	Age: 4.1 (0.6 SD) Gender: 54%m/46%f SES not reported	Questionnaire assessing characteristics of the ELC's was completed by the centre Director. Outdoor characteristics of relevance were gradient shade, vegetation, surface material (grass).	N/A	Physical activity	Multilevel linear regression Covariate: age, gender and time spent outdoors
Zamani (2013), USA. 36 children / 1 ELC	Cross-sectional (mixed-methods – thesis)	Age: 4-5 years Gender: 21M/15 F SES not reported	Natural zone: wild landscape with non-structured green space (0.40 acres). The natural zone is rich in natural loose elements, such as leaves, twigs, dirt, stones and includes two looped and one straight pathways and boulders. The crawling equipment referred as the "green tube" is the sole manufactured element. This zone also includes three rope settings, tied to the trees. Mixed zone: A widespread mixed outdoor environment of 0.48 acres referred as the "hill". The mixed zone has a moderate, downward slope from its entrance. There is rocking	N/A	Play	Chi square analysis

			equipment, a linear pathway along the hill, a music wall with a stage, a set of six swings, a sand box, a gazebo, a stoned stone-lined swale without water, and two dramatic play settings. There is also a wood which includes a wooden platform, ropes, and musical instruments attached to the trees Manufactured zone: a dramatic play setting (play house), a looped pathway, a composite play structure, a porch, a sand play setting (covered with a shade structure), bike sheds, bikes and scooters, storage (for storing toys and loose material), three gathering settings (benches and tables), a swing pergola, and a basketball loop. This zone also includes a transitional space between the indoors and outdoors. The manufactured zone has a smaller square footage (0.11 acres) compared to the other zones.			
Author, year and country	**Study design**	**Age (range or mean ± SD), sex (n or % m/f), SES.**	**Exposure and comparison**	**Follow-up time point**	**Outcome(s)**	**Data analysis**
Garden-based intervention						
Lillard (2016), USA. E: 55 children / 1 ELC Delay Gratification E: 34 children	Uncontrolled before & after	Age: delay gratification= 4.16 years (9.9 months); Beery = 4.07 years (339.38 days) Gender: 40m/51f (based on students who were assessed) SES not reported	Gardening programme (not clearly described).	6 months	Cognitive	Repeated measures ANOVA

Visual motor integration E: 39 children						
Park et al (2016), South Korea. E: 336 children /12 ELC Science investigation abilities and attitudes= 68 children	Uncontrolled before & after	Age: 5-7 years Gender: 169m/167f SES not reported.	The intervention consisted of horticultural activities that increase children's knowledge of seeds, soil, planting and harvesting etc. The intervention consisted of 24 sessions delivered once per week and lasted an average of 50 minutes per session	Intervention lasted 24 weeks. Outcomes were assessed one week prior to the intervention and one-week post intervention	Cognitive Social and emotional	Paired samples t-test

Abbreviations: E= experimental; C= control; n= number; m=male; f= female; ELC = early learning and childcare (includes preschools, day care, kindergarten etc.); SD= standard deviation; SE= standard error; SES= socioeconomic status; USD= US Dollars; GLM = General linear modelling.

Table 2. Characteristics of included qualitative studies					
Author, year and country	**Age (range or mean ± SD), sex (n or % m/f), SES.**	**Exposure and comparison**	**Research aims**	**Data collection method**	**Details of analysis**
Nature-based ELC					
Bjørgen (2016), Norway. 24 children / 1 ELC	Age: 3-5 years Gender: 10m/14f SES not reported.	Children played in the ELC outdoor play space for 3 hr/day, and each week would go on trips (1 or 2x) to natural environments. The large outdoor area consists of outdoor toys (buckets, shovels, trucks, balls), swings, sandboxes, climbing racks, natural materials, small trees, a varied surface of grass, sand, asphalt, and small hills. The destination for excursions in diverse natural landscape environment is approximately 300–700m from the centre. One type of natural environment was open fields suitable for tobogganing, running and playing on skis. Another natural environment consisted of woods. Trips were made to the natural environments all year round.	What is the relation between environmental affordances and PA levels among 3–5 year olds?	Observations were made with video recording the different seasons of the year for 20 days, 10 days on trips in a natural environment and 10 days in the centres play space. A total of 50 h of direct observation was conducted. Coding of the physical activity levels of children was assessed and adapted using the Observational System for Recording Physical Activity in Children-Preschool Version (OSRAC-P) manual.	Thematic analysis - the first phases of coding were assessing and identifying the children's level of PA in different play situations. Figures were used as an analytical tool helped to discern patterns, differences and similarities in the data material, which laid foundations for the qualitative analysis of the affordances. Thereafter themes of affordances are identified within the data. The theory of affordances and criteria from the 7Sc were used in the analysis process.
Dowdell et al (2011), Australia.	Age: 2-6 years Gender: 6m/6f	E: Has an emphasis on nature and sustainable education. The space is large and consists of sandpit, fairy garden, play equipment, grass area and vegetable garden.	How are children's play behaviours and social interactions	Play behaviours were recorded using a behaviour mapping schedule. Each child was observed individually and	Once all the observations were made for each child at each centre they were then tallied up.

E: 6 children / 1 ELC C: E: 6 children / 1 ELC	SES not reported.	C: Located in a warehouse this centre has an entirely artificial indoor play area. It consists of a bike track, home corner (playhouse etc), climbing structures, quiet play area, sandpit and obstacle course.	influenced by the opportunities and materials present in their outdoor play environment?	every 10 seconds an observation based on social interaction and play behaviour was recorded.	Play behaviours were then categorised into four different groups: social activities, cognitive activities, physical and motor skill activities and other activities.
Liu (2020), USA Nature interaction: E: 29 children / 1 ELC C: 26/ 1 ELC Restorative experiences: E: 10 children / 1 ELC C: 9 children/ 1 ELC	Age: 4-5 years Gender: 30m/ 25f SES: E: 48,000 US (household income); C: 59,000 (household income) of children attending each centre	E: contains high levels of nature with a variety of perceived affordances. Outdoor time = 1.5 hours/day. 32 types (categories-vegetation (tress, shrubs, flowers, grasses), natural ground surface (wood chips, meadow, multipurpose lawns), natural materials, natural play structures (e.g. wood, stick, water, sand logs, ice, leaves), animals, experiential elements (rain, snow, sky view, light, air) of natural elements and play settings and 4 types of non-nature-based play settings (concrete track, bicycles, concrete hall, concrete sq.) were identified C: low levels of nature and perceived affordances. Outdoor time = 1.5 hours/day. 13 types of natural elements and 11 (vegetation, natural ground, animals) types of non-nature-based play settings (examples include: play structure, playhouse, outdoor kitchen, bicycles) were identified.	How does the designed nature-based outdoor play environment in ELC impact children's interaction with natural elements? How does the designed nature-based outdoor play environment in ELC impact children's restorative experience?	RQ 1. Field observation, behaviour mapping, semi-structured interview with teachers. RQ2. Field observation, structured Interview with children, semi-structured interview with teachers.	Content analysis was used for: children's frequent play locations, types of play behaviors, frequency and diversity of different ways of interaction with natural elements, as well as restorative experience from semi-structured interviews with teacher and structured interview with children. Themes (coding categories) were drawn from the theoretical framework. Specifically, children's types of play behaviors and their ways of interacting with natural elements were coded using function taxonomy of affordance (Heft, 1988; Kyttä, 2002) and Gibson's affordance theory.

Maynard et al (2013), Wales, UK. 48 children / 8 ELC	Age: 4-7 years Gender: 24m/24f SES not reported.	Educators introduced child-initiated learning in the outdoor environments. The kinds of activities varied and incorporated free play with natural resources (e.g. ELC A, F and H); growing vegetables (ELC C); (ELC B); and more structured investigations – for example, of snails (ELC D), air/wind (ELC E) and flight (School G). All the teachers had access to a small tarmac yard or grassed area. These were seen by the teachers as 'outdoor classrooms' and used for painting, sand and water play, construction activities etc. The teachers also had access to some additional outdoor space – playing fields, vegetable gardens or common land. 3 ELC settings (A, G and H) had extensive outdoor environments incorporating different types of play equipment or natural features such as a willow tunnel and pond.	To explore these perceived differences as well as teachers' perceptions of 'underachievement'.	Researcher visited teachers three times to undertake individual semi-structured interviews. Interviews were audio recorded and field notes at each interview. Teachers also provided case studies of each student	Interviews were transcribed using Nvivo8. A thematic analysis approach was used where data were analysed in three ways with increasing depth: 1. perceived difficulties of children 2. case studies 3. theoretic issues related to "place and space"
Sandseter (2009), Norway. 29 children from both experimental and control groups E: 1 ELC	Age: 4-5 years Gender: 21f/8m SES not reported.	E: Located in a forest with no fixed play equipment and fencing and children spent most of their time outdoors. C: fixed equipment, such as swings, climbing tower, play hut and a few trees.	To explore affordances for risky play in two different play environments: an ordinary ELC playground and a nature playground.	7 days were spent on each of the ELC playgrounds. Video recordings and field notes of risky play situations were collected based on categories of risky play; a) great heights, b) high speed c) dangerous tools, d) dangerous elements, e) rough-and-tumble play, f)	A content analysis was performed on the data. The analysis was theory-driven. Firstly, each of the play environments' potential affordances for risky play, as categorized by Sandseter (2007), were analysed in relation to the most relevant affordance

C: 1 ELC				where the children can disappear/get lost. Both the children's play and the staff's supervision were observed. The field notes and the video recordings were transcribed into an electronic word file. 12 children in the ordinary preschool and 11 children in the nature and outdoor preschool participated in a one-to-one qualitative interview with the researcher. Each interview was approximately 20-30 minutes and was recorded on audiotape. The interviews were semi-structured, using an interview guide list of questions and issues. The interview guide was based on the six categories of risky play and aimed to explore the types of risky play that the children engaged in within the different play environments and whether the staff constrained or intervened in their actions. Upon completion of the interviews, the audiotapes were professionally transcribed verbatim into an electronic word file.	categories to evaluate their potential affordances for risky play. Secondly, the transcriptions of the video observations, field notes, and interviews were examined to determine the types of risky play children engaged in within different environments. Thirdly, the observations and the interviews were analysed to determine the degree to which children experienced mobility license while engaging in risky play. The transcriptions of the video observations were examined to determine the extent to which, and in which situations, the staff had children under surveillance while they engaged in risky play or was taking initiative to or constrained risky play.

Streelasky (2019), Canada. 15 children / 1 ELC	Age: 5-6 years Gender not reported. SES not reported.	The ELC setting had an outdoor, nature-based focus where children spent afternoons in the forested area. The teacher who was involved in an Outdoor Environmental Leadership Programme engaged the students in an integrated learning approach where key curriculum areas were addressed (e.g. language arts, social studies, science and physical education). Children also had time to freely explore the forest.	What learning experiences do kindergarten children value at school? and what modes are they choosing to express and represent their valued school learning experiences?	Qualitative interpretative approach involving (i) group discussions, (ii) participant observations, (iii) anecdotal notes, (iv) artefact collection and (v) individual semi-structured interviews (children's narratives).	Data were analysed and grouped into themes. Image based analysis was used to develop deeper understanding of children's interests and knowledge. Thematic analysis was used to gain insight into children's practices which followed 6 phases: (i) familiarising oneself with the data and identifying items of potential interest, (ii) generating initial codes, (iii) searching for themes, (iv) reviewing potential themes, (v) defining and naming themes and (vi) reporting the themes.
Author, year and country	**Age (range or mean ± SD), sex (n or % m/f), SES.**	**Exposure and comparison**	**Research aims**	**Data collection method**	**Details of analysis**
Naturalised playgrounds					
Herrington & Studtmann (1998), USA.	Age: 2-6 years Gender:	Pre-modification: Lab A: consisted of a patio area, grass lawn, play structures, swing	What natural materials and conditions of the outdoor	Phase 1: sequence sampling of children during free-play. Children were video-taped interacting	20 hours of videotapes were analysed. During analysis, notes were made. For Phase 1 the

36 children / 1 ELC (2 “labs”)	16m/20f SES not reported.	set, doll house, trees and vegetation. Lab C consisted of a porch area, grass lawn, play areas, swing set, trees and vegetation. Post-modification: Playground were naturalised with increased natural elements: ice sculptures, wind chimes, canopy, chalk, buckets, playhouse, water pay, vegetation and trees were added to the labs. Lab A received more natural elements than lab C but both were more natural post intervention.	environment can contribute to the development of young children ranging from 2 to 6 years old?	with the site for 1 month. Once the modifications were made, data collection began a week later. Data collection involved video-taping, sound recording, and field notes. Videotaping involved following a child for 20 minutes as they moved throughout the yard in free play. Voice recordings of the children were made of one of the two selected children from each Lab. Voice recordings were transcribed into text documents. Field notes (weather, teacher and children present, anecdotal observations etc.) were made daily by researchers. Notes were recorded by researchers on a pre-printed notation sheet that displayed a plan view of both yards. Phase 2: Video documentation and anecdotal notes were employed to record event sampling. Event sampling allowed subjects to be taped if they interacted with the plant	notes were: (1) interaction with an intervention (2) duration of interaction (3) children's behavioural modification made between pre and post intervention (4) children's movement changes made between pre and post intervention. For Phase 2 the criteria were: (1) which children were engaged in the intervention; (2) how many children were engaged (3) the duration and nature of their engagement with the intervention (4) how behavior and paths of movement changed between pre and post intervention. Video clips were selected that illustrated the notes. These clips were put together on one VCR tape using a television and VCR recorder. The conversations of the children participating in Phase 1 were transcribed at 10 second intervals. The anecdotal

				interventions. The specific intervention sites were recorded on a rotating basis. Children were video-taped using the same schedule as in Phase 1 and fieldnotes were made in the same manner as in Phase I	notes were reviewed and complied.
Puhakka et al (2019), Finland. 12-24 children (not clear) / 6 ELC	Age: 3-5 years Gender not reported. SES not reported.	Playground yards were transformed through enhancing the biodiversity by incorporating more greenspace and vegetation. For example, replacing areas covered in gravel with forest floor. Children spent time outdoors every day (0.5–2 h in the morning and in the afternoon) as well as participating in teacher led activities 4-5 days/ week.	Does biodiversity exposure and greening playgrounds affect 3–5 years-old children's physical activity and play, their environmental relationships, and their well-being in the urban environment in Finland.	Educators and child nurses completed interviews and surveys respectively. 49 parents completed surveys. Surveys were completed one month after the playground was modified. Surveys included both structured and open ended questions which related to children's play activities, and enthusiasm. Interviews with parents focussed on children perception of modifications. The educator thematic interviews focused on possible changes in children's play and other activities in the yard, in children's and educators interest in and knowledge of nature, their well-being, attitudes towards outdoor activities, and	Interviews were recorded and transcribed verbatim. Survey and interview data were analysed using qualitative content analysis to identify different affordances. The affordances were then classified into 6 themes which emerged from analysis and coding. How these affordances supported children's relationship with the modified playground were then mapped. Finally, these two elements were brought together to form three perspectives.

				practices and atmosphere in the ELC setting	
Wishart et al (2019), Australia. 75 children / 1 ELC	Age:4-5 years Gender not reported. SES not reported.	The two playgrounds were located on different sides of the building, each extending to the back of the building where a connecting gate was sometimes opened to allow free-flow of children between the two spaces. E: Traditional equipment was replaced with terraces, inclines, logs and rocks designed to afford physical activities and gross motor skills such as climbing and balancing. other elements included: Natural gardens with fruit trees; herb garden and small plants; logs; stepping-stones; log enclosure; small tree forest; sandpit with pebbles and medium-size rocks. C: standard equipment: slide, ladders, swings, climbing frames, sand-pit, surfaces open area. This area also included a grass area, veg garden, trees and shrubs.	Does the naturalised design of the new space provide equivalent actualisable affordances for different types of physical activity to those provided by the more traditional playspace, with its conventional equipment and resources	Behaviour mapping using a time-sampling observation tool. Observations were conducted between 10:30–15:30 during sessions. The two playscapes were divided into zones and children were observed in 3 minute cycles. For each observation, the tool also noted: number of boys and girls (no further count of children was taken); presence of educators; whether play was solitary or group; location and general contextual information. 40 observations in the naturalised space and 42 observations in the traditional space were made.	Behaviour mapping tracked the incidence of different categories of movement across different areas of the two playscapes, to investigate if different categories of movement were more likely to occur in specific areas or in relation to specific features.
Author, year and country	**Age (range or mean ± SD), sex (n or % m/f), SES.**	**Exposure and comparison**	**Research aims**	**Data collection method**	**Details of analysis**
Types of natural elements					

Zamani (2015), USA. 36 children / 1 ELC	Age: 4-5 years Gender: 21M/15 F SES not reported.	See quantitative study characteristics table.	How does an outdoor learning environment with natural features can stimulate children's cognitive play behaviors	1. Photo preference - researcher captured photos based on particular behavior settings or elements of the outdoor environment. The photos represented particular spaces in which children engaged in certain behaviors. The researcher used photo preference to ask children to select their preferred outdoor settings and elements and explain about their play. 2. Drawings from children - The researcher asked children to draw their favourite outdoor play spaces as a means for the researcher to evaluate each setting's cognitive play affordances and the elements children enjoyed. 3. Structured interviews with children - Interview questions aimed toward understanding children's choice of photos, drawings, and opinions of the outdoor learning environment. 4. structured interviews with teachers - to understand the teachers'	1. Used with transcribed child interviews and then coded these into different cognitive play behaviours. The photos were used to understand child's explanations. 2. The analysis of the drawings included three stages. In the first stage, the researcher quantified all 22 drawings by coding their visual features; The drawing codes established the element or behavior setting types depicted in the image; The researcher further evaluated the drawings on the frequency that certain settings or elements appeared 3. Interviews recorded and transcribed and then grouped by themes 4. transcribed and then grouped into themes related to teachers view on curriculum, outdoor learning environment, value of children's play, what children prefer, cognitive play affordances.

				perspectives toward the outdoor environment and children's daily interactions. The interview questions (6) prompted teachers to discuss the play opportunities the different zones provided for children. The following section explains the protocols regarding each of the described methods.	
Abbreviations: E= experimental; C= control; n= number; m=male; f= female; ELC = early learning and childcare (includes preschools, day care, kindergarten etc.); SES= socioeconomic status; PA= physical activity.					

Appendix D. Quality of included quantitative studies as assessed by the EPHPP tool

Study ID	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawals and drop-outs	Final Grade
Agostini et al (2018)	3 = Weak	1 = Strong	3 = Weak	3 = Weak	1 = Strong	3 = Weak	**3 = Weak**
Barrable et al (2020)	3 = Weak	3 = Weak	3 = Weak	3 = Weak	1 = Strong	N/A	**3 = Weak**
Boldemann et al (2004)	3 = Weak	3 = Weak	1 = Strong	3 = Weak	1 = Strong	N/A	**3 = Weak**
Boldemann et al (2006)	2 = Moderate	3 = Weak	1 = Strong	3 = Weak	1 = Strong	N/A	**3 = Weak**
Brussoni et al (2017)	2 = Moderate	2 = Moderate	2 = Moderate	3 = Weak	1 = Strong	1 = Strong	**2 = Moderate**
Carrus (2012)	3 = Weak	3 = Weak	3 = Weak	3 = Weak	3 = Weak	N/A	**3 = Weak**
Choi et al (2014)	3 = Weak	1 = Strong	2 = Moderate	3 = Weak	3 = Weak	1 = Strong	**2 = Moderate**
Christian et al (2019)	2 = Moderate	3 = Weak	1 = Strong	3 = Weak	1 = Strong	N/A	**3 = Weak**
Cloward Drown & Christensen (2014)	3 = Weak	3 = Weak	1 = Strong	3 = Weak	1 = Strong	N/A	**3 = Weak**
Cooper (2018)	3 = Weak	1 = Strong	3 = Weak	3 = Weak	1 = Strong	3 = Weak	**3 = Weak**
Cordiano et al (2019)	3 = Weak	1 = Strong	3 = Weak	3 = Weak	1 = Strong	3 = Weak	**3 = Weak**
Cosco et al (2014)	1 = Strong	2 = Moderate	1 = Strong	3 = Weak	1 = Strong	3 = Weak	**3 = Weak**
deWeger (2017)	2 = Moderate	3 = Weak	2 = Moderate	3 = Weak	1 = Strong	N/A	**3 = Weak**
Dyment et al (2013)	1 = Strong	3 = Weak	3 = Weak	3 = Weak	1 = Strong	N/A	**3 = Weak**
Elliot et al (2014)	3 = Weak	1 = Strong	2 = Moderate	3 = Weak	1 = Strong	1 = Strong	**2 = Moderate**
Ene-Voiculescu &Ene-Voiculescu (2015), Fjortoft (2004), Fjortoft (2001)	3 = Weak	1 = Strong	1 = Strong	3 = Weak	1 = Strong	3 = Weak	**3 = Weak**
Ernst (2014)	2 = Moderate	3 = Weak	3 = Weak	3 = Weak	3 = Weak	N/A	**3 = Weak**
Ernst & Burcak (2019)	3 = Weak	1 = Strong	2 = Moderate	3 = Weak	1 = Strong	3 = Weak	**3 = Weak**

Ernst et al (2019) & Ernst & Burcak (2019)	3 = Weak	2 = Moderate	2 = Moderate	3 = Weak	1 = Strong	3 = Weak	**3 = Weak**
Wojciehowski & Ernst (2018) & Ernst & Burcak (2019)	3 = Weak	2 = Moderate	2 = Moderate	3 = Weak	1 = Strong	3 = Weak	**3 = Weak**
Burgess & Ernst (2020)	3 = Weak	1 = Strong	2 = Moderate	3 = Weak	1 = Strong	3 = Weak	**3 = Weak**
Zamzow & Ernst (2020) & Ernst & Burcak (2019)	3 = Weak	1 = Strong	2 = Moderate	3 = Weak	1 = Strong	3 = Weak	**3 = Weak**
Frenkel et al (2019)	2 = Moderate	3 = Weak	1 = Strong	3 = Weak	1 = Strong	N/A	**3 = Weak**
Fyfe-Johnson et al (2019)	3 = Weak	3 = Weak	3 = Weak	3 = Weak	1 = Strong	N/A	**3 = Weak**
Giusti et al (2014)	2 = Moderate	3 = Weak	1 = Strong	3 = Weak	3 = Weak	N/A	**3 = Weak**
Gubbels et al (2018)	3 = Weak	3 = Weak	1 = Strong	3 = Weak	1 = Strong	N/A	**3 = Weak**
Lillard (2016)	3 = Weak	2 = Moderate	1 = Strong	3 = Weak	1 = Strong	1 = Strong	**3 = Weak**
Luchs, & Fikus (2013)	3 = Weak	3 = Weak	3 = Weak	3 = Weak	3 = Weak	N/A	**3 = Weak**
Luchs, & Fikus (2018)	3 = Weak	3 = Weak	1 = Strong	3 = Weak	1 = Strong	N/A	**3 = Weak**
Lysklett et al (2019)	3 = Weak	3 = Weak	2 = Moderate	3 = Weak	1 = Strong	N/A	**3 = Weak**
Määttä at al (2019)	3 = Weak	3 = Weak	2 = Moderate	3 = Weak	1 = Strong	N/A	**3 = Weak**
Määttä et al (2019b)	3 = Weak	3 = Weak	2 = Moderate	3 = Weak	1 = Strong	N/A	**3 = Weak**
Maartensson et al (2009)	3 = Weak	3 = Weak	1 = Strong	3 = Weak	1 = Strong	N/A	**3 = Weak**
Meyer et al (2017)	3 = Weak	3 = Weak	3 = Weak	3 = Weak	3 = Weak	N/A	**3 = Weak**
Moen et al (2007)	2 = Moderate	3 = Weak	1 = Strong	3 = Weak	3 = Weak	N/A	**3 = Weak**
Morrissey et al (2017)	3 = Weak	3 = Weak	3 = Weak	3 = Weak	3 = Weak	N/A	**3 = Weak**
Müller et al (2017)	3 = Weak	1 = Strong	3 = Weak	3 = Weak	1 = Strong	1 = Strong	**3 = Weak**
Nazaruk & Klim-Klimaszewska (2017)	3 = Weak	2 = Moderate	3 = Weak	3 = Weak	3 = Weak	1 = Strong	**3 = Weak**
Ng et al (2020)	3 = Weak	1 = Strong	1 = Strong	3 = Weak	1 = Strong	1 = Strong	**2 = Moderate**
Olesen et al (2013)	2 = Moderate	3 = Weak	1 = Strong	3 = Weak	1 = Strong	N/A	**3 = Weak**
Park et al (2016)	3 = Weak	2 = Moderate	3 = Weak	3 = Weak	1 = Strong	1 = Strong	**3 = Weak**

Rice & Torquati (2013)	3 = Weak	3 = Weak	3 = Weak	3 = Weak	1 = Strong	3 = Weak	**3 = Weak**
Robertson et al (2020)	3 = Weak	3 = Weak	3 = Weak	3 = Weak	3 = Weak	N/A	**3 = Weak**
Sando (2019)	2 = Moderate	3 = Weak	2 = Moderate	3 = Weak	1 = Strong	3 = Weak	**3 = Weak**
Sando & Sandseter (2019)	3 = Weak	3 = Weak	2 = Moderate	3 = Weak	1 = Strong	N/A	**3 = Weak**
Scholz & Krombholz (2007)	3 = Weak	3 = Weak	1 = Strong	3 = Weak	3 = Weak	N/A	**3 = Weak**
Söderström at al (2013)	2 = Moderate	3 = Weak	1 = Strong	3 = Weak	1 = Strong	N/A	**3 = Weak**
Storli et al (2010)	3 = Weak	3 = Weak	1 = Strong	3 = Weak	1 = Strong	N/A	**3 = Weak**
Sugiyama et al (2012)	3 = Weak	3 = Weak	2 = Moderate	3 = Weak	1 = Strong	N/A	**3 = Weak**
Torkar & Rejc (2017)	3 = Weak	3 = Weak	3 = Weak	3 = Weak	3 = Weak	N/A	**3 = Weak**
Weisshaar et al (2006)	2 = Moderate	3 = Weak	2 = Moderate	4 = Weak	1 = Strong	N/A	**3 = Weak**
Wright (2019)	3 = Weak	3 = Weak	3 = Weak	3 = Weak	3 = Weak	N/A	**3 = Weak**
Yılmaz et al (2020)	3 = Weak	2 = Moderate	3 = Weak	3 = Weak	2 = Moderate	1 = Strong	**3 = Weak**
Zamani (2013)	3 = Weak	3 = Weak	1 = Strong	3 = Weak	2 = Moderate	N/A	**3 = Weak**

Appendix E. Findings per eligible study

Quantitative

PHYSICAL

Table 1. Nature-based ELC on physical activity								
Study details (Author, year and country) **Sample size** (n children / n ELC)	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Accelerometer								
Nature-based ELC								
Müller et al (2017), Canada. E: 43 children / 1 ELCs C: 45 children / 1 ELCs	Controlled before & after	SB and MVPA ActiGraph GT1M measured for 5 consecutive school days on three separate occasions: Oct (start of school yr), Jan and Apr (end of school yr). Cut points not described	SB (mins/ ELC day)	E: Oct= 167 Jan= 174 C: Oct= 178 Jan= 178	Apr= 151 Apr= 152	Within-group seasonal differences, but no between-group differences. (inferential statistics not provided)	▲	Weak
			MVPA (mins/ ELC day)	E: Oct= 74 Jan= 79 C: Oct = 79 Jan= 79	Apr = 68 Apr= 62	As above.	▲	
Fyfe-Johnson et al (2019), USA.	Controlled cross-sectional	PA and SB ActiGraph GT3X+ accelerometer worn for a minimum if 5	Habitual PA (mins/ day) SB	E: 467 (60 SD) C: 453 (51 SD)	Mean diff: 14.4, (95% CI: -29.1, 58.0)	Children who attended nature-based ELC engaged in more SB, and less light PA and MVPA.	▼	Weak

E: 20 children / 1 ELCs C: 13 children (waitlist control or 2-hour nature-based, outdoor enrichment class provided by experimental ELCs		days (inc 1 weekend). Weartime for total PA was 656 (59 SD), C= 667 (59 SD) Pate et al. (2006) cut points	Light MVPA	E: 91.6 (13 SD) C: 102 (10 SD) E: 97.4 (16 SD) C: 113 (24 SD)	-10.1 (95% CI: -19.2, -1.0) -15.5 (95% CI: -31.9, 0.87)			
			Habitual Weekday PA (mins/day) SB Light MVPA	 E: 468 (66 SD) C: 461 (54 SD) E: 93.5 (18 SD) C: 101 (15 SD) E: 97.1 (21 SD) C: 112 (30 SD)	 6.9 (95% CI: -40.1, 54.0) -7.3 (95% CI: -20.1, 5.4) -14.9 (95% CI: -36.3, 6.5)	As above.	▼	
			Habitual Weekend PA (mins/day) SB Light MVPA	 E: 486 (65 SD) C: 453 (51 SD) E: 88.7 (14 SD) C: 103 (15 SD) E: 95.8 (16 SD) C: 113 (22 SD)	 33.0 (95% CI: -14.8, 80.9) -14.2 (95% CI: -25.9, -2.4) -17.7 (95% CI: -33.8, -1.5)	As above.	▼	
			PA (mins/ ELC day – 9.00-13.00) SB Light	 E: 153 (19 SD) C: 166 (13 SD) E: 31.8 (11 SD) C: 32.7 (5 SD)	 -13.5 (95% CI: 63.3, 54.2) -0.9 (95% CI: -2.1, 0.64)	As above, but the differences in light PA and MVPA were much smaller.	▼	

			MVPA	E: 33.2 (15 SD) C: 34.7 (7 SD)	-1.5 (95% CI: -2.8, 1.2)			
			Sedentary bouts (ELC day) Bout, total number Bouts, number per day Bouts, total length Bout, average length	 E: 6.3 (3 SD) C: 6.4 (4 SD) E: 1.9 (1 SD) C: 2.0 (1 SD) E: 88.9 (47 SD) C: 100 (59 SD) E: 12.8 (5 SD) C: 16.1 (3 SD)	 -0.05 (95% CI: -2.9, 2.8) -0.11 (95% CI: -0.94, 0.73) -11.3 (95% CI: -54.4, 31.7) -3.3 (95% CI: -6.7, 0.13)	Children who attended nature-based ELC had similar total bouts and number of bouts per day to the control group. The bout total and average length were also higher in the control group.	▼	
Study details / Sample size	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Naturalised Playground								
Brussoni et al (2017), Canada. E: 48 children / 2 ELC	Uncontrolled before & after (mixed methods)	MVPA ActiGraph GT3X/GT3X+ worn during scheduled outdoor time (20 mins). Pate et al. (2006) cut points	MVPA (mins/ outdoor time)	Not presented.	- 1.32 min, 0.37 SE, p< 0.001	There was a significant decrease in time spent in MVPA from T1 to T2 across ELC's.	▼	Moderate
Luchs, & Fikus (2018), Germany.	Cross-sectional	Gait cycles Microprocessor-based pedometer	Gait cycles/mins at playground	E: 25 (4.99 SD) C: 28.55 (9.60 SD)		No significant difference in mean gait cycles/min between the nature	▼	Weak

E: 17 children / 1 ELC		(StepWatch, Orthocare Innovations, Washington DC, USA) Worn twice for 45 minutes, once on the nature playground and once on the traditional playground.		p = 0.109, d = 0.54)		and traditional playground.		
Storli et al (2010), Norway. E: 16 children / 1 ELC	Cross-sectional	CPM ActiGraph (model not described) Worn for three separate days over 6 months, including 2 days of outdoor activity on the pre-school playground (winter and spring) and one day in nature (spring). Wear time varied between 102–136 minutes Cut points not described,	Mean CPM	E: (spring) 1292 (307 SD) C: (spring) 1261 (426 SD) C: (winter) 1496 (475 SD) (*p*= 0.01)		There is an association between the levels of PA for the natural environment and traditional (spring and winter) playgrounds meaning PA levels are similar across the environments.	▲(spring)	Weak
Torkar & Rejc (2017), Slovenia. E: 25 children / 1 ELC	Cross-sectional	Distance (km) Measured using GPS for 20 mins.	Distance (km)	E: 0.72 (0.49 SD) C: 0.49 (0.19 SD) (p= 0.132, r= 0.21)		There were no significant differences between the forest and traditional playground.	▲	Weak

Study details / Sample size	Study Design	Outcome and measurement	Units	Baseline or one time point (cross-sectional)	Follow-up (if applicable) or mean difference	Summary of Findings	Effect Direction	Quality Rating
Types of natural element								
Ng et al (2020), Australia. E: 159 children / 6 ELC C: 138 children / 5 ELC	Controlled before and after	PA ActiGraph GTX3+ worn during ELC days ELC monitoring days were considered valid based on at least 1 day at ELC with 75% wear time Pate et al. (2006) cut points	Total PA min/ ELC day) MVPA min/ ELC day)	β= 14.46, p< 0.01 β= 10.04, p< 0.01		Natural grassed area was positively associated with Total PA and MVPA. Non-significant time x group interaction for natural elements on Total PA and MVPA (regression coefficients not presented)	▲ N/A	Weak
Boldemann et al (2006), Sweden. E: 199 children / 11 ELC	Cross-sectional	Step counts Yamax Digiwalker SW-200, MLS 2000 pedometer. Wear time not detailed.	Step counts/ min ELC day	High environment = 21.6 (95% CI: 20.6–22.5) Low environment = 17.7 (95% CI: 16.8–18.6) p<0.001		High environment score increased step count	▲	Weak

Christian et al (2019), Australia. E: 678 children / 48 ELC	Cross-sectional	Total PA Actigraph GT3TX+ Valid data included at least 1 day at ELC with 75% wear time. Data was averaged for children who attended more than 1 day during the 7-day monitoring period. Pate et al. (2006) cut points	Total PA (min/ ELC day)	% < 3m vegetation: β<-0.01 (95% CI: -0.22,0.21), p= 0.96) % > 3m vegetation: β = 0.02 (95%CI: -0.28, 0.32), p=0.89		Shade-related variables (vegetation < 3 metres in height and vegetation > 3 metres in height) were not significantly associated with minutes/day of total PA.	▲	Weak
			MVPA (min/ ELC day)	% < 3m vegetation: β = -0.01 (95% CI: -0.18, 0.16), p=0.91 % > 3m vegetation: β = 0.08 (95%CI: -0.16, 0.32), p=0.52		As above for MVPA	▲	
deWeger (2017), Australia. E: 274 children / 12 ELC	Cross-sectional	Total PA and MVPA (min/day at ELC), cpm and step counts Actigraph GT3X+ Accelerometers were worn for one ELC week (range of 1-5 days). Mean wear time was 390 minutes (87.4) or for 6.5 hours (1.5).	Total PA (min/ ELC day)	intercept= 59.5, coefficient= 3.5, 1.8 SE, t= 1.89, p= 0.060		No significant association between setting with natural elements on total PA.	▲	Weak
			MVPA (min/ ELC day)	intercept= 10.3, coefficient= 1.7, 1.2 SE, t= 1.37, p= 0.17		As above for MVPA.	▲	
			Mean CPM / ELC day	intercept= 102000.5, coefficient= 4511.9, 5683.5 SE, t= 0.79, p= 0.43		As above for CPM.	▲	

		Pate et al. (2006) cut points	Step counts / ELC day	intercept= 2889.9, coefficient= 199.5, 89.8 SE, t= 2.22, p= 0.027		There was a positive association between settings with natural elements and step counts.	▲	
Gubbels et al (2018), Netherlands. E: 151 children / 22 ELC	Cross-sectional	SB, MVPA and CPM Actigraph GT3X+ Children were asked to wear the monitor for 7 consecutive days during their waking hours. Minimal wear time per day was 360 minutes and children had to have at least one valid ELC day to be included. Pate et al. (2006) cut points	Habitual SB %	β= −0.31, p < 0.001		Natural elements were significantly and positively associated with a reduction in percent time spent in SB	▲	Weak
			Habitual MVPA %	β= 0.27, p< 0.01		Natural elements were significantly and positively associated with an increased percent time spent in MVPA	▲	
			Habitual Mean CPM	β= 0.21, p< 0.01		Natural elements were significantly and positively associated with increased CPM.	▲	
Määttä et al (2019), Finland. E: 864 children / 66 ELC	Cross-sectional	Total PA Actigraph GT3X Worn for 7 days, 24-hours/day. A minimum wear time of 240 min during preschool hours was set. Evenson et al. (2008) cut points.	Total PA (min/hour in ELC)	Grass: β= 0.31, (95%CI: −0.84 - 1.46) Forest: β= −0.59, (95%CI: −1.87 - 0.69) Trees: β= --0.34, (95%CI: −2.13 - 1.45) Rocks:		There were no significant main or effect for grass, forest, trees or rocks	▲ ▼ ▼ ▲	Weak

				β= 0.01, (95%CI: −1.21 - 1.24)				
Määttä et al (2019b), Finland. E: 655 children / 66 ELC	Cross-sectional	Sedentary Time As above.	Sedentary time (min/hour in ELC)	Frequency of nature trips β= −1.026 (95%CI: −1.804, −0.248), p= 0.010		Frequency of nature trips was associated with children's lower sedentary time.	▲	Weak
Olesen et al (2013), Denmark. E: 441 children / 42 ELC	Cross-sectional	MVPA ActiGraph accelerometer Children wore the monitors for 1 week. Minimum wear time was 3 pre-school days, with at least 3 hours of measurement. Median wear-time was 4 weekdays, 7.15 hours per day. Evenson et al. (2008) cut points.	MVPA (percent/ ELC day)	Vegetation: - 0.7; 95% CI: -1.3 to -0.0, p= 0.04)		The multilevel analysis showed that the daily percentage of MVPA was significantly negatively associated with vegetation	▼	Weak
				Hilly landscape - 0.4; 95% CI: -1.1 to 0.2, p= 0.18.		The multilevel analysis showed that the daily percentage of MVPA was no association with hilly landscape.	▼	
Sugiyama et al (2012), Australia. E: 89 children / 10 ELC	Cross-sectional	MVPA and SB ActiGraph GT1M a Worn for 3 days at ELC. Minimum wear time was 2 days for at least 4 hours during the ELC day. Average wear time was 6 hours 40 minutes per ELC	MVPA (min/ outdoor time)	Mostly natural surface: β= −5.8, (95% CI: −9.9, −1.7), p<0.01		Children attending ELC's with mostly natural surfaces were found to engage in significantly less MVPA compared with ELC with mostly "built" surfaces.	▼	Weak
				More vegetation:		No association.	▼	

		day. Sirard et al. (2005) cut points.		β= −1.2, (95% CI: −5.9, 3.5)				
				Some gradient: β= 1.3, (95%CI: −4.5, 7.0)		As above.	▲	
				Much shade: β= 2.3, (95%CI: −3.5, 8.0)		As above.	▲	
			SB (min/ outdoor time)	Mostly natural surface: β= 8.0, (95% CI: −1.4, 17.4)		Natural surfaces, vegetation, gradient, and shade were not associated with SB.	▼	
				More vegetation: β= 2.3, (95% CI: −7.0, 11.6)			▼	
				Some gradient: β= −2.4, (95% CI: −13.7, 8.9)			▲	
				Much shade: β= −0.9, (95% CI:−12.6, 10.8)			▲	
Study details / Sample size	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Observational								
Nature-based ELC								
Meyer et al (2017), Canada. E: 46 children / 3 ELC C: 35	Controlled cross-sectional	PA and PA types OSRAC-P Sampling Observation System which includes coding for body movements (stationary, slow-easy, moderate, and vigorous	PA frequencies: Stationary Slow-easy Moderate	 E:0.56 (0.15 SD) C: 0.84 (0.02 SD) E:0.30 (0.08 SD)		Children in the nature kindergarten were less stationary and engaged in more slow-easy and moderate physical activity compared to the control ELC.	N/A	Weak

children / 2 ELC		movements) and specific activity types (including climb, crawl, jump/skip, push/pull, rough and tumble, run, sit/squat, stand, throw, walk, and other). 2 students were observed at a time for 30-second intervals (5 sec observation, 25 sec coding). Observations occurred every 30 seconds for a period of 5 minutes which resulted in 20 observations. This was then repeated.	Vigorous	C: 0.16 (0.02 SD) E:0.12 (0.08 SD) C: 0 (0 SD)				
			PA types: (frequencies) Sit/Squat Walk Stand Fine Motor Eat Lie Down Push/Pull Rough & Tumble Run Climb	E: 0.02 (0 SD) C: 0 (0 SD) E: 0.19 (0.13 SD) C: 0.53 (0.09 SD) E: 0.17 (0.02 SD) C: 0.06 (0.01 SD) E: 0.14 (0.08 SD) C: 0.16 (0 SD) E: 0.14 (0.06 SD) C: 0.12 (0.09) E: 0.08 (0.03 SD) C: 0 (0 SD) E: 0.01 (0.01 SD) C: 0 (0 SD) E: 0.01 (0.01 SD) C:			N/A	

			Jump Throw Crawl Balance Other	E: 0 (0 SD) C: 0 (0 SD) E: 0.04 (0.02 SD) C: 0 (0 SD) E: 0.10 (0.07 SD) C: 0 (0 SD) E: 0 (0 SD) C: 0 (0 SD) E: 0.01 (0.01 SD) C: 0 (0 SD) E: 0.01 (0.01 SD) C: 0.01 (0.01 SD) E: 0.05 (0.04 SD) C: 0.01 (0.01 SD) E: 0.05 (0.02 SD) C: 0.10 (0 SD)				
Wright (2019), USA. 48 children / 2 ELC	Cross-sectional	PA Children were observed and recorded over 2 school years. A randomised time sampling protocol was used with 10	overall frequency / relative frequency (% each type of activity was out of total instances of all PA)			“manipulation” was the most frequent PA type observed. balance, run, sit stand and squat were less frequent.	N/A	Weak

		min intervals at five zones. A sub-sample of the recordings was taken and coded at the 0:00, 1:00 and 2:00 mark for 20-second intervals. An adapted version of (OSRAC-P) was used to code the PA types.	Balance: Climb: Dig/Rake: Jump/Skip: Lie Down: Manipulation: Push/Pull: Resistive: Run: Sit: Stand: Squat: Throw: Walk:	34 / 7% 22 / 5% 19 / 4% 29 / 6% 9 / 2% 107 / 23% 21 / 4% 28 / 6% 34 / 7% 33 / 7% 38 / 8% 44 / 9% 16 / 3% 16 / 3%				
Study details / Sample size	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Naturalised Playground								
Cosco et al (2014), USA. E: not clear / 27 ELC	Uncontrolled before & after	PA Children's Activity Rating Scale (CARS) CARS allows trained observers to record children's PA on a five-point scale: 1) stationary or motionless, 2) stationary with limb or trunk movements, 3) slow-easy, 4) moderate, and 5) fast.	PA		Unstandardised (standardised effects) 0.113 (0.067), p= 0.001	At post-intervention there was an effect on children's PA.	▲	Weak
			Non sedentary PA		0.202 (1.22), p= 0.001	As above for non-sedentary PA.	▲	
			MVPA		0.061 (1.063), Non-sig	Non-significant	▲	

Study details / Sample size	Study Design	Outcome and measurement	Units	Baseline or one time point (cross-sectional)	Follow-up (if applicable) or mean difference	Summary of Findings	Effect Direction	Quality Rating
Types of natural elements								
Sando (2019), Norway. E: 80 children / 8 ELC	Cross-sectional	PA Observational System for Recording PA in Children-Preschool (OSRAC-P) PA is coded from 1 (stationary) to 5 (fast movement). 2 children were filmed per day. The 1st for 2 minutes followed by a 6-minute break, then the 2nd child. Filming alternated between each child until 6 video observations of each child were recorded. 480 video clips in the outdoor environment constituted a full sample. There was a total of 471 video clips in the final analysis.	PA (1-5)	3.2 (0.9 SD), (regression coefficient= 0.004)		Nature was not a statistically significant predictor of PA.	▲	Weak

Sando & Sandseter (2019), Norway. E: 73 / 8 ELC	Cross sectional (mixed-methods)	PA and wellbeing (combined outcome) Wellbeing - Leuven Wellbing Scale measures wellbeing on a scale 1 (extremely low) -5 (extremely high). A score of 1 is when children exhibit high levels of discomfort (whining, screaming, sadness) and 5 is clear signs of happiness, relaxed and lively. Physical activity: see above, OSRAC-P which codes PA from 1 (stationary) to 5 (fast-movement)	PA and wellbeing	Nature: No association Sand: b =−0.027, (95% CI =−0.043–0.011), p= 0.001. Nature materials: b =−0.008, (95% CI =−0.015–0.001), p = 0.028. Water: no association Mud: no association		Nature is not associated with observations with high wellbeing and PA.	▼	Weak

Abbreviations: E= experimental; C= control; n= number; ELC = early learning and childcare (includes preschools, day care, kindergarten etc.); PA= physical activity; MVPA= moderate to vigorous PA; SB= sedentary behaviour; CPM= counts per minute; Yr= Year; min = minutes; SD= standard deviation; SE= standard error; CI= confidence intervals.

Effect direction explained:
▲: positive health impact
►: no change/ conflicting findings
▼: negative health impact
▲: positive health impact and statistical significance (p<0.05)
▼: negative health impact and statistical significance (p<0.05)
No arrow: no inferential statistics reported

Controlled before & after studies – difference between experimental and control group at follow-up (unless stated) or difference in change between experimental or control group. Uncontrolled before & after studies – change since baseline (unless stated). Controlled cross sectional – difference between experimental and control (unless stated). Cross-sectional – positive, negative or no association

Table 2. Nature-based ELC on motor skills								
Study details (Author, year and country) **Sample size** (n of children / n ELC settings for exp and con)	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Nature-based ELC								
Agostini et al (2018), Italy. E: 41 children / 7 teachers / 1 school C: 52 children / 13 teachers / 1 school	Controlled Before & After	Body function, gross motor skills and fine motor skills Kuno Beller Developmental Tables completed by educators which assesses development in 8 developmental areas: Body Function, Awareness of the Surrounding Environment, Social and Emotional Development, Play, Language, Cognitive Development, Gross and Fine Motor Skills.	Body Function	T1 (Jan 2014) E:11.02 (0.81 SD) C:10.15 (1.03 SD)	T4 (May 2015) 12.81 (0.71 SD) 12.39 (1.24 SD) p= 0.010; ηp^2= 0.27	There was a significant time x group interaction on children's body function. There were no significant differences between groups at T4.	▲	Weak
			Gross Motor Skills	E:11.79 (1.01 SD) C:10.87 (0.91 SD)	13.32 (0.80 SD) 12.96 (1.07 SD) p= 0.021; ηp2= 0.24	As above.	▲	
			Fine Motor Skills	E:10.86 (0.76 SD) C:10.01 (1.34 SD)	12.73 (0.88 SD) 12.56 (1.28 SD) p= 0.000; ηp2= 0.15.	As above.	▲	

Ene-Voiculescu & Ene-Voiculescu (2015), Fjortoft (2004), Fjortoft (2001), Norway. E: = 46 children / 1 kindergarten C: 29 children, / 2 kindergartens	Controlled Before & After	Motor fitness The EUROFIT Physical Fitness Test which consists of: flamingo balance test (standing on 1 foot - balancing); plate tapping (tapping of 2 plates alternatively- speed of limb movement); sit and reach (flexibility); standing broad jump (jumping for distance from a standing start – explosive strength); sit-ups (max n of sit-ups in 30 secs); bent arm hang (from a bar- functional strength); shuttle run (running and turning, shuttle - speed and agility) Beam walking to test dynamic balance and Indian skip (clapping right knee with left hand and vice versa - coordination), which were added.	Flamingo balance test / n of instabilities in 30 secs	E: 4.7 (0.8 SE) C: 4.0 (0.6 SE)	E: 1.5 (0.3 SE), p<0.001 C: 3.3 (0.7 SE)	At post-test, there were significant differences in the intervention group compared to the control group in the Flamingo balance test (p< 0.001).	▲	Weak
			Plate tapping / time in secs for 50 taps	E: 35.0 (1.9 SE) C: 29.9 (1.1 SE)	E: 28.1 (1.2 SE), p<0.001 C: 27.4 (2.6 SE)	No significant differences at post-test.	▼	
			Sit and reach / cm	E: 24.9 (0.8 SE) C: 25.3 (1.0 SE)	E: 24.4 (0.8 SE) C: 25.5 (0.9 SE)	As above.	▼	
			Standing broad jump / cm	E: 102.8 (2.9 SE) C: 103.1 (4.3 SE)	E: 113.1 (3.6 SE), p<0.001 C: 111.3 (3.8 SE), p<0.01	As above.	▲	
			Sit-ups / reps.30 secs	E: 5.3 (0.6 SE) C: 5.9 (0.8 SE)	E: 6.5 (0.6 SE) p<0.01 C: 7.0 (1.1 SE)	As above.	▼	
			Bent arm hang / sec	E: 2.6 (0.4 SE) C: 2.6 (0.6 SE)	C: 7.0 (1.0 SE), p<0.001 C: 5.4 (1.1 SE), p<0.001	As above.	▲	
			Beam walking / sec	E: 11.4 (1.4 SE) C: 7.7 (0.8)	E: 7.5 (0.7 SE), p<0.01 C: 7.2 (1.1 SD)	As above.	▼	
			Indian skip / reps.30 secs	E: 21.8 (2.2 SE)	E: 43.6 (1.9 SE), p<0.001	At post-test, there were significant differences in the	▲	

				C: 27.8 (2.4 SE)	C: 37.2 (1.8 SE), p<0.001	intervention group compared to the control group in the Indian skip co-ordination test (p< 0.01).		
			Shuttle run run/sec	E: 31.9 (0.7 SE) C: 30.7 (0.8 SE)	E: 29.7 (0.5 SE), p<.01 C: 30.3 (0.7 SE)	No significant differences at post-test.	▼	
Müller et al (2017), Canada. E: 43 children / 1 nature-kindergarten C: 45 children / 1 traditional kindergarten	Controlled before & after	Perceived physical competence, and locomotor and object control skills. Subscale of the Pictorial Scale of Perceived Competence and Social Acceptance for Young Children (six items) - children were asked to indicate who they are more like based on two descriptions of children (one competent and one not). Each item was scored on a four-point scale, where 4 indicates a high degree of perceived competence and 1 indicates a low score. TGMD-2 - assesses 6 locomotor and 6 object control skills.	Perceived Physical Competence	E: 18.72 (0.47 SE) C: 18.58 (0.44 SE)	E: 19.03 (0.48 SE) C: 19.47 (0.44 SE) p= 0.45, η2= 0.01	At post-test there was a small and non-significant effect	▼	Weak
			Locomotor skills	E: 24.68 (1.01 SE) C: 24.61 (0.94 SE)	E: 28.03 (0.82 SE) C: 25.72 (0.80 SE) p= 0.03, η2= 0.06	At post-test there was a moderate and significant effect	▲	
			Object control skills	E: 21.71 (0.98 SE) C: 23.05 (0.91 SE)	E: 23.97 (0.89 SE) C: 23.05 (0.91 SE) p= 0.15, η2= 0.03	At post-test there was a small and non-significant effect	▲	

		Scored either 1 or 0 depending on whether component was performed correctly.						
Lysklett et al (2019), Norway. E: 43 children / 4 preschools C: 49 children / 4 preschools	Controlled cross sectional	Motor competence Assessed using the Movement Assessment Battery (MABC-2). The test includes 8 subtests divided into 3 categories: 1) manual dexterity (posting coins, threading beads and drawing a line into a trail), 2) ball skills (catching beanbag and rolling ball into goal), and 3) static and dynamic balance (one-leg balance, walking heel raised and jumping over cord). Children are scored from 0-5. The total score sums the eight tests with a score of 0 the best and 40 the poorest.	Manual dexterity Ball Static and dynamic balance Total	E: 3.72 (2.99 SD) C: 3.29 (2.67 SD) E: 2.60 (2.34 SD) C: 2.41 (1.67 SD) E: 1.08 (1.71 SD) C: 0.94 (1.58 SD) E: 7.41 (4.91 SD) C: 6.64 (3.72 SD)	Mean difference 0.43 (95% CI: −0.74–1.59), p= 0.498 0.20 (95% CI: −0.64–1.03), p= 0.641 0.14 (95% CI: −0.53–0.82), p= 0.678 0.76 (95% CI: −1.03–2.56), p= 0.399	No significant differences in scores between the nature and traditional preschools for total and subtest scores.	▼	Weak
		The assessment for fitness consisted of 9 subtests: standing broad jump, Jumping on two feet, Jumping on one foot, Throwing a tennis	Standing broad jump (cm)	E: 94.78 (14.07 SD) C: 97.63 (15.59 SD)	Mean difference −2.86 (95% CI: −9.26–3.55), p= 0.378	Children attending the traditional preschools performed better in the shuttle run, reduced Cooper test and the total score	▼	

		ball (m), Putting a medicine ball, Climbing wall bars, Shuttle run, 20 m sprint, Reduced Cooper test. A total test score was calculated and transformed into z-scores (standardized scores).	Jumping on two feet (s)	E: 6.16 (3.58 SD) C: 5.18 (1.61 SD)	0.98 (95% CI: −0.22–2.18), p= 0.108	compared to the nature playground. The rest were non-significant.	▼	
			Jumping on one foot (s)	E: 5.48 (2.19 SD) C: 4.85 (1.19 SD)	0.63 (95% CI: −0.22–1.49), p= 0.144		▼	
			Throwing a tennis ball (m)	E: 6.00 (2.17 SD) C: 6.21 (1.88 SD)	−0.21 (95% CI: −1.06–0.64), p= 0.623		▼	
			Putting a medicine ball (m)	E: 1.88 (0.49 SD) C: 1.96 (0.43 SD)	−0.08 (95% CI: −0.27–0.11), p= 0.379		▼	
			Climbing wall bars (s)	E: 32.32 (14.60 SD) C: 31.21 (11.38 SD)	1.11 (95% CI:−4.37–6.59), p= 0.688		▼	
			Shuttle run (s)	E: 31.40 (3.96 SD) C: 30.00 (2.45 SD).	1.40, 95% CI: 0.05–2.74, p= 0.043		▼	
			20 m sprint (s)	E: 5.66 (0.48 SD) C: 5.53 (0.57 SD)	0.13 (95% CI: 0.13 – −0.08), p= 0.232		▼	
			Reduced Cooper test (m)	E: 740.09 (120.44 SD) C: 817.56 (105.32 SD)	77.47, 95% CI: −124.22–−30.71, p= 0.001),		▼	

			Total test score (z)	C: −0.12 (0.65 SD) E: 0.17 (0.57 SD)	0.29, 95% CI: −0.55– −0.04, p= 0.025		▼	
Scholz & Krombholz (2007), Germany E: 45 children / 10 forest kindergartens C: Rural = 42 children / 2 ELC; Urban = 42 children / 2 ELC	Controlled cross-sectional	Fundamental movement skills (test not described) Consisted of the following domains: balancing forward (balance); balancing backward (balance); jumping left and right; (coordination, speed); long jump; (coordination, speed); jumping forwards on one leg (coordination, endurance); hanging on pull up bar (strength endurance); shuttle run (speed, coordination)	Balancing forward (n of correct steps)	E:22.5 (1.7 SD) C (R): 20.5 (3.5 SD) C (U): 19.4 (3.6 SD) p<0.000		There was a significant higher performance in forest nurseries vs conventional rural and urban nurseries for balancing forwards and backwards, hanging on pull up bar, jumping left/right, shuttle run and one-leg jump forward on left.	▲	Weak
			Balancing backward (n of correct steps)	E: 51.5 (10.1 SD) C (R): 39.9 (10.9 SD) C (U): 35.5 (14.3 SD) p<0.000			▲	
			Jumping left and right (n of jumps)	E: 29.9 (6.0 SD) C (R): 31.1 (7.3 SD) C (U): 27.0 (7.1 SD) p=0.012			►	
			Long jump (distance in cm)	E: 94.0 (16.1 SD) C (R): 102.4 (18.4 SD) C (U): 94.0 (18.7 SD)			►	
			Hanging on pull up bar (time in seconds - max 30 sec)	E: 25.6 (6.2 SD) C (R): 20.7 (7.7 SD) C (U): 19.7 (7.0 SD) p<0.000			▲	
				E: 9.6 (1.2 SD)			▼	

			Shuttle run (time in seconds) Jumping forwards on one leg (n of jumps on each leg – max 20)	C (R): 9.1 (0.8 SD) C (U): 10.2 (1.5) p<0.000 Right: E: 17.5 (4.4 SD) C (R): 17.2 (4.9 SD) C (U): 16.0 (6.0 SD) Left: E: 17.8 (4.5) C (R): 16.8 (5.3), C (U): 14.1 (6.8) p=0.007			▲ ▲	
Ernst (2014), USA. E: 46 educators	Cross-sectional	Physical development Questionnaire (not described) on importance of natural outdoor settings on children's cognitive, social, and physical development and their appreciation for the environment. Responses were provided on a five-point scale, ranging from one (strongly disagree) to five (strongly agree)	Physical development (1-5)	4.39 (1.31 SD), r= 0.05		Educators agreed that experiences in natural settings were important for children's physical development. There was no association between frequency of nature experiences and belief regarding importance of outdoor settings for physical development.	▲	Weak

Abbreviations: E= experimental; C= control; n= number; ELC = early learning and childcare (includes preschools, day care, kindergarten etc.); SD= standard deviation; SE= standard error; CI= confidence intervals; cm= centimetres; sec= seconds; R= rural; U= urban

Effect direction explained:
▲: positive health impact
►: no change/ conflicting findings
▼: negative health impact
▲: positive health impact and statistical significance ($p<0.05$)
▼: negative health impact and statistical significance ($p<0.05$)
No arrow: no inferential statistics reported

Controlled before & after studies – difference between experimental and control group at follow-up (unless stated) or difference in change between experimental or control group. Uncontrolled before & after studies – change since baseline (unless stated). Controlled cross sectional – difference between experimental and control (unless stated). Cross-sectional – positive, negative or no association

Table 3. Nature-based ELC on weight status								
Study details (Author, year and country) **Sample size** (n of children / n ELC settings for exp and con)	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Types of natural elements								
Söderström at al (2013), Sweden. E: 172 children / 9 ELCs	Cross-sectional	BMI Weight = digital scale, height = measuring tape	BMI	Low OPEC Overweight= 16% Normal weight= 82% High OPEC Overweight= 7% Normal weight= 87% p= - 0.07		Outdoor environment quality was not significantly associated with BMI or waist.	▲	Weak
		Waist Measuring tape	Waist (cm)	Low OPEC: 52.6 (3.5 SD) High OPEC: 52.2 (3.5 SD) p= 0.25			▲	

Abbreviations: E= experimental; C= control; n= number; ELC = early learning and childcare (includes preschools, day care, kindergarten etc.); SD= standard deviation; BMI= body mass index; cm= centimetres; OPEC= outdoor Play Environmental Categories

Effect direction explained:
▲: positive health impact
►: no change/ conflicting findings
▼: negative health impact
▲: positive health impact and statistical significance ($p<0.05$)
▼: negative health impact and statistical significance ($p<0.05$)
No arrow: no inferential statistics reported

Controlled before & after studies – difference between experimental and control group at follow-up (unless stated) or difference in change between experimental or control group. Uncontrolled before & after studies – change since baseline (unless stated). Controlled cross sectional – difference between experimental and control (unless stated). Cross-sectional – positive, negative or no association

Table 4. Nature-based ELC on Sleep								
Study details (Author, year and country) **Sample size** (n of children / n ELC settings for exp and con)	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Nature-based ELC								
Choi et al (2014), South Korea. E: 18 children / 1 ELC C: 19 children / ELC	Controlled Before & After study	Sleep Parents competed the CSHQ which consists of 33 items with a 3 point scale, "usually (5–7 times a week)", "sometimes (2–4 times a week)", and "rarely (0–1 time a week)". This questionnaire consists of 8 domains: bedtime resistance, sleep onset delay, sleep duration, sleep anxiety, night wakings, parasomnia, sleep-disordered breathing, and daytime sleepiness. These domain scores are accumulated for a total CSHQ Score.	Total score of CSHQ Total sleep time (hours) Bedtime resistance Sleep onset delay Sleep duration Sleep anxiety	E: 51.6 ± 8.2 C: 55.6 ± 6.6 E: 10.5 ± 1.1 C: 10.7 ± 1.1 E: 11.8 ± 2.6 C: 12.7 ± 2.5 E: 1.3 ± 0.6 C: 1.2 ± 0.5 E: 3.7 ± 1.1 C: 4.1 ± 1.4 E: 7.1 ± 2.0	E: 47.7 ± 5.7, p= 0.02 C: 55.8 ± 6.5, p= 0.92 Between group: p < 0.01 E: 10.5 ± 1.0, p= 0.68 C: 10.4 ± 0.9, p= 0.21 E: 11.3 ± 2.4, p= 0.34 C: 12.8 ± 2.2, p= 0.98 E: 1.2 ± 0.4, p= 0.08 C: 1.4 ± 0.7, p= 0.36 E: 3.3 ± 0.6, p= 0.13 C: 3.7 ± 1.3, p= 0.37 E: 6.5 ± 2.0,	After post-test, the CSHQ total score, sleep disordered breathing and daytime sleepiness were significantly lower in children from the forest kindergarten program compared with the regular kindergarten program. There was no significant difference in total sleep time or other sub-scales.	▲ ▲ ▲ ▲ ▲ ▲	Moderate

		Total sleep time was also reported.		C: 7.4 ± 1.8	p= 0.28 C: 7.5 ± 1.5, p= 0.84			
			Night wakings	E: 3.6 ± 0.8 C: 3.6 ± 0.8	E: 3.5 ± 0.4, p= 0.71 C: 3.6 ± 1.0, p= 0.99		▲	
			Parasomnia	E: 9.2 ± 2.0 C: 10.0 ± 1.8	E: 8.6 ± 1.5, p= 0.11 C: 9.3 ± 1.9, p= 0.12		▲	
			Sleep disordered breathing	E: 3.3 ± 0.6 C:3.4 ± 0.8	E: 3.1 ± 0.5, p= 0.16 C: 3.7 ± 1.0, p= 0.10 Between group: p = 0.04		▲	
			Daytime sleepiness	E: 11.6 ± 2.5 C: 13.3 ± 2.9	E: 9.8 ± 1.0, p= 0.02 C: 13.7 ± 3.5, p= 0.52 Between group: p < 0.01		▲	
Study details / Sample size	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Types of natural elements								
Söderström at al (2013), Sweden. E: 172 children / 9 ELC	Cross-sectional	Sleep A sleep diary was completed for one week by the children's parents. Parents recorded the time the children	Mean sleep time (minutes)	Low OPEC (n= 103): 642 (32 SD) High OPEC (n= 66): 658 (44 SD)		Outdoor environment quality was significantly associated with night sleep	▲	Weak

		woke up and the time they went to sleep. Sleep time was calculated as a mean of the seven days.		p= 0.03				

Abbreviations: E= experimental; C= control; n= number; ELC = early learning and childcare (includes preschools, day care, kindergarten etc.); CSHQ= Children's Sleep Habits Questionnaire; OPEC= outdoor Play Environmental Categories

Effect direction explained:
▲: positive health impact
►: no change/ conflicting findings
▼: negative health impact
▲: positive health impact and statistical significance ($p<0.05$)
▼: negative health impact and statistical significance ($p<0.05$)
No arrow: no inferential statistics reported

Controlled before & after studies – difference between experimental and control group at follow-up (unless stated) or difference in change between experimental or control group. Uncontrolled before & after studies – change since baseline (unless stated). Controlled cross sectional – difference between experimental and control (unless stated). Cross-sectional – positive, negative or no association

Table 5. Nature-based ELC on UV Exposure								
Study details (Author, year and country) **Sample size** (n of children / n ELC settings for exp and con)	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Types of natural elements								
Boldemann et al (2004), Sweden. E: 64 children / 2 ELC	Cross-sectional	UV Exposure Measured using a Dosimeter (Biosense VioSpor blue line, type III 0.8–33 MED). Each child wore 2 Dosimeters attached to each shoulder using safety pins. They were worn during the school day.	UV exposure per day (JCIE/m^2)	Site 1: 222 JCIE/m^2, 15.3 % (95% CI 14.3–17.5, $p<0.05$) Site 2: 175 JCIE/m^2, 13.3 % (95% CI 9.9–14.6, $p<0.05$)		The was a statistically significant difference in UVR exposure between site 1 and site 2.	▲	Weak
Boldemann et al (2006), Sweden. E: 199 children / 11 ELC	Cross-sectional	UV Exposure Measured using a Polysulphone dosimeter (Diffey, 1984; Herlihy et al., 1994) The Dosimeter was pinned to the right shoulder and worn during school hours.	UV Exposure (J/m^2)	Low environment: ELC 3: 160 (95%CI:130–190) ELC 4: 241 (95%CI:200–281) ELC 6: 156 (95%CI:115–196) ELC 7: 83 (95%CI: 67–98) ELC 8: 269	Daily UV exposures ranged between 74 and 292 J/m	Outdoor environment quality was significantly associated with UV Exposure.	▲	Weak

				(95%CI:214–324) ELC 10: 243 (95%CI:217–268) High environment: ELC 1: 104 (95%CI: 95–113) ELC 2: 129 (95%CI:104–154) ELC 5: 289 (95%CI:230–348) ELC 9: 292 (95%CI:232–351) ELC 11: 196 95%CI: 177–215)				
Christian et al (2019), Australia. E: 678 children / 48 ELC	Cross-sectional	UV Exposure Measured using a Polysulphone film mounted cardboard holders (UV badge) The UV badge was attached to the child's left shoulder and worn each day whilst at ELC for up to 3 days.	UV exposure (J/m^2) per average day of ELC.	% <3 m vegetation: β = -2.26 (95%CI -3.03, -1.49); p <0.01 % >3m vegetation: β = 0.91 (95%CI -12.46, 14.28), p= 0.89		ELC centre vegetation was significantly negatively associated with children's UVR exposure. For every 1% increase in centre vegetation, children's UVR exposure decreased by 2.3 J/m2 per day at ELC (p <0.01).	▲	Weak

Abbreviations: E= experimental; C= control; n= number; ELC = early learning and childcare (includes preschools, day care, kindergarten etc.); SD= standard deviation; SE= standard error; CI= confidence intervals.

Effect direction explained:
▲: positive health impact
►: no change/ conflicting findings

▼: negative health impact
▲: positive health impact and statistical significance (p<0.05)
▼: negative health impact and statistical significance (p<0.05)
No arrow: no inferential statistics reported

Controlled before & after studies – difference between experimental and control group at follow-up (unless stated) or difference in change between experimental or control group. Uncontrolled before & after studies – change since baseline (unless stated). Controlled cross sectional – difference between experimental and control (unless stated). Cross-sectional – positive, negative or no association

Table 6. Nature-based ELC on harms								
Study details (Author, year and country) **Sample size** (n of children / n ELC settings for exp and con)	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Nature-based ELC								
Frenkel et al (2019), USA. E: 71 children / 5 ELC C: 70 children / 4 ELC	Controlled cross-sectional	Illness and injury Educators completed a standardised weekly illness and injury tracking log developed for this study. An illness episode was when a child was absent for at least 1 day due to illness (fever, respiratory, stomach, other).	Illness total Fever Respiratory Stomach Other	E: 1.49 C: 1.62 (age adjusted IRR: 0.93, 95% CI: 0.64, 1.34). E: 0.25 C: 0.47 E: 0.92 C: 1.01 E: 0.29 C: 0.37 E: 0.18 C: 0.07		No significant difference in the incidence of total illness between nature ELC and traditional ELC	▲	Weak
		An injury was counted if it required first-aid attention from teachers	Total injury	E: boys= 0.94 girls= 1.87 C: boys= 0.96 girls= 0.34		No significant difference in minor injury was found between boys at nature and traditional ELC. Girls at nature ELC had a significantly higher incidence of minor	▲ (boys) ▼ (girls)	

				boys: (age-adjusted IRR: 1.46, 95% CI: 0.59, 3.6) Girls: (age-adjusted IRR: 5.91, 95% CI: 1.98, 17.7).		injury compared with girls at traditional ELC.		
			Open wound/cut	E: boys= 0.60 girls= 1.31 C: boys= 0.48 girls= 0.23				
			Sprain	E: boys= 0 girls= 0 C: boys= 0 girls= 0				
			Child Bite	E: boys= 0.17 girls= 0 C: boys= 0 girls= 0				
			Other	E: boys= 0.17 girls= 0.56 C: boys= 0.48 girls= 0.11				
Moen et al (2007), Norway.	Controlled cross-sectional	Sickness absenteeism	Sickness absenteeism	estimate =		No statistically significant difference in sickness	▼	Weak

E: 267 children / 37 ELC C: 264 children / 32 ELC		Parent noted daily reports of sickness absenteeism Absenteeism refers to the ratio of the total number of sickness absenteeism days to the sum of the number of sickness absenteeism days and the number of days the child was attending the day care centre during the study period.		- 0.0083, SE= 0.1830, t= 20.045, p> 0.05		absenteeism between the outdoor ELC and regular day ELC.		
Weisshaar et al (2006) E: 506 children / 25 ELC C: 1201 children / 28 ELC	Controlled cross-sectional	Tick bites and borreliosis Self- report questionnaire. Presence of at least 1 tick bite (yes/no). Presence of borreliosis (yes/no)	Tick bite % (presence – yes/no) Risk	Yes: E: 73.2% C: 26.6% No: E: 26.8% C: 73.4% p=0.0001 Adj OR= 6.74, 95% CI: 5.29–8.60		Children attending forest kindergartens reported a significantly higher prevalence of tick bites compared to the traditional kindergartens. Attending a forest kindergarten was a risk factor for having at least one tick bite when adjusting for age, sex, skin inspection and recommended vaccination.	▼	Weak
			Borreliosis % (presence – yes/no)	Yes: E: 2.0% C:0.4%		As above	▼	

			Risk	No: E: 98.0% C: 99.6% (p= 0.004) Adj OR= 4.61, 95% CI: 1.50–14.17				
Study details / Sample size	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Types of natural elements								
Söderström at al (2013), Sweden. E: 172 children / 9 ELC	Cross-sectional	Symptoms (illness) The sum of days with symptoms of illness (runny nose, cough, fever, respiratory problems/asthma, itchy skin, diarrhoea, stomach ache, ear pain, body ache, sticky eyes, any medicine taken and days where parents had worries for their child). High score = less healthy.		p= 0.12 (descriptive statistics not presented)		Outdoor environment quality was not significantly associated with symptoms	N/A	Weak

Abbreviations: E= experimental; C= control; n= number; ELC = early learning and childcare (includes preschools, day care, kindergarten etc.); SD= standard deviation; SE= standard error; CI= confidence intervals.

Effect direction explained:
▲: positive health impact
►: no change/ conflicting findings
▼: negative health impact
▲: positive health impact and statistical significance (p<0.05)

▼: negative health impact and statistical significance ($p<0.05$)
No arrow: no inferential statistics reported

Controlled before & after studies – difference between experimental and control group at follow-up (unless stated) or difference in change between experimental or control group. Uncontrolled before & after studies – change since baseline (unless stated). Controlled cross sectional – difference between experimental and control (unless stated). Cross-sectional – positive, negative or no association

COGNITIVE

Table 7. Nature-based ELC on cognitive outcomes								
Study details (Author, year and country) **Sample size** (n of children / n ELC settings for exp and con)	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Nature-based ELC								
Agostini et al (2018), Italy. E: 41 children / 7 teachers / 1 school C: 52 children / 13 teachers / 1 school	Controlled Before & After	See Table 2.	Language	T1 (Jan 2014) E:11.01 (1.30 SD) C:9.83 (1.53 SD)	T4 (May 2015) 12.88 (1.03 SD) 12.74 (1.24 SD) p= 0.000; ηp^2= 0.42	There was a significant time x group interaction on children's language. There were no significant differences between groups at T4.	▲	Weak
			Cognitive development	E:10.94 (0.89 SD) C:9.63 (1.35 SD)	12.49 (0.95 SD) 12.58 (1.31 SD) p= 0.000; ηp2= 0.51.	As above	▼	
Cooper (2018), United Kingdom (England). E: 13 children	Controlled before & after study	Communication Assessed using FOCUS-34 (Focus on the Outcomes of Communication Under Six) which evaluates communication development.	Communication (median and range)	E: 206 (73) C: 214 (93)	206 (73), Z=2.49 p=0.0013 214 (93), Z=2.85 p=0.004 U=54.5 p=0.694	No significant between-group differences at T2	▼	Weak

C: 11 children Children from the same school		FOCUS -34 is divided into 2 sections (34 items in total) and scored on a 7-point Likert scale.						
		The Devereux Early Childhood Assessment for Pre-schoolers, Second Edition (DECA-P2) consists of 38 items on a 5-point likert scale. The assessment measures protective factors and screen for behavioural concerns. The protective factors are divided into 3 subscales: initiative **self-regulation** and attachment/ relationships which form an overall measure of social and emotional wellbeing when combined. Parent and teachers completed the form and they were asked to reflect on the child's behaviour for the previous 2 weeks.	Self-regulation (median and range)	E: 24 (22) C: 23 (19)	25 (20); Z=1.48 p=0.138 24 (18); Z=1.63 p=0.102 **U=56.0 p=0.767**	No statistically significant between-group differences at T2 for self-regulation, initiative	▲	

Cordiano et al (2019), USA. E: 12 children / 1 ELC class. C: 14 children / 1 class. Children from the same school.	Controlled before & after study	Kindergarten readiness Tool assessed letter number recognition, sorting and classifying information, counting, rhyming, and recognizing one's name. The skills were rated by the teachers as "Never," "Sometimes," "Often," or "Always".	Kindergarten readiness	T1 - baseline E:19.09 (3.86 SD) C:23.42 (3.44 SD)	T3 - endpoint 24.72 (2.87 SD) 26.79 (1.71 SD) Within group: η^2p= 0 .10 (small effect), p>0.05 Between group: F= 4.05, η2p= 0.16, p> 0.05.	Non-significant and moderate effect for between group differences.	▼	Weak
Ernst & Burcak (2019), USA E: 34 children / 2 ELC C: 43 children / 2 ELC	Controlled Before & After study	Curiosity Curiosity Drawer Box task - There are a total of 12 possible points (1 point per drawer) for each of these three dependent measures (toys out, toys explored, toys engaged with further), with higher numerical scores indicating higher levels of the respective forms of curiosity. If a child returns to a drawer or toy after having already opened that drawer or interacted with that toy, they do not receive additional points.	Toys Taken Out: Toys Explored: Toys Engaged With:	E: 8.38 (3.39 SD) C: 7.81 (4.19 SD) E: 6.44 (3.09 SD) C: 3.50 (2.71 SD) E: 4.15 (2.60 SD) C: 4.23 (2.89 SD)	Adj post-test (mean and SE) 9.61 (0.46 SE) 8.85 (0.40 SE) p = 0.21, ηp2 = 0.02 6.05 (0.66 SE) 6.24 (0.57 SE) p = 0.83 ηp2 < 0.01 7.61 (0.48 SE) 5.92 (0.42 SE) p = 0.01 ηp2 = 0.09	At post-test, there were no significant differences between the nature and non-nature groups for toys taken out or toys explored, toys engaged with was significant. (controlled for pre-test, age, gender, and prior participation)	▲ ▼ ▲	Weak

Burgess & Ernst (2020). E: 84 children / 4 ELC C: 24 children / 2 ELC		Learning behaviours Preschool learning behaviours scale which consists of 24 items with 3 dimensions: competence motivation; attention/ persistence and attitudes. Teachers score on a 3-point Likert scale (doesn't apply, sometimes, apply, most often applies)	Adj means (SE) Competence motivation Attention/ persistence Attitudes Total	 E:16.73 (0.45 SE) C:19.53 (0.83 SE) E:13.18 (0.37 SE) C:+ SE) E:11.11 (0.28 SE) C:11.77 (0.39 SE) E:36.53 (0.83 SE) C:41.77 (1.51 SE)	 E:20.41 (0.33 SE) C:18.66 (0.65 SE) p=0.02, n2=0.05 E:16.66 (0.30 SE) C:16.13 (0.59 SE) p=0.41, n2=0.01 E:12.74 (0.22 SE) C:12.22 (0.42 SE) p=0.27, n2=0.01 E:44.16 (0.68 SE) C:41.76 (1.34 SE) p=0.12, n2=0.02	At post-test, the nature ELC had significantly higher competence motivation compared to the non-nature ELC. (adjusted for pre-test levels, age, gender, prior participation, and part v. full-time participation)	▲ ▲ ▲ ▲	
Zamzow & Ernst (2020). E: 78 / 4 ELC C: 44 children / 2 ELC	Controlled Before & After study	Executive functions Minnesota Executive Function Scale (MEFS) - conducted using an App, children perform a game like activity where they sort cards to boxes. This games changes commands to assess cognitive flexibility, inhibitory control, and	 Executive functions	 E:41.78 (14.89 SD) C:38.54 (14.40 SD)	Adj post-test (mean and SE) 50.86 (1.29 SE) 49.72 (1.73 SE) p= 0.60, ηp2 < 0.01	No significant differences between the nature and non-nature groups when controlling for pre-test, age, gender, and prior participation.	▲	

		working memory and provides an executive function total score.						
Wojciehowski & Ernst (2018). E: 75 children / 4 ELC Ernst et al (2019). E: 78 children / 4 ELC	Uncontrolled Before & After study	Creative thinking Thinking Creatively in Action and Movement (TCAM) consists of four activities that measure fluency, originality, and imagination.	Fluency Originality Imagination	E: 89.89 (17.76 SD) E: 96.13 (20.16 SD) E: 89.85 (17.68 SD)	104.76 (28.35 SD), p < 0.001 113.61 (36.58 SD), p< 0.001 99.99 (18.42 SD), p< 0.001	Significant improvements in fluency, originality, and imagination in the nature preschool from baseline to follow-up.	▲	
		Resilience Devereux Early Childhood Assessment for Preschoolers, Second Edition (DECAP2) - Parents and teachers evaluate 27 positive behaviors, which form 3 subscales: initiative, **self-regulation**, and attachment. Three subscales were converted to standard scores (T-scores) with a mean of 50 and SD of 10.	Teacher: Self-regulation:	E:54.49 (6.00 SD)	56.78 (8.05 SD), p= 0.01	Significant improvements in self-regulation scores in the nature preschool from baseline to follow-up.	▲	
			Parent Self-regulation:	E:49.31 (7.98 SD)	53.35 (9.34 SD), p= 0.01	Significant improvements in self-regulation in the nature preschool from baseline to follow-up.	▲	
Müller et al (2017), Canada.	Controlled before & after study	Executive functions Working memory: the boxes task is a touch-screen	Working memory	E:25.38 (1.25 SE) C:26.69 (1.18 SE)	E:20.85 (1.91 SE) C:24.84 (1.87 SE)	At post-test there was a small and non-significant effect for working memory and	▲	Weak

E: 43 children / 1 nature-kindergarten C: 45 children / 1 traditional kindergarten		operated, self-ordered search task designed to measure working memory. Attention: Continuous Performance Test (CPT)- a computer based task that requires children to respond to stimuli by touching an animal on the touchscreen and to refrain from responding to a number of other stimuli types. The task lasted 5 minutes and included 200 stimulus of which 29 were targets. The number of correctly identified targets was used as performance indicator of directed attention. Inhibition: The Head-Shoulders-Knees-Toes task (HSKT) - a task that involved children listening to commands and performing the opposite (e.g. touching head when researcher instructed them to touch their feet). Children were	Attention Inhibition	E:22.67 (0.92 SE) C:23.87 (0.86 SE) E:28.96 (3.24 SE) C:27.83 (3.16 SE)	p= 0.19, η2= 0.02) 23.70 (1.01 SE) 24.98 (0.94 SE) p= 0.51, η2= 0.01 34.73 (2.34 SE) 33.44 (2.29 SE) p= 0.76, η2= 0.00	attention. No effect for inhibition.	▼ ▲	

		given a score out of 40.						
		Social Skills Rating Scale (SSRS) completed by parents and teachers. This assesses the following social skills: cooperation, assertiveness, social responsibility and **self-control** and items assessing psychological health (internalising and externalising behaviour). Questionnaires were completed by teachers and parents. They were asked to indicate how often a behavior occurred (never, sometimes, very often).	Teacher Self-control Parent Self-control	 E:16.12 (0.56 SE) C:14.71 (0.55 SE) E:14.75 (0.54 SE) C:14.68 (0.70 SE)	 18.10 (0.56 SE) 13.52 (0.55 SE) p= 0.00, η2= 0.32 15.78 (0.53 SE) 15.00 (0.69 SE) p= 0.29, η2= 0.02	 At post-test there was a large and significant effect. At post-test there was a small and non-significant effect.	 ▲ ▲	
Fyfe-Johnson et al (2019), USA. E: 20 children / 1 ELC C: 13 children (waitlist control or 2-hour nature-	Controlled cross-sectional	Child behaviour SDQ: 25-items consisting of 5 domains: emotional problems, conduct problems, **hyperactivity/ inattention**, peer relationship problems, and prosocial behavior. Parents rated their child on a scale of 0	Hyperactivity/ inattention	E: 2.74 (2.27 SD), C: 3.58 (2.27 SD)	Mean diff -0.88 (95% CI: -2.71, 0.94)	Children in the nature ELC did not differ compared to the control.	▲	Weak

based, outdoor enrichment class provided by experimental ELC		to 2 per question (0=not true; 1=somewhat true; 2=certainly true). Overall score was calculated (sum of all domain scores except prosocial behavior; overall score range: 0-40). Prosocial was scored separately.						
Ernst (2014), USA. E: 46 educators	Cross-sectional	Cognitive development See Table 2.	Cognitive development (1-5)	4.33 (1.30 SD), r= 0.05		There was no association between frequency of nature experiences and belief regarding importance of outdoor settings for cognitive development.	▲	Weak
Study details / Sample size	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Naturalised Playgrounds								
Carrus (2012), Italy. E: 16 children / 1 ELC	Cross-sectional	Visual spatial task (indicator of children's direct attention) Children were asked to colour or to glue paper on to a drawing provided. Performances were evaluated by two independent coders.	Visual spatial task	No inferential stats provided.		Children exposed to free play in external green spaces exhibited a higher accuracy in the performance of the visual-spatial tasks compared to the control.	N/A	Weak

Study details / Sample size	Study Design	Outcome and measurement	Units	Baseline or one time point (cross-sectional)	Follow-up (if applicable) or mean difference	Summary of Findings	Effect Direction	Quality Rating
Types of natural elements								
Martensson et al (2009), Sweden. E: 198 children / 11 ELC	Cross-sectional	Attention The Early Childhood Attention Deficit Disorders Evaluation Scale (ECADDES, School) consists of 2 domains: inattention (32 items) and hyperactivity/ impulsivity (24 items) which are rated by two members of staff who observe the children in their daily routines. Each item is rated from 0-4 (0= child does not engage in the behavior at all, 1= behavior occurs one to several times per month, 2= behavior occurs one to several times per week, 3= behavior occurs one to several times per day, and 4= behavior occurs one to several times per hour) with a lower score indicating a lower occurrence. Rating are summed per child and raw scores	Hyperactivity/ impulsivity Inattention	OPEC: Low Score= 1.59; High Score= 1.23, F= (-) 4.25, p= 0.069 OPEC: Low Score= 1.87; High Score= 1.46, F= (-) 7.38, p<.05		OPEC was significantly related to inattention dimension only:	▲ ▲	Weak

		converted into standard scores taking into account sex and age.						
Study details / Sample size	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Garden-based intervention								
Park et al (2016), South Korea. E: 336 children /12 ELC Science investigation abilities and attitudes= 68 children	Uncontrolled before & after	Scientific attitudes The Scientific Attitude Survey revised by Lee (2000) was used. This consists of 27 questions on a five-point likert scale (strongly agree - strongly disagree) with 9 subcategories: curiosity, volunteerism and activeness, forthrightness, objectivity, openness, criticism, objectivity, cooperation, and patience. Teachers completed this questionnaire based on their daily observations. Higher scores indicate better scientific attitude.	Scientific attitudes (1-5) Curiosity Activeness Forthrightness Objectivity Openness Criticism Judgement reservation Cooperation Patience	 3.17 ± 0.98 3.13 ± 0.95 3.31 ± 0.77 3.07 ± 0.72 2.98 ± 0.64 2.79 ± 0.69 2.72 ± 0.74 3.13 ± 0.67 2.57 ± 0.77	 4.11 ± 0.67, p=0.000 4.10 ± 0.65, p=0.000 4.07 ± 0.54, p=0.000 3.88 ± 0.69, p=0.000 3.55 ± 0.58, p=0.000 3.46 ± 0.59, p=0.000 3.42 ± 0.70, p=0.000 3.94 ± 0.65, p=0.000 3.77 ± 0.89, p=0.000	There were significant improvements in Science attitudes subcategories from baseline to follow-up.	▲	Weak

		Scientific investigations ability of younger children questionnaire revised by Lee (2000) was used. This consists of 21 questions on a five-point likert scale (strongly agree - strongly disagree) with 5 subcategories: prediction, observation, classification, measurement, and discussion. A higher score indicates better investigation ability.	Scientific investigation abilities (1-5) Prediction Observation Classification Measurement Discussion	 3.11 ± 0.83 3.34 ± 0.92 3.25 ± 0.93 2.88 ± 0.97 3.04 ± 0.85	 3.54 ± 0.63, p=0.002 3.99 ± 0.67, p=0.000 3.93 ± 0.66, p=0.000 3.70 ± 0.68, p=0.000 3.55 ± 0.81, p=0.001	As above.	▲	
Lillard (2016), USA. E: 55 children / 1 ELC Delay Gratification E: 34 children Visual motor integration E: 39 children	Uncontrolled before & after	Delay Gratification Participants were assessed individually. The researcher followed a script which involved the child receiving a treat if they waited for the researcher to complete a task. If they wanted the treat immediately, they could ring a bell for the researcher to come back but would get a smaller treat. Measurement was in seconds from when they rang the bell, or	Delay Gratification (seconds)	426.15	676.18, Non-sig	There was not a significant improvement from baseline to follow-up	▲	Weak

		they reached 15 minutes.						
		Visual Motor Integration Assessed using the Beery-Buktenica Developmental Test of Visual-Motor Integration 5th Edition (short form). This was a short pencil and paper test in which participants copy a sequence of shapes. Raw scores ranged from 0-20 and were transformed to standardized scores. Standard scores I have a mean of 100 (15 SD). Scores are age specific.	Visual Motor Integration (scores)	98.62	100.37, non-sig	As above		

Abbreviations: E= experimental; C= control; n= number; ELC = early learning and childcare (includes preschools, day care, kindergarten etc.); SD= standard deviation; SE= standard error; CI= confidence intervals; OPEC= Outdoor Play Environment Categories.

Effect direction explained:
▲: positive health impact
►: no change/ conflicting findings
▼: negative health impact
▲: positive health impact and statistical significance ($p<0.05$)
▼: negative health impact and statistical significance ($p<0.05$)
No arrow: no inferential statistics reported

Controlled before & after studies – difference between experimental and control group at follow-up (unless stated) or difference in change between experimental or control group. Uncontrolled before & after studies – change since baseline (unless stated). Controlled cross sectional – difference between experimental and control (unless stated). Cross-sectional – positive, negative or no association

Social, Emotional and Environmental

Table 8. Nature-based ELC on social and emotional outcomes								
Study details (Author, year and country) **Sample size** (n of children / n ELC settings for exp and con)	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Nature-based ELC								
Agostini et al (2018), Italy. E: 41 children / 7 teachers / 1 school C: 52 children / 13 teachers / 1 school	Controlled Before & After study	See Table 2.	Social and emotional development	T1 (Jan 2014) E:11.18 (1.09 SD) C:10.24 (1.14 SD)	T4 (May 2015) 12.96 (0.94 SD) 12.86 (0.94 SD) p= 0.000; ηp2= 0.38	There was significant time x group interaction on children's social and emotional development. There were no significant differences between groups at T4.	▲	Weak
Cooper (2018), United Kingdom (England). E: 13 children C: 11 children	Controlled before & after study	The Devereux Early Childhood Assessment for Pre-schoolers, Second Edition (DECA-P2) consists of 38 items on a 5-point likert scale. The assessment measures protective factors and screen for behavioural concerns. The protective factors are	Attachment / relationships Self-regulation	E: 23 (13) C: 25 (15) Presented in cognitive domain E: 21 (14)	27 (11); Z=2.82 p=0.005 31 (17); Z=2.61 p=0.009 **U=32.0 p=0.058** Presented in cognitive domain 26 (13); Z=2.41	No statistically significant between-group differences at T2 for attachment/ relationships, initiative, and social and emotional wellbeing	▼ ▼	Weak

Children from the same school		divided into 3 subscales: initiative, self-regulation and attachment/ relationships which form an overall measure of social and emotional wellbeing when combined. Parent and teachers completed the form and they were asked to reflect on the child's behaviour for the previous 2 weeks.	Initiative Social and emotional wellbeing (median and range)	 C: 20 (12) E: 69 (40) C: 71 (39)	p=0.016 29 (16); 2.63 p=0.009 **U=40.5 p=0.187** 76 (32); Z=2.49 p=0.013 83 (48); Z=2.49 p=0.013 **U=42.0 p=0.224**		▼	
Cordiano et al (2019), USA. E: 12 children / 1 ELC class. C: 14 children / 1 class. Children from the same school.	Controlled before & after	Preschool and Kindergarten Behavior Scales, Second Edition (PKBS-2) is a 76-item behavior rating instrument which assesses social skills and behavioural problems. The Social Skills scale assess the dimensions of Social Cooperation, Social Interaction, and Social Independence. The Problem Behavior scale assesses the dimensions of Externalizing Problems and	Social skills Teacher Parent	T1 - baseline E: 101.92 (11.69 SD) C: 110.07 (7.41 SD) E: 102.20 (15.51 SD); C: 104.00 (7.29 SD)	T3 - endpoint 106.21 (13.34 SD) 112.96 (6.29 SD) Within-group: p= non-sig, η2p= 0.01 Between group: F=1.98, η2p= 0.08, p> 0.05 108.40 (12.67 SD) 128.73 (64.96 SD) Within-group: p= non-sig, η2p= 0 .08 Between group:	Small effect for between group Small effect for between group	▼ ▼	Weak

		Internalizing Problems			F= 0.87, η2p= 0.05, p> 0.05			
			Behavioural problems Teacher Parent	 E: 91.58 (9.14 SD) C: 82.46 (6.39 SD) E: 97.00 (21.12 SD) C: 101.10 (13.16 SD)	 89.96 (12.26 SD) 83.93 (5.03 SD) Within-group: p= non-sig, η2p= 0.01 Between group: F=4.81, η2p= 0.17, p<0.05 92.67 (16.52 SD) 95.20 (9.94 SD); Within-group: p= non-sig, η2p= 0.21 Between group: F= 0.15, η2p= 0.01, p>0.05	 Moderate effect for between group No effect for between group	 ▼ ▲	
Müller et al (2017), Canada. E: 43 children / 1 nature-kindergarten C: 45 children / 1 traditional	Controlled before & after study	Social Skills Rating Scale (SSRS) completed by parents and teachers. This assesses the following social skills: cooperation, assertiveness, social responsibility and self-control and items assessing	Teachers Assertiveness Cooperation	 E:17.15 (0.57 SE) C:12.40 (0.55 SE) E:17.14 (0.52 SE) C:15.00 (0.49 SE)	 19.16 (0.47 SE) 12.86 (0.45 SE) p= 0.00, η2= 0.34 18.63 (0.45 SE) 15.25 (0.43 SE) p= 0.00 η2= 0.20	 At post-test there was a large and significant effect. As above.	 ▲ ▲	Weak

kindergarten		psychological health (internalising and externalising behaviour). Questionnaires were completed by teachers and parents. They were asked to indicate how often a behavior occurred (never, sometimes, very often).	Self-control Externalizing Behavior: Internalizing Behavior	Presented in cognitive domain. E: 2.63 (0.48 SE) C: 1.91 (0.47 SE) E: 0.96 (0.16 SE) C: 0.36 (0.15 SE)	Presented in cognitive domain. 2.05 (0.43 SE) 1.98 (0.41 SE) p= 0.11, η2= 0.03 0.20 (0.11 SE) 0.41 (0.10 SE) p= 0.04, η2= 0.05	At post-test there was a small and non-significant effect. At post-test there was a small and significant effect.	▼ ▲ ▲	
			Parent Assertiveness Social Responsibility Cooperation Self-control Externalizing Behavior: Internalizing Behavior	 E:15.27 (0.43 SE) C:15.31 (0.62 SE) E:11.58 (0.48 SE) C:10.50 (0.67 SE) E:12.76 (0.37 SE) C:12.00 (0.52 SE) Presented in cognitive domain. E: 3.67 (0.38 SE) C: 3.79 (0.50 SE)	 16.24 (0.42 SE) 14.75 (0.60 SE) p= 0.01, η2= 0.13 13.10 (0.44 SE) 11.06 (0.61 SE) p= 0.03, η2= 0.11 13.18 (0.36 SE) 11.75 (0.52 SE) p= 0.06, η2= 0.08 Presented in cognitive domain. 3.06 (0.36 SE) 3.63 (0.47 SE) p= 0.25, η2= 0.03 0.94 (0.17 SE)	At post-test there was a moderate and significant effect. As above. At post-test there was a moderate but non-significant effect. As above. At post-test there	▲ ▲ ▲ ▲ ▼	

				E: 1.17 (0.17 SE) C: 0.79 (0.23 SE)	0.90 (0.23 SE) p= 0.68, η2= 0.00	was a non-significant effect.		
Ernst et al (2019) & Ernst & Burcak (2019), USA E: 78 children / 4 ELC	Uncontrolled Before & After study	Resilience Devereux Early Childhood Assessment for Preschoolers, Second Edition (DECAP2) - Parents and teachers evaluate 27 positive behaviors, which form 3 subscales: initiative, self-regulation, and attachment. Three subscales were converted to standard scores (T-scores) with a mean of 50 and SD of 10.	Teacher: Total protective factors Initiative: Self-regulation: Attachment:	 E:54.54 (5.95 SD) E:52.74 (7.98 SD) presented in cognitive domain. E:55.26 (6.91 SD)	 57.71 (7.87 SD), p=0.01 56.93 (8.55 SD), p= 0.01 presented in cognitive domain. 57.21 (7.45 SD)	 Significant improvements in total protective factors and initiative in the nature preschool from baseline to follow-up. No significant improvements in attachment scores.	 ▲ ▲ ▲	Weak
			Parent Total protective factors Initiative Self-regulation: Attachment:	 E:50.21 (7.62 SD) E:49.84 (8.45 SD) presented in cognitive domain. E:51.64 (7.24 SD)	 53.13 (8.81 SD), p = 0.01 53.63 (8.17 SD), p= 0.01 presented in cognitive domain. 51.39 (9.93 SD)	 Significant improvements in in the total protective factors, and initiative in the nature preschool from baseline to follow-up. No significant improvements in attachment scores.	 ▲ ▲ ▲	

Fyfe-Johnson et al (2019), USA. E: 20 children / 1 ELC C: 13 children (waitlist control or 2-hour nature-based, outdoor enrichment class provided by experimental ELC	Controlled cross-sectional	Child behaviour SDQ: 25-items consisting of 5 domains: emotional problems, conduct problems, hyperactivity/ inattention, peer relationship problems, and prosocial behavior. Parents rated their child on a scale of 0 to 2 per question (0=not true; 1=somewhat true; 2=certainly true). Overall score was calculated (sum of all domain scores except prosocial behavior; overall score range: 0-40). Prosocial was scored separately.	Overall Score Emotional problems Conduct problems Hyperactivity/ inattention Peer relationship problems Prosocial behavior	E: 6.55 (4.35 SD) C: 7.51 (4.23 SD) E: 1.20 (1.67 SD) C: 1.00 (0.95 SD) E: 1.63 (1.54 SD) C: 1.83 (1.59 SD) presented in cognitive domain. E: 1.05 (0.94 SD), C: 1.08 (1.24 SD) E: 8.15 (1.57 SD), C: 7.83 (1.59 SD)	Mean diff -0.95 (95% CI: -4.39, 2.49) 0.2 (95% CI: -0.82, 1.22) -0.23 (95% CI: -1.49, 1.03) presented in cognitive domain. -0.03 (95% CI: -0.95, 0.88) 0.32 (95% CI: -0.95, 1.59)	Children in the nature ELC did not differ in behavioural scores compared to the control.	▲ ▼ ▲ ▲ ▲	Weak
Ernst (2014), USA. E: 46 educators	Cross-sectional	See table 2.	Social development (1-5)	4.43 (1.31 SD), r= 0.05		There was no association between frequency of nature experiences and belief regarding importance of outdoor settings for social development.		Weak

Study details / Sample size	Study Design	Outcome and measurement	Units	Baseline or one time point (cross-sectional)	Follow-up (if applicable) or mean difference	Summary of Findings	Effect Direction	Quality Rating
Naturalised Playground								
Brussoni et al (2017), Canada. E: 48 children / 2 childcare centres	Uncontrolled before & after (mixed methods)	Sociometric status was determined by rating how "dominant or influential" and "popular" each child is with peers	Sociometric: Dominance Acceptance		 Centre A= 3.42 Centre B= 2.70 Centre A= 3.44 Centre B= 3.25	Mean sociometric scores remained stable over time.	 ▲ ▲	Moderate
		Strengths and difficulties questionnaire (SDQ)-25 items that measure emotional symptoms, conduct problems, hyperactivity, peer relationships, and prosocial behaviour.	Strengths and difficulties (median)	2.3	2.0; z= -2.10, p= 0.036	There was a significant decrease in the SDQ peer problems scale. No other scores differed significantly (not reported).	▲	
		Preschool social behaviours skill (PSBS-T) - 19 items assessing relational aggression, overt aggression, depressed affect.	Social behaviour (median)	6.0	3.0 z= -2.24, p= 0.03	There was significant decrease in The PSBS depression score. No other scores differed significantly (not reported).	▲	
Cosco et al (2014), USA. E: not clear / 27 centres.	Uncontrolled Before & After study	Social interactions Observational behaviour mapping was conducted. Location of children, gender, PA level, social interactions	Custodial (i.e tying shoe laces, offering water) teacher-child interaction		-0.156, B=-0.095), p< 0.05	At follow- up, observations highlighted significantly less custodial teacher-child interactions, more negative teacher-child	▼	Weak

		(alone, pair, group), teacher interactions (not present, positive, custodial, negative) were recorded by observers and entered into a handheld computer.	Negative teacher-child interaction No teacher present Positive teacher-child interaction Child is alone Child is with one other child Child is in group		0.030, B= - 034, p< 0.05 0.082, B= - 0.002, non-sig - 0.064, B= - 0.088, p< 0.05 - 0.195, B= not estimated - 0.034, B= - 0.031, p< 0.05 - 0.168, B= - 0.113, p< 0.05	interactions, less positive teacher-child interactions and less children with another child or in a group:	▼ ▼ ▼ ▼ ▼	
Carrus (2012), Italy. E: 16 children / 1 ELC	Cross-sectional	Social interactions Frequency of small group play, self-organised play, direct interventions by educators, boredom feelings episodes were observed. Trained observers recorded and coded these on a six-step scale, ranging from 0= never to 5 = always.	small group play self-organised play direct interventions by educators boredom feelings episodes	t (9)= 2.36; p= 0.02) t (9)= 2.36; p= 0.03 t (9) = -1.42; p = 0.09 t (9) = -1.48; p= 0.09		There was a significantly higher frequency of small group play and self-organised play in the external green space compared to the internal space. There was not a significantly lower frequency of direct interventions by educators and of boredom feelings episodes	▲ ▲ ▲ ▲	Weak
		Stress	Dispute-resolution	F (1, 9) = 7,63; p= 0.022; eta square = 0.46		There was a significant 2- way interaction for	▲	

		Frequency of dispute-resolution interventions by educators, crying episodes and capacity of being quickly comforted in case of crying were observed. Trained observers recorded and coded these on a six-step scale, ranging from 0= never to 5 = always.	interventions by educators Crying episodes Capacity of being quickly comforted in case of crying	F (1, 9) = 4,46; p= 0.064; eta square = 0.33 F (1, 9) = 9,17; p = 0.014; eta square = 0.50		frequency of dispute resolution interventions by educators and capacity of being quickly comforted in case of crying, but not frequency of crying episodes.	▲ ▲	
Study details / Sample size	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Types of natural elements								
Sando (2019), Norway. E: 80 children / 8 ELC	Cross-sectional	Emotional wellbeing Leuven Well-Being Scale which assesses children's emotional wellbeing. This is an observational assessment where children are scored on a scale from 1 to 5. 1= clear signs of discomfort (screaming, anger, sadness) and 5= happy, relaxed.	Emotional Wellbeing (1-5)	Well-being 3.6 (0.6 SD), (regression coefficient = 0.004, p=< 0.05)		Nature was a statistically significant predictor of emotional wellbeing	▲	Weak

Söderström at al (2013), Sweden. E: 172 children / 9 ELC	Cross-sectional	Stress The Salivette®kit (Sarstedt, Numbrecht, Germany). Children were asked to chew a swab for 1 min once in the mid-morning (AM cortisol, 9–10 am) and again the afternoon (PM cortisol, 1 –2 pm). The difference between PM cortisol and AM cortisol was calculated. A positive value implied a rise in PM cortisol level suggesting increased stress.	Stress (PM = AM cortisol)	Low OPEC: -0.4 (1.3 SD) High OPEC: -4.4 (1.9 SD) p= 0.03		Outdoor environment quality a significantly association with stress.	▲	Weak
Study details / Sample size	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Garden-based intervention								
Park et al (2016), South Korea. E: 336 children /12 ELC Prosocial behaviour: 133 children Emotional intelligence: 135 children	Uncontrolled before & after	The revised prosocial behavior questionnaire by Lee (1996) was used. This consists of 20 questions on 4 subscales: helping, sharing, cooperation and kindness. Answers are given on a three-point likert scale (agree, neutral, disagree. Teachers completed this questionnaire based	Emotional intelligence (1-5): Utilization of emotions Recognition and consideration of others' emotions Recognition and	3.35 ± 0.83 3.36 ± 0.59 3.86 ± 0.73	4.01 ± 0.88, p=0.000 3.79 ± 0.68, p=0.000	Emotional intelligence: There was significant improvements in emotional intelligence subcategories from baseline to follow-up	▲	Weak

		on their daily observations. Higher scores indicate a more positive behaviour.	expression of own emotions Emotional regulation and impulse control Relationships with teachers Relationships with peers	 3.62 ± 0.65 3.77 ± 0.90 3.73 ± 0.92	4.30 ± 0.63, p=0.000 4.11 ± 0.81, p=0.000 4.19 ± 0.71, p=0.000 4.09 ± 0.84, p=0.000			
		The emotional intelligence questionnaire consisted of 50 questions on a five-point likert scale (strongly agree - strongly disagree) which was completed by teachers. Higher scores indicate a more positive behaviour.	Prosocial behaviour (1-3). Helping Sharing Cooperation Kindness	 2.37 ± 0.46 2.53 ± 0.41 2.42 ± 0.43 2.30 ± 0.38	 2.57 ± 0.43, p = 0.000 2.66 ± 0.36, p= 0.001 2.66 ± 0.38, p= 0.000 2.55 ± 0.40, p= 0.000	Prosocial behaviour: There was significant improvements in prosocial behaviour subcategories from baseline to follow-up.	▲	

Abbreviations: E= experimental; C= control; n= number; ELC = early learning and childcare (includes preschools, day care, kindergarten etc.); SD= standard deviation; SE= standard error; CI= confidence intervals.

Effect direction explained:
▲: positive health impact
►: no change/ conflicting findings
▼: negative health impact
▲: positive health impact and statistical significance (p<0.05)
▼: negative health impact and statistical significance (p<0.05)
No arrow: no inferential statistics reported

Controlled before & after studies – difference between experimental and control group at follow-up (unless stated) or difference in change between experimental or control group. Uncontrolled before & after studies – change since baseline (unless stated). Controlled cross sectional – difference between experimental and control (unless stated). Cross-sectional – positive, negative or no association.

Table 9. Nature-based ELC on nature connectedness

Study details (Author, year and country) **Sample size** (n of children / n ELC settings for exp and con)	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Nature-based ELC								
Agostini et al (2018), Italy. E: 41 children / 7 teachers / 1 school C: 52 children / 13 teachers / 1 school	Controlled Before & After study	See Table 2.	Awareness of surrounding environment	T1 (Jan 2014) E:11.35 (1.22 SD) C:10.07 (1.80 SD)	T4 (May 2015) 13.20 (0.66 SD) 12.86 (1.09 SD) p= 0.004, ηp2= 0.30.	There was a significant time x group interaction on children's awareness of surrounding environment. There were no significant differences between groups at T4.	▲	Weak
Elliot et al (2014), Canada. E: 21 children / 1 ELC	Controlled Before & After (mixed-methods)	Nature relatedness and environmentally responsible behavior An activity where children played against the interviewer. 11 choices were presented (4 nature	Nature Relatedness (out of 8) Environmentally	E: 6.43 (1.25 SD) C: 6.05 (1.05 SD) E:10.57 (0.93 SD)	6.62 (0.97 SD) 5.82 (1.50 SD), p < 0.05 10.71 (1.06 SD)	At post-test, there was a significant difference in nature relatedness scores between the groups. At post-test, there was no significant	▲ ▼	Moderate

C: 22 children / 2 ELC		and 6 environmental behaviour) and the child chose between 2 options. Children received a score of 2 for choosing the more nature-oriented action or environmentally responsible option, and 1 for choosing the alternative option. The max score for nature relatedness was 8 and 12 for environmental behavior.	responsible behavior (out of 12)	C:10.59 (1.14 SD)	10.73 (0.83 SD), p< 0.40	between group differences.		
Müller et al (2017), Canada. E: 43 children / 1 nature-kindergarten C: 45 children / 1 traditional kindergarten	Controlled before & after	As above.	Nature Relatedness (out of 8) Environmentally responsible behavior (out of 12)	E: 6.37 (0.17 SE) C: 5.82 (0.16 SE) E:10.49 (0.18 SE) C:10.29 (0.17 SE)	6.52 (0.18 SE) 6.14 (0.17 SE) p= 0.22, η2= 0.02 10.49 (0.18 SE) 10.51 (0.17 SE) p= 0.83, η2= 0.00	At post-test there was a small and non-significant effect At post-test there was no significant effect	▲ ▼	Weak
Nazaruk & Klim-Klimaszewska (2017), Poland. E: 90 children (50	Uncontrolled before & after	Knowledge and skills of nature Pre-test: A standard card test consisting of 6 illustrated worksheets with tasks for children to	Knowledge and skills of nature categorised into the following: pre-test:	City Low= 12% Average= 56% High= 32% Rural Low= 0%	City Low= 0% Average= 28% High= 72% Rural Low= 0% Average= 20%	Children scored higher at post-test compared to pre-test.	▲	Weak

urban / 40 rural)		complete. Teachers explained and conducted the test. Children's performance was rated on a scale of 1 to 3 (1= nature skills have not been mastered, 3= nature skills have been fully mastered). Children could score a max of 18 points. Post-test: Observation and a picture test consisting of 10 illustrated worksheet cards with tasks for children. A similar scoring to pre-test was used and the children could get a max of 30 points.	Low (0-9) Average (10-14) High (15-18) Post-test: Low (0-15) Average (16-23) High (24-30)	Average= 50% High= 50% p = 0.3	High= 80% p = 0.8093			
Yilmaz et al (2020), Turkey. 40 children / 1 ELC	Uncontrolled before & after	Biophilia Adapted tool originally developed by Rice and Torquati (2013) below.	Biophilia Scores (out of 11)	19.78, 1.510 (SD), 0.239 (SE)	20.33, 1.309 (SD), 0.207 (SE) Mean diff: -0.55, 1.584 SD, 0.251 SE (95% CI: -1.057, -0.043), p= 0.034	There was a significant difference in the Biophilia scores from pre-test to post-test.	▲	Weak
Barrable et al (2020), UK (England, Scotland, Wales).	Controlled cross-sectional	Connectedness to nature The connectedness to Nature Index for	Total CNI score	E: 4.22 (0.47 SD) C: 3.92 (0.60 SD)		Children attending nature nurseries scored higher for	▲	Weak

E: 141 /12 ELC C: 110 children / 6 ELC		Parents of Preschool Children (CNI-PPC) consists of 16-items and responses are given on a five-item Likert scale ranging from “strongly disagree” to “strongly agree”. It consists of 4 dimensions: enjoyment of nature, empathy for nature, responsibility toward nature and awareness of nature.	Enjoyment of nature Empathy for nature Responsibility toward nature Awareness of nature	E: 4.41 (0.54 SD) C: 4.05 (0.67 SD) ($\beta = 0.59$, $p = 2.61 \times 10^{-15}$) E: 3.78 (0.71 SD) C: 3.63 (0.80 SD) E: 3.96 (0.68 SD) C: 3.85 (0.71 SD) ($\beta = 0.76$, $p = 2 \times 10^{-16}$) E: 4.45 (0.53 SD) C: 3.98 (0.67 SD)		enjoyment and responsibility	▲ ▲ ▲ ▲	
Giusti et al (2014), Sweden. E: 11 children / 2 ELC C: 16 children / 5 ELC	Controlled cross-sectional	Children's affinity with biosphere The teacher presented children with image-based tasks (games) in which they had to select an image based on set questions. This assesses emotional and cognitive affinity to nature.	Emotional Affinity with the Biosphere Cognitive Affinity with the Biosphere	E: 0.792 (0.121 SD) C: 0.665 (0.154 SD), p= 0.031, d= 0.916 E: 0.771 (0.134 SD) C: 0.660 (0.133 SD), p= 0.045, d= 0.845		Children with nature-rich routines score significantly higher than children with nature-deficit routines. As above.	▲ ▲	Weak

Rice & Torquati (2013), USA. E: 68 children / 6 ELC C: 46 children /4 ELC	Controlled cross-sectional	Biophilia Interview consisting of 11-items which assess preference for being outdoors, enjoyment of sensorial aspects of nature, curiosity about nature, and interacting with nature. Biophilic responses were scored 1 and non-biophilic responses were scored 0.	Biophilia Scores (out of 11)	E: 7.7 (2.3 SD) C: 7.7 (2.4 SD), p= 0.94		There was no significant difference between the nature and non-nature groups	►	Weak
Ernst (2014), USA. E: 46 educators	Cross-sectional	Development of environmental appreciation See table 2.	Environmental appreciation (1-5) Belief regarding difficulty in using natural outdoor settings Belief regarding one's relationship with nature	4.43 (1.31 SD) r= 0.83, p ≤ 0.05 b= 0.71, SE= 0.08, B= 0.83, p<.001 r= 0.31, p ≤ 0.05 b= 0.25, SE= 0.21, B= 0.11, p= 0.25		There was an association between frequency of nature experiences and belief regarding difficulty in using natural outdoor settings and belief regarding one's relationship with nature Belief regarding difficulty in using natural outdoor settings was a significant predictor of use of natural outdoor settings with their preschool students, belief regarding one's	▲ ▲	Weak

						relationship with nature was not.		

Abbreviations: E= experimental; C= control; n= number; ELC = early learning and childcare (includes preschools, day care, kindergarten etc.); SD= standard deviation; SE= standard error; CI= confidence intervals.

Effect direction explained:
▲: positive health impact
►: no change/ conflicting findings
▼: negative health impact
▲: positive health impact and statistical significance ($p<0.05$)
▼: negative health impact and statistical significance ($p<0.05$)
No arrow: no inferential statistics reported

Controlled before & after studies – difference between experimental and control group at follow-up (unless stated) or difference in change between experimental or control group. Uncontrolled before & after studies – change since baseline (unless stated). Controlled cross sectional – difference between experimental and control (unless stated). Cross-sectional – positive, negative or no association

Table 10. Nature-based ELC on play behaviour								
Study details (Author, year and country) **Sample size** (n of children / n ELC settings for exp and con)	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Nature-based ELC								
Agostini et al (2018), Italy. E: 41 children / 7 teachers / 1 school C: 52 children / 13 teachers / 1 school	Controlled Before & After study	Play See Table 2.	Play (mean and SD)	T1 (Jan 2014) E:11.26 (1.08 SD) C: 9.89 (1.22 SD)	T4 (May 2015) 13.15 (0.99 SD) 12.78 (1.14 SD) p= 0.00; ηp2= 0.41	There was a significant time x group interaction on children's play. There were no significant differences between groups at T4.	▲	Weak
Cordiano et al (2019), USA. E: 12 children / 1 ELC class. C: 14 children / 1 class. Children from the same school.	Controlled before & after study	Play Interaction, Play Disruption, and Play Disconnection Assessed using the Penn Interactive Peer Play Scale (PIPPS), which is a 32-item behaviour rating instrument assessing aspects of children's peer play behaviors. Pretend Play rating consisted of 5	Teacher Play interaction Pretend play	T1 - baseline E:49.46 (6.99 SD) C:54.96 (2.64 SD) E:15.18 (1.66 SD) C:18.21 (2.12 SD)	T3 - endpoint 54.69 (5.07 SD) 55.82 (2.76 SD) Within group: p<0.01, η^2p= 0.26 Between group: (F=2.70, η2p= 0.11, p>0.05) 23.45 (2.12 SD) 18.86 (3.35 SD) Within group: p<0.01 η2p= 0.29	Small effect for between group No effect for between group	▼ ▲	Weak

		questions on a 5 point likert scale to assess children's imagination in play, use of make-believe, enjoyment of play, amount of emotion expressed in play, and use of make-believe in dramatic play.			Between group: F=0.00, η2p= 0.00, p>0.05			
			Play disruption	E:50.38 (5.96 SD) C:43.69 (6.43 SD)	47.71 (7.26 SD) 38.31 (5.53 SD) Within group: non-sig, η2p= 0.06 Between group: F=17.64, η2p= 0.45, p<0.001	Large effect for between group	▼	
			Play disconnection	E:52.13 (7.34 SD) C:43.71 (5.63 SD)	45.75 (9.28 SD) 40.14 (4.69 SD) Within group non-sig, η2p= 0.08 Between group: F=14.59, η2p= 0.39, p<0.01	Large effect for between group	▼	
			Parent Play interaction	E:46.90 (6.72 SD) C:48.00 (7.00 SD)	51.30 (7.46 SD) 51.22 (9.91 SD) non-sig, η2p= 0 .07	There were non-significant and small effects for between group and school x time across all four play types.	▲	
			Pretend play	E:20.90 (3.54 SD) C:21.80 (3.58 SD)	21.50 (3.24 SD) 22.00 (4.03 SD) non-sig, η2p= 0 .00		▼	
			Play disruption	E:49.11 (9.21 SD) C:50.00 (3.81 SD)	44.89 (8.25 SD) 44.00 (7.50 SD) non-sig, η2p= 0 .02		▼	

			Play disconnection	E:49.63 (11.20 SD) C:50.33 (8.54 SD)	48.38 (10.04 SD) 46.11 (9.32 SD) non-sig, η2p= 0 .03		▼	
Burgess & Ernst (2020), USA. E: 84 children / 4 ELC C: 24 children / 2 ELC	Controlled Before & After study	Play behaviours The Penn Interactive Peer Play Scale consists of 32 items with 3 dimensions: play interaction, play disruption and play disconnection Teachers and parents indicate frequency of behaviours on a 4-point Likert scale (never, seldom, often, always)	Adj means (SE) Teacher: Play interaction	E: 23.44(0.31 SE) C:17.75 (0.37 SE)	E:28.82 (0.32 SE) C:26.13 (0.63 SE) p<.001, η2= 0.12	At post-test children in the nature ELC had significantly higher play interaction scores and lower play disruption and disconnection scores compare to the non-nature ELC. (adjusted for pretest levels, age, gender, prior participation, and part v. full-time participation)	▲	Weak
			Play disruption	E:28.11 (0.67 SE) C:25.19 (1.69 SE)	E:20.06 (0.48 SE) C:25.22 (0.95 SE) p <001, η2=0.19		▲	
			Play disconnection	E:19.40 (0.53 SE) C:15.88 (1.47 SE)	E:12.44 (0.32 SE) C:15.17 (0.65 SE) p<.001, η2= 0.12		▲	
			Parent: Play interaction	E:25.77 (0.30 SE) C:25.33 (0.75 SE)	E:27.15 (0.28 SE) C:26.92 (0.58 SE) p= 0.72, η2<.01	No significant differences between the nature and non-nature ELC at post-test.	▲	
			Play disruption	E:29.82 (0.45 SE) C:28.47 (1.20 SE)	E:27.85 (0.45 SE) C:28.45 (0.94 SE) p= 0.57, η2< .01		▲	
			Play disconnection	E:17.75 (0.37 SE)	E:16.06 (0.33 SE)		▼	

				C:18.27 (1.27 SE)	C:16.03 (0.69 SE) p= 0.97, η2<.001			
Robertson et al (2020), Australia. E: 15 children / 1 ELC C: 15 children / 1 ELC	Controlled cross-sectional	Sociodramatic play Smilansky Scale for the Evaluation of Dramatic and Socio Dramatic play (SSEDSP). Observation of each child (6x5 minute intervals) and scored: 0=characteristic is not present 1=characteristic is present but to a limited degree 2=characteristic is present to a moderate degree 3=characteristic is present consistently and in many situations during the child's play Total score was calculated using sum of each 5 min interval (score could be 0 - 18) and represented overall complexity of play	Sociodramatic play: Role play Make believe with objects Actions and situations Persistence Interaction	E: 6.35 (1.96 SD) C: 2.04 (2.65 SD) t (28) = 5.07, p= 0.00) E: 1.04 C: 0.34 SD= 0.16, p= 0.00, eta squared= 0.39 E: 0.92 C: 0.31 SD= 0.14, p= 0.00, eta squared= 0.42 E: 0.99 C: 0.34 SD=0.14, p= 0.00, eta squared= 0.44 E: 1.11 C: 0.27 SD= 0.16, p= 0.00, eta squared= 0.50 E: 1.20 C: 0.34 SD= 0.14, p= 0.00, eta squared= 0.56	Mean diff= 0.86, (95% CI: - 2.04–6.35, eta squared = 0.47).	There was a significant difference between the sociodramatic play of children in nature ELC compared to the control The magnitude of the differences in the means was large. There were also significant differences in characteristic of Socio Dramatic Play.	▲ ▲ ▲ ▲ ▲	Weak

			Verbal communication	E: 1.20 C: 0.34 SD= 0.15, p= 0.00 eta squared= 0.53			▲	
Study details / Sample size	**Study Design**	**Outcome and measurement**	**Units**	**Baseline or one time point (cross-sectional)**	**Follow-up (if applicable) or mean difference**	**Summary of Findings**	**Effect Direction**	**Quality Rating**
Naturalised Playground								
Brussoni et al (2017), Canada. E: 48 children / 2 childcare centres Play: 16 children (sub-sample)	Uncontrolled before & after (mixed methods)	Play behaviours Each child was observed twice over 30 min of outdoor play at baseline and follow-up by two researchers. Observations were coded as follows: prosocial behaviours (co-operative play, social conversation), antisocial behaviours (physical and verbal aggression, object possessiveness, rejected bids for engagement), lack of engagement in play (onlooking, unoccupied), channel surfing (transitioning frequently between activities), child teacher interactions (teacher initiated, child-initiated, interruption by	Play: Prosocial behaviours Antisocial behaviours Lack of engagement in play Channel surfing, Child teacher interactions Play with natural materials Risky play Gender-segregated play		OR: 2.81, (95% CI: 1.17-6.91), p< 0.05 OR: 1.40, (95% CI 0.47-4.13) OR: 0.52, (95% CI: 0.24-1.14) No change. OR: 1.30, (95% CI: 0.65-2.57) OR: 7.29, (95%CI: 1.53-38.09), p< 0.05 OR: 1.11, (95% CI: 0.55-2.27) No change.	There were a significant intervention effects for play with natural materials and prosocial behaviour. There were no significant intervention effects for the remaining play types. Channel surfing and gender segregated play did not change.	▲ ▲ ▲ ► ▲ ▲ ▲ ► ▲ ►	Moderate

		teacher), play with natural materials (natural loose materials, natural play elements), risky play (rough and tumble, height, mastery, unstable, speed, risk of getting lost), and gender-segregated play.	Solitary play		OR: 1.13, (95% CI 0.60-2.15).		▲	
Cloward Drown et al (2014), USA. E: 24 children / 1 ELC (observed in 2 different playgrounds, natural vs manufactured)	Controlled cross-sectional	Dramatic Play Smilansky Scale (modified) was used to code children's dramatic play. The scale uses 5 behaviors and persistence of a play episode to indicate dramatic play: imitative role-play, make-believe with objects, make-believe with actions and situations, interaction, verbal communication and persistence of play episode	Dramatic Play (%) Playground type (natural vs manufactured) Play props (natural, manufactured, none)	E: 12% C: 10% Pearson x2 = (3, 1006) = 12.19, p = 0.007) Pearson x2 = (6, 802) = 23.09, p= 0.001)		Playground type and type of dramatic play were found to be significantly related with the natural playground affording more dramatic play than the manufactured playground. A significant relationship was found between play prop use and dramatic play Natural play props were not used frequently or highly associated with dramatic play.	▲ ▲ ▲	Weak
		Social Play MildredParten's (1932) stages of play were used to describe social interaction and maturity of play:	Social Play (%) Playground type (natural vs manufactured)	Pearson x2 = (3, 751), 5.07, p= 0.167		There was no relationship between playground type and type of social play indicating both playgrounds provided similar affordances for social		

		unoccupied play, solitary play, onlooker play, parallel play, associative play, cooperative play. Child's play was observed in 30-second intervals for ten-minute period. Observers recorded a child's location at the start of each 30-second interval and or the remainder of 30-second interval, the play types, persitance and location (natural, manufactured, none).	Play props (natural, manufactured, none)	No association		play.		
Luchs, & Fikus (2013), Germany. E: 38 children / 1 ELC C: 21 children / 1 ELC	Controlled cross-sectional	Play episodes and frequency Observation - information on place, duration, social category of play and narrative was collected. The play episodes were then coded afterwards: **-play with**: functional play and constructional play. -**play as**: well-known meaning and displays a different object within the child's play and imagination,	Number of play episodes Duration of play episodes 0-5mins 6-10 mins 11-15mins 16-20mins:	E: 3.05 ± 1.71 C: 5.57 ± 1.47. E: 36% C: 58% E: 32% C: 35% E: 12% C: 7% E: 8% C: 0%/ E: 5% C: 0%		During the 30 minutes observed, there were significantly different number of play episodes between the natural and contemporary playgrounds.		Weak

		orientation on role-models, not only copying but also developing their own play while realizing their own ideas, wishes and needs **-play for**: play with rules, organizing activities of several players **- others** **- combination**	21-25mins	E: 8% C: 0%				
			26-30mins					
			Frequency of play categories Play with	E: 1.45 ±1.37 C: 3.14 ±1.68 p= 0.000		Children in the contemporary playground engaged in significantly higher play episode categories. Combination was non-significant	▼	
			Play as	E: 0.53 ±0.83 C: 0.62 ±0.97 p= 0.701			▼	
			Play for	E: 0.13 ±0.41 C: 0.52 ±0.68 p= 0.023			▼	
			Other	E: 0.24 ±0.49 C: 0.67 ±0.73 p= 0.022			▼	
			Combination	E: 0.71 ±0.8 C: 0.62 ±0.8 p= 0.677			▼	
			Combination Patterns of play categories (%) Play with	E: 44.66 ±35.67 C: 56.18 ±27.45 p= 0.204		Play for and combination play were significantly different.	▼	
			Play as	E:18.92 ±27.87		Combination play which was preferred	▼	

				C: 11.78 ±23.28 p= 0.324		by children in the nature playground.		
			Play for	E: 3.23 ±10.46 C: 9.93 ±13.45 p= 0.056			▼	
			Other	E: 6.3 ±13.34 C: 11.45 ±12.31 p= 0.151			▼	
			Combination	E: 26.9 ±32.71 C: 10.66 ±15.0 p= 0.012			▲	
Dyment et al (2013), Australia. E: 120 children / 3 ELC C: 40 children / 1 ELC	Cross-sectional	Play types System for Observing Play and Leisure Activity in Youth (SOPLAY) was used to collect data on play types across various playground areas. The categories of play types were functional, constructive, symbolic, self-focused/looking on and talking.	Play types in natural areas Functional (physical play activities)	E: ELC A= 24.0 ELC C= 58.3 ELC D= 52.2 C: ELC B= N/A		Functional play was the most popular type of play in natural areas in the experimental schools. Symbolic play was infrequent and only observed in one experimental ELC.		Weak
			Constructive (building play activities)	E: ELC A= 14.7 ELC C= 19.2 ELC D= 13.0 C: ELC B= N/A				
			Symbolic (creative/ imaginative play)	E: ELC A= 8.0 ELC C= 0 ELC D= 0 C: ELC B= N/A				

Morrissey et al (2017), Australia. E: 28 children / 1 ELC C: 28 children / same school as E.	Cross-sectional	Sociodramatic play episodes Observation (2 independent researchers) using the Dramatic Play Data Collection Tool. The following play behaviours were coded: - Play themes or roles were identified as present or absent in the episode: fantasy, domestic, occupational, conventional superhero or other. - Frequencies of object substitutions - Frequencies of imaginative transformations - Frequencies of explicit metacommunications used to plan and organise play Additional contextual information was also collected	Fantasy Domestic Occupational Superhero Other Relationship between sociodramatic play variables and context. Object substitutions Explicit metacommunication Imaginative transformations	E: 10 / C: 4 E: 8 / C: 15 E: 1 / C: 3 E: 2 / C: 0 E: 0 / C: 2 $\chi 2 = 21.71$, $p < 0.001$ $\chi 2 = 10.04$, $p < 0.01$ $\chi 2 = 6.63$, $p < 0.05$		There were significant associations between object substitutions, explicit metacommunication and imaginative transformations and the yard type (natural versus traditional). Children from the natural playground engaged in longer episodes of sociodramatic play episodes compared to children from the traditional playground and were more likely to engage in object substitutions, explicit metacommunication and imaginative transformations.	▲ ▲ ▲	Weak

Study details / Sample size	Study Design	Outcome and measurement	Units	Baseline or one time point (cross-sectional)	Follow-up (if applicable) or mean difference	Summary of Findings	Effect Direction	Quality Rating
Types of natural elements								
Zamani (2013), USA. 36 children / 1 ELC	Cross-sectional (mixed-methods – thesis)	Cognitive Play Behaviour mapping - assesses individual cognitive play in the different zones. Children are observed for 7 days in 12 observation sessions during recess (11.30am and 4.15pm - lasted 45 minutes). The researcher scanned each zone and repeated for 4 rounds per recess. Childs location, gender, ethnicity, behaviour setting type, physical elements, cognitive play behaviour and teacher interactions were recorded. Each child was observed for 10 seconds and recorded for 20.	% time in play categories Functional Constructive Exploratory Dramatic Games with rules Functional Constructive Exploratory Dramatic	**Natural:** Within = 30.7; withinCog= 27.5 Within = 8.1; withinCog= 47.2 Within = 12.8; withinCog= 45 Within = 37.1; withinCog= 40.2 Within = 3.1; withinCog= 3.1 x= 281.70, 4*** **Mixed:** Within = 35.2; withinCog= 35.2 Within = 4.5; withinCog= 29.1 Within = 10.9; withinCog= 42.7 Within = 26.8; withinCog= 32.5 Within = 13.9; withinCog= 62.1		All zones mainly afforded functional play opportunities. The natural zone afforded higher levels of dramatic, exploratory and constructive play compared to the other zones.	N/A	Weak

			Games with rules Functional Constructive Exploratory Dramatic Games with rules	x= 201.46, 9*** **Manufactured:** Within = 44.2; withinCog= 37.3 Within = 4.3; withinCog= 23.6 Within = 3.7; withinCog= 12.3 Within = 26.7; withinCog= 27.3 Within = 6.8; withinCog= 25.7 x= 224.86 3***				

Abbreviations: E= experimental; C= control; n= number; ELC = early learning and childcare (includes preschools, day care, kindergarten etc.); SD= standard deviation; SE= standard error; CI= confidence intervals.

Effect direction explained:
▲: positive health impact
►: no change/ conflicting findings
▼: negative health impact
▲: positive health impact and statistical significance ($p<0.05$)
▼: negative health impact and statistical significance ($p<0.05$)
No arrow: no inferential statistics reported

Controlled before & after studies – difference between experimental and control group at follow-up (unless stated) or difference in change between experimental or control group. Uncontrolled before & after studies – change since baseline (unless stated). Controlled cross sectional – difference between experimental and control (unless stated). Cross-sectional – positive, negative or no association

Qualitative

Table 12. Findings from eligible qualitative studies			
Theme	**Sub-theme**	**Studies**	**Quotes**
Natural settings provide more affordances compared to traditional settings	Natural settings **enable** children to **diversify** their **play** (inc. imaginative, spontaneous, risky, manipulative, cognitive, exploratory and active play)	Dowdell et al (2011); Herrington & Studtmann (1998); Liu (2020); Puhakka et al (2019); Sandseter (2009); Wishart et al (2019); Zamani (2015).	*"The children also invent themselves; when they have stimulus for their eyes, children invent it [activity] without your help. And it should be like this; some part should be like this. But you need to have stimulus. It's not enough to have a brown yard and a climbing frame. So, it [green yard] added somehow; they definitely had good games. They pretended that they had a campfire, they got the stones as sand pretended that they were on a trip. And their imagination was in use there, and when children use their brains, natural tiredness arises, and it did them good, a lot of good. Then rest comes naturally, and you have a good appetite and we're in the positive cycle. So they could use their imagination, and we encouraged them. We didn't prohibit them, we just advised them not to rip anything." (Puhakka et al, 2019).*
	Natural settings **enable** children to engage in **high intensity physical activity**	Bjørgen (2016); Puhakka et al (2019).	*"High physical-motor levels are created, the children jump down and run back up. They talk, shout and laugh. Three of the girls jump together and try to land in differing ways. They hold hands and try to jump together from the small knoll. There is laughter. They are eager and enduring. The small knoll has many opportunities for variation, in height and width, which invite challenges suitable for each child's resources. The children have visual, verbal and physical contact with each other. The top of the knoll provides an overview. Some find it scary the first time they try, but together they challenge each other, supporting and encouraging each other. The children decide how much they will participate and how they jump, and how they wish to solve the challenges offered by the knoll" (Bjørgen, 2016).*
	Natural settings **afford** children with **higher levels of risk** compared to traditional settings	Sandseter (2009); Streelasky (2019).	*I like playing in the fallen logs and trees on the playground; it is so much fun, but a bit scary too! I like the big pile of sticks and logs that we made – it is for another fort that is going to be really high off the ground." (Streelasky, 2019)*

	Natural settings **afford** more variation (the space and elements) to support children to **use and increase their imagination and creativity**	Liu (2020); Streelasky (2019); Zamani (2015).	*"I like being outside with my friends. We make shelters and we make up different games, like getting trapped on an island, or being on a boat and making our escape! I like doing science outside too – like different experiments, especially when the sun is out." (Streelasky, 2019).*
	Natural settings **enable peers and teachers to interact differently**	Bjørgen (2016); Dowdell et al (2011); Liu (2020); Streelasky (2019).	*"The children are shouting 'X… can't you catch us? Please catch us, try to catch us …'. The staffs join the situation and run after the children. The children are shouting 'Catch me … can't catch me' … There is excitement and the staff are running after the children, catching them and holding them before releasing them. The staffs have high energy, the children focus on the adults, avoiding being caught. The adults show empathy, holding and hugging the child when it is caught. The game is exciting and creates enthusiasm. A high level of physical activity is created, by climbing up, sliding down, running around and hiding in the tower to escape capture by the adults. They run at high speed and the children's body language shows that they are very much engaged in the game" (Bjørgen, 2016)*
	Natural settings **increase child-initiated learning** and students perceiving themselves as capable learners compared to traditional settings	Dowdell et al (2011); Maynard et al (2013), Zamani (2015).	*"[CogG] has poor concentration, sees herself as the baby, finds it difficult to sit and listen to story. She is extremely lacking in confidence … shy … she won't look at you indoors. With child-led learning she is totally engrossed and remains on task. Outside is the best learning environment for her … she remains on task. When outside she will come over and say 'I like this' and 'I like doing that', 'this is my favourite place'." (Maynard et al, 2013).*
	Children have **increased contact with nature** enabling them to increase their knowledge of nature	Dowdell et al (2011); Liu (2020); Puhakka et al (2019).	*"Especially about the forest floor mat, I remember that our children kept asking, 'what is it' and 'what's growing there', and explored it very carefully; they were almost lying on their stomachs there. Especially the older ones, and they had a lot of questions about it." (Puhakka et al, 2019).*
Natural and traditional settings	**Movement types and intensity** similar across	Wishart et al (2019).	Not available.

provide similar affordances	natural and traditional spaces		
	Frequency of risky play is similar in both natural and traditional settings	Sandseter (2009)	Not available.
Children's preferences of setting types	**Natural environment** is more diverse and engaging and **preferred** by children compared to traditional settings	Bjørgen (2016); Streelasky (2019).	*"I like going outside and playing! I like playing with my friends, Sydney and Megan. We play hide and seek on the playground and hide in the forest in the logs and trees. I like outside because it's so fun and I really like to play. Sometimes I play with my sister too; I like all the colours outside and all the space." (Streelasky, 2019).*
	Mixed areas (combining both natural with traditional elements) are **preferred** by children	Zamani (2015).	Not available.
Restorative effect of nature		Liu (2020); Puhakka et al (2019),	*"Now it's become very difficult to finish playing. They would rather continue, and those who need to take a nap, they've had a nice, long time outdoors and nice games so they fall asleep more easily, and it affects their energy in the afternoon. Some children have very long days here. They come in the morning and stay until five o'clock; they seem to be somehow energetic and lively in the yard. This is new for us. The contrast to the previous yard is so great that the effects can be seen here very quickly." (Puhakka et al, 2019).*

Table of figures

social research

The views expressed in this report are those of the researcher and do not necessarily represent those of the Scottish Government or Scottish Ministers.

This document is also available from our website at www.gov.scot.
ISBN: 978-1-80004-767-9

The Scottish Government
St Andrew's House
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Produced for
the Scottish Government
by APS Group Scotland
PPDAS842066 (03/21)
Published by
the Scottish Government,
March 2021

GSR
GOVERNMENT SOCIAL RESEARCH
Social Science in Government

Social Research series
ISBN 978-1-80004-767-9

Web Publication
www.gov.scot/socialresearch

PPDAS842066 (03/21)