

## **How does nature support early language learning? A systematic literature review**

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### **Abstract**

The way a young child uses language has an impact on their future life. Early language acquisition is a determinant in adult employment, mental health and relationships with others. At the same time there is a broad evidence base that play and learning in the natural environment is beneficial for young children's physical, emotional, social and cognitive development. However, literature about how these two contributions to children's early development intersect and combine, in particular whether and how early language learning in children aged between 3-7 years might be enhanced in nature, is harder to find. For this paper, we undertook a systematic literature review to explore and report on research within this important area. Based on an in-depth study of 181 articles, we found that scant literature exists about how children's language is developed within natural environments. Although this appears to be a topic that is discussed in practice-oriented publications, it was found that very few researchers are focusing on and reporting within this area. Twelve papers were thoroughly analysed and three themes identified and discussed; desire to communicate, communication skills and literacy skills. This paper concludes by suggesting areas for future research.

**Key words:** nature, speech and language development, systematic literature review, forest school, natural environments, early childhood

### **Introduction**

It is widely reported that early language development has an impact on young children's holistic development (Richardson, 2019; Saxton, 2017; Hayes, 2016) and also on outcomes in later life (Law *et al.*, 2010; Clegg *et al.*, 2005).

At the same time as this recognition, there has been a considerable increase of international attention over the last decade given to a broad spectrum of benefits of play and learning within the natural outdoor environment (Dyment and Green, 2018; Green and Rayner, 2022). This attention intensified following the recent Covid-19 pandemic as much evidence points to the benefits of learning in nature from a health perspective as well as developmental viewpoint (Gomes *et al.*, 2021).

Nevertheless, there is a relative paucity of literature that focuses on intersections between nature and specific desired outcomes and very little literature combining early verbal language development and nature play and learning, and discussing how natural environments can benefit young children's speech and language development. We therefore set out to search the literature systematically for research that included these two elements, with a view to enhancing practice within this area and supporting language through nature-based programmes. Our research question was: what is known about how early language development and natural learning environments interact?

### **Rationale and key terms**

Children who display difficulties with speech and language within the early years can experience lasting effects into adulthood. In fact, children who have issues within this area at the age of five are one-and-a-half times more likely to be suffering with mental health issues at the age of 34 (Law *et al.*, 2010), and one third of these children's mental health issues will be severe enough to require medical treatment in later life (Clegg *et al.*, 2005). These same children also have reduced chances of employability, being twice as likely to be unemployed than their peers with normal language development (Law *et al.*, 2010).

International evidence indicates that, on average, around 6% of children across the globe between the ages of two and five, have difficulty within the area of speech and language development (Law *et al.*, 2000; Marshall and Lewis, 2013). The data within this area however is particularly difficult to analyse; the prevalence that is reported differs vastly within each country and can have a 22% differential within the same country (Wren *et al.*, 2016). McLeod and Harrison (2009) reported that between 16 and 22% of children would be diagnosed with a speech difficulty in Australia if they were to undertake an assessment at the age of 5. Canadian children presented with language impairments in 8.04% of the population (Beitchman *et al.*, 1986). Nigerian children have a prevalence of between 8 and 30% (Nwosu, 2015). Finnegan and Warren (2015) report that 23% of children within England are not at the expected level of speech and language and this is noticeably higher for those children living in poverty. The differential in international prevalence figures may stem from variable definitions of difficulty, the extent to which speech and language difficulties are reported, and the sampling processes that have been adopted (Wren *et al.*, 2016; Nwosu, 2015). These methodological issues may distort estimates of prevalence, however, if 6% of children are estimated conservatively to have a problem with speech and language development worldwide, this equates to 132 million children throughout the world (UNICEF, 2014) and therefore demands significant attention. Although this was a motivation for our study, we wanted to focus on how atypical language development was supported within nature rather than focusing on responses to perceived deficits.

Bronfenbrenner (1979) recognised the importance of the environment for children's development and it has subsequently been acknowledged that young children's overall development differs depending on the environment within which they are situated (Hughes, 2010). This equally applies to speech and language development (Neaum, 2012). It has been established that both the environment and the interactions that occur within that environment are crucial

elements that impact upon a child's development (Sutterby and Frost, 2006; Bruce, 2004). However, it is the natural environment that was the focus of this review and how this environment impacts on early language development. Early Years settings recognise the importance of natural environments for young children's development and research into forest schools show them to be beneficial for learning and development (O'Brien and Murray, 2006). For the purpose of this study, a natural environment is that which is defined as that which is naturally occurring, using natural resources and that which fosters a relationship with the natural world (Wellings, 2012).

Natural outdoor play and learning environments, although contested terms, have continued to build on the pioneering work of Macmillan (1919) who highlighted the importance of natural outdoor play for children to be able to improve developmentally and improve overall health and well-being. Pretty *et al.* (2009) assert that, in addition to the well documented physical benefits, natural environments enable children to develop a deeper knowledge and understanding of their environment, develop socially and enhance behaviour strategies. Self-esteem levels are also reportedly enhanced by having access to a natural environment (Pretty *et al.*, 2009; Swarbrick *et al.* 2004; Richardson, 2014). Although it could be argued that each of these areas of development are intrinsically linked to speech and language development, it appears that very little literature exists that considers the impact of nature on speech and language development per se (Dockrell *et al.*, 2015), and this systematic literature review therefore set out to explore this area specifically. The wider context for our review is an ERASMUS + project, Early Language Development in Nature (ELaDiNa), with partners in Slovenia, Germany and Sweden, which is developing a model and training to support practitioners in this field (ELaDiNa, 2020).

We looked for relevant research with children aged 3 to 7 years old, speaking their main home language. This purposeful selection was also the focus for the ELaDiNa (2020) project in recognition that most children within this age range are able to speak using a level of language that is understandable and therefore analysable, making practices more visible and comparable. Halliday (1975:262) reports that at around the age of 30 months a child 'makes the crucial discovery that, with language, he can both observe and interact with the environment at the same time'. It is therefore asserted that by the age of 36 months, children should be using language at a level that is appropriate to be assessed. At this age they should also be playing and learning within different environments; indoor classrooms, outdoor classrooms, natural environments.

This paper discusses the findings from this extensive literature search in relation to the points raised above and our research question. The section that follows outlines the materials and methods used.

## **Materials and Methods**

### Protocol

Our systematic review of literature followed the PRISMA guidelines (PRISMA, 2020). This ensured that all five academics participating in the review had clear expectations for the process with consistent inclusion and exclusion criteria.

Studies were included in the review if they reported on influences and effects on language development in natural outdoor contexts. The focus age group was 3-7 years, but it was decided that studies close to this range would be included. As well as these inclusion criteria, through discussion, we decided that studies focused on language in older children or adults, acquisition of a second language, special educational needs, concerned with home learning environments, or those that did not specifically address skills linked to language development, should not be included.

The search covered the period from 01/01/2000 to 31/12/21.

### **The process of the systematic literature review**

Petticrew (2001) suggests that the main objective of a systematic literature review is to remain unbiased and to maintain transparency throughout and this was a driver at all times. Although there is no definitive process in performing a systematic literature review (Lame, 2019), we felt that a staged approach with regular monthly meetings would help ensure rigour and transparency. The three stages we adopted are discussed below.

#### Stage one

The initial search process was divided amongst all five members of the team according to various combinations of the agreed terms, and the following databases used to search for peer reviewed research:

- ERIC Education Resources Information Centre (Proquest)
- EBSCO
- PsycINFO
- Directory of Open Access Journals
- Sage
- Scopus
- Web of Science
- Google Scholar (first 20 pages) (to pick up grey and practitioner-focused literature)

Initially the search was undertaken using the title, abstract and keywords of an article and the terms shown in the table below were used, combining the first term with various combinations of subsequent words using "AND" to capture the maximum results.

First term	AND....	AND....
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Early Childhood	Language development	Nature
Early Years	Oracy	Natural Environments
Pre-school	Literacy	Biodiversity
Nursery	Vocabulary	Affordance
Kindergarten	Elaborated language	Green space
Young children	Communicat*	Outside
Infant	Speaking	Wild*
Foundation	Expressive	Outdoor
	Utterances	Forest school
	Listening	Woodland

Table 1: Key words and word combinations used in literature search

The team adopted an inclusive approach to this search, meaning if in doubt a paper was included (Okoli and Schabram, 2010). Our initial searches yielded a total of 181 papers which appeared to meet the inclusion criteria from perusal of the title and abstract. The papers found were added to a shared spreadsheet that enabled the team to avoid the duplication of articles within this list from the different search combinations of terms. Following discussion at our regular meetings, we agreed that we had met a saturation point and no further new papers were likely to be found; the stopping rule was therefore applied (Levy

and Ellis, 2006). The first stage of the process was deemed successful in identifying all possibly relevant literature.

Following this, two reviewers examined each paper in more detail to determine if it indeed met the parameters for inclusion, in line with recommendations by Gomersall *et al.* (2015). Partners were varied throughout the process and papers authored by one of the team were reviewed by another two to minimise bias. Each paper was independently looked at by each partner. If there was disagreement in opinions, a decision was reached through discussion during our meetings. If it was still unclear whether a paper should progress to the next round, the whole team reviewed the article and a general consensus was reached. This approach supported consistency throughout the process. 51 papers met the criteria and were passed to stage two.

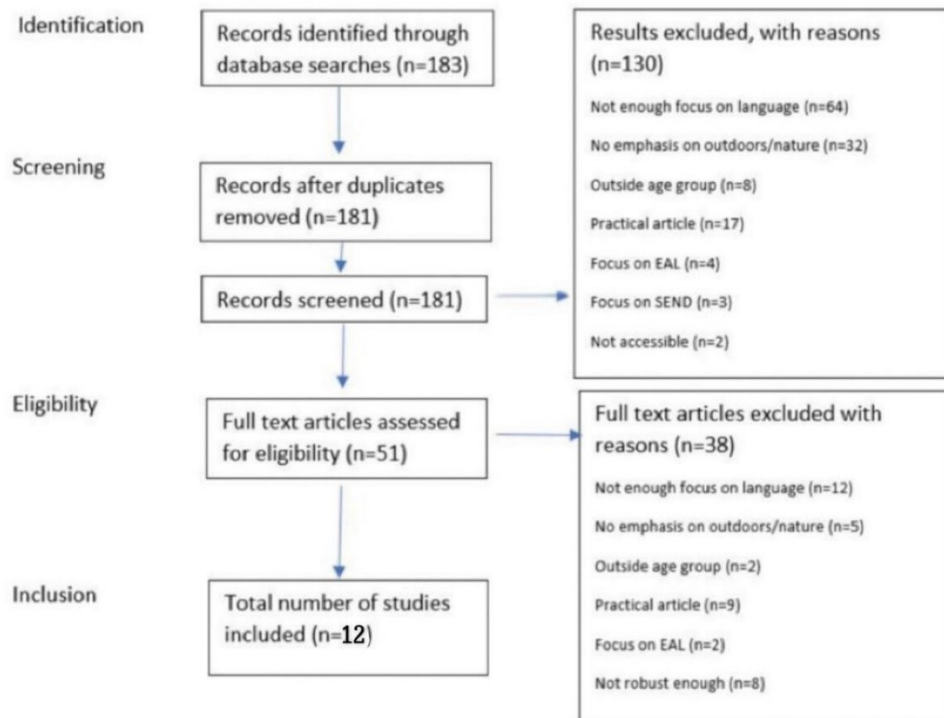
### Stage two

The 51 papers that made it to stage two were analysed using established critical appraisal tools; either JBI critical appraisal checklist for qualitative research (Joanna Briggs Institute (JBI), 2020) or the Quantitative Research Assessment Tool (Child Care and Early Education Research Connections (CCEERC), 2022).

At the outset, we discussed what scores would signal that papers might be acceptable to be included in the final systematic review. It was decided that our measure of 'quality' needed to be organic rather than a numerical threshold given the paucity of literature in this field and would be determined through ongoing conversations as issues emerged through the application of these tools to the selected articles.

When analysing the papers, it was noted that neither the CCEERC tool nor JBI was suitable for assessing literature review articles. Although they are sometimes excluded from systematic reviews, we decided that good quality literature reviews should be included as they provided summaries of relevant insights beyond the dates we had determined and so helped augment the small pool of relevant articles available for this topic. We also took account of the positioning of primary research within the literature as a crucial aspect of its quality whether they were quantitative or qualitative studies.

The 51 papers were distributed amongst the research team with two reviewers allocated to each paper. They were analysed for quality using the tools discussed and further explored to ensure they fit the parameters of the study. Through detailed discussion, it was decided to pass 12 papers to the final review stage to report on in depth as these fitted the parameters of the study and were sufficiently methodologically robust. The 39 papers that did not pass through at this stage were omitted due to insufficient focus on language development or the natural environment, or serious flaws in terms of the quality of the evidence presented. Although not all of the remaining 12 papers scored particularly highly on the appraisal tools, it was decided that due to the limited literature available that all these 12 papers should be reviewed in depth. Our staged approach is shown in further detail in figure 1 below:



Footnote: English as an additional language (EAL), Special Educational Needs and Disability (SEND)

The characteristics and the findings from these papers will now be reported in the section that follows.

### **Potential impacts of nature: a variety of studies**

Only 12 papers were identified as being relevant and robust enough for reporting in this review. Of these 12, four were researched and authored in Canada, four in United Kingdom, three in United States of America and one in Sweden. 9 were qualitative in nature and 3 used mixed methods. It is recognised that there can be 'hazards' when combining qualitative and quantitative studies in one review (Xiao and Watson, 2019:104) however the analysis of quality shown below was applied in percentage terms (see table two, final column) to give a comparable set of data. As previously mentioned, the absolute quality of reports was deemed less important than relevance to the topic given the small number of studies. Table two below provides the details of the 12 papers that made it through to the final stage for review.

Reference	Country	Methodology	Key words/phrases	Sample	Environment in which study took place	Relevance	Findings	Quality rating tool and score
Bucholz, B.A. & Pyles, D.G. (2018) Scientific Literacy in the Wild: Using Multimodal Texts in and out of School. The Reading Teacher Vol. 72, No. 1, Access (July/August 2018), pp. 61-70.	USA	Qualitative, ethnographic		28 kindergarten students and their two teachers	Zoo with birds	The focus is on learning of practicing informational oral and written language in contrast to narrative storytelling and on using language in a scientific manner. The artifact used is an Aviary guide with scientific information that is used before, during and after a study visit at a zoo.	The conclusion is that teachers can support development of scientific literacy through "rich literacy practices intertwined with learning sciences, over a length of time, with multiple, varied, and scaffolded uses of an authentic, out-of-school learning experience."	JBI 15 out of 20. 75%
Canning, (2013). "Where's the bear? Over there! - creative thinking and imagination in den making. Early Child Development and Care, 183(8), 1042-1053. <a href="https://doi.org/10.1080/03004430.2013.772989">https://doi.org/10.1080/03004430.2013.772989</a>	England	Qualitative	creative thinking; children's play; den making; outdoor environment	5-8 children, 3-4 year olds	Woodland a short walk from the nursery	The relevance is low because language development is "hidden". Language is weakly discussed - stronger focus on creativity and play.	Findings are presented as six conversations extracts (for me it looks like "raw" material) between children and between author and teacher. Four extracts from conversations between children while playing and two extracts from discussions with teachers. The discussion is about how: Children found ways to use the woodland environment to fulfil curiosity, motivation, and creative thinking. (I) Children's play space and the outdoor environment. (II) Social interactions and children's communication and (III) Practitioners' responses to children's ideas. In the conclusions the paper return to imaginative play in the woods.	10 out of 20 JBI score. 50%
Flannigan, C. and Dietze, B. (2017) Children, outdoor play and loose parts. Journal of Childhood Studies, 42(4), pp. 53-60.	Canada	Qualitative	Outdoor play, loose parts, early childhood development, unstructured play, natural environment s, play development	27 x 4-5 year olds	"A rural outdoor natural environment" An outdoor play green space at the front of daycare building	There is no real substantiated evidence to support the claims around language development – it all feels rather tenuous and circumstantial. Although it does mention the impact on language dev.	* The outdoor environment provides a rich context that supports children in developing language and communication skills. * A peaceful area surrounded by nature and free of background noise can motivate children to express themselves. * Children can use their voice in a variety of ways, including pitches and volumes, without the usual constraints imposed in the indoor environments. * The addition of loose parts in an outdoor environment provides further language development through the use of unfamiliar objects, new experiences, and the array of play possibilities.	JBI, 6 out of 20. 30%
French, L. (2004) Science as the Center of a Coherent, Integrated Early Childhood Curriculum Early Childhood Research Quarterly, 19(1), 138-149.	USA	Mixed methods	Science Start; early childhood curriculum; Coherent	357 preschool under 4 in multiple cohorts between 1995-2002 tested	variety of indoor and outdoor contexts	the use of indoors and outdoor contexts weakens its relevance but teachers & parents positive about vocabulary acquired and its transfer to other situations	narrative assessment showed statistically significant increases. Peabody is standardised and increases not expected in short term, yet mean standard score rose from 79 to 87 (p<0.001), however some confounding of teacher & condition so cannot be attributed to the intervention. Author concludes that "children need to be in an environment that is both experience-rich and language-rich. An experience-rich environment	QRAT 5 out of 10. 50%. Neither checklist fitted well with study



Hackett et al. (2021) Reconceptualising early language development: matter, sensation and the more human. <i>Studies in the cultural politics of education</i> , Vol. 2 (6), 913-929	UK	Qualitative (backed up with data from two ECaT scores from two cohorts of children)	Early childhood; language; more-than-human; Deleuze; posthumanism	Ethnographic study in day care centre with 28 2-year-olds	Two (?) different outdoor environments	The qualitative data presented is rather limited, giving examples from a few children only. The qualitative data are supported by ECaT scores from two cohorts of children (before and after intervention), but these quantitative data are not well analysed ("increase in scores... appears to indicate"). Furthermore, study is described as ethnographic.	fuels development by providing events and materials that can be comprehended, represented, and further processed by the child, extensive opportunities for self-directed exploration, and adult support in interpreting experience. The intervention of moving part of the daily routines outdoors to a teepee appeared "to have been a marked change in the children's language practices". After moving outdoors "nearly all children were speaking during 'teepee time'". Children scored higher across all four categories on ECaT (Every Child a Talker) assessments. Researchers mean that educators' task is to "create the conditions where talking as a bodily, as well as a linguistic act feels comfortable, easy and right." Situations with many possibilities but little obligation to talk, "coupled with and avoidance of trying to pin down the intended audience and function for talk, are some possible conditions for this". According to the authors this might mean "paying less attention to words, grammar and meaning, in favour of fostering participation in dynamic, multisensory, collective events".	JBI checklist did not fit well with this study
McVittie, J. (2018) Sensuous and languaged learning: Children's embodied and playful connections to nature. <i>The International Journal of Early Childhood Environmental Education</i> , 6(1), pp.21-34.	Canada	Qualitative	Early Childhood, environment, embodied learning, play, nature	11-30 children aged 2.5-5 years experienced with outdoor play & 2-4 day care staff	Natural garden within day care setting	Focus of paper is on embodied experiences of children – written in a way that very much focusses on senses and feelings in the body. Identified themes being: close sensory observation of the world, language in learning and emotion in play. Language therefore one of three themes.	Language discussion focuses on interactions with adults and peers – the need for social interaction. Talks of sharing learning. It also focuses on how children share their feelings without the use of words.	JBI score – 18 out of 20. 90%
Miller, D. (2007) The Seeds of Learning: Young Children Develop Important Skills through Their Gardening Activities at a Midwestern Early Education Program. <i>Applied environmental education and communication</i> , 6(1), 49-66.	USA	Qualitative	Keywords missing in paper. Suggested: Garden based learning, key skills, case study, preschool, kindergarten	19 teachers and documentation of 169 students (kindergartens and preschoolers) (3-6?)	greenhouse in outdoor garden	Language/literacy is one of 7 key skills presented in the paper including: <ul style="list-style-type: none"> <li>• recognizing and using symbols</li> <li>• naming</li> <li>• telling stories</li> <li>• spelling</li> <li>• reading</li> <li>• creating pledges, poems, songs</li> <li>• conversing with other children and adults</li> <li>• recognizing that print has meaning/is verbal language translated into written form</li> <li>• practising letters, forming words, formatting them on the page</li> </ul>	The results are rather vague in its description of language development in nature. Motivation and rich experiences are what is highlighted as factors promoting language development. (A teacher noted (p. 62) that outdoor experiences can provide the motivation needed for activities promoting literacy. "Both examples illustrate that gardening activities can serve as a link to literacy.")	JBI score 13 out of 20. 65%

Moffatt, (2016). Start with a Seedling: Uncovering the Kindergarten Language and Literacy Curriculum One Leaf at a Time. <i>Language &amp; Literacy</i> (Kingston, Ont.), 18(3), 89–105. <a href="https://doi.org/10.20360/G2RC84">https://doi.org/10.20360/G2RC84</a>	Canada	Qualitative	Kindergarten , gardening, food, mandated curriculum, language and literacy, environment al	24 Kindergarten children (aged 4-5 years) paired with 17 "garden buddies" (volontairs)	kindergarten classroom, a community garden	This study can be relevant, but one limitation is that it doesn't specify outdoor activities. The study informs theories of how literacy learning is constructed in local contexts - but not with special light on nature itself.	Findings show evidence, by counting language incidents and by excerpts, that the program supported significant pieces of the mandated kindergarten language and literacy curriculum.	JBI score 10 out of 20. 50%
Norling, M., & Sandberg, A. (2015). <i>Language Learning in Outdoor Environments: Perspectives of preschool staff</i> . Nordisk barnhagoforskning, 9. <a href="https://doi.org/10.7577/nbf.749">https://doi.org/10.7577/nbf.749</a>	Sweden	Qualitative	Language learning, outdoor environment , preschool	questionnaires to 165 preschool staff, 55 focus groups (2-6 participant, n= 165) & 6 months later second round of 47 focus groups (n=138)	Data obtained through teachers about role of outdoor environment in language development, analysed through latent content analysis	Identification of how preschool teachers perceive outdoors as stimulating language learning.	Emergent themes: <b>play</b> 'children play in different groups and with other peers than otherwise' without toys; <b>other activities</b> , little distinction between inside and outside but comment ' It is the environment that inspires language'; <b>pedagogical dialogue</b> , teachers said they talked with children about what they see e.g. weather; <b>interaction</b> (between children of different ages), with fewer <b>loud games</b> ; and; <b>freedom</b> , perceived as more peaceful but sometimes adults too far from children to support their language. Conclusion: 'The outdoor environment provides endless opportunities for metacognitive conversations in which language is constantly challenged'	JBI score 18/20. 90%
Richardson, T. (2014). <i>Speech and Language Development in a Forest school environment: An action research project</i> . SAGE Research Methods Cases Part 1	England	Mixed methods	children, communication, early years, education, ethics, forest school, natural environment s, outdoor play, parents, self-esteem, speech and language	5 children 3-4 year-old	quantitative baseline assessment was undertaken followed by a post-assessment after the 8 weeks of a <b>forest school</b> intervention. Semi-structured interviews with parents and keyworkers. Focus group for children using photos of the children's activities in the forest school.	'can a natural environment make a difference on speech and language?'	overall improvement of all areas of speech and development (clarity of speech, a range of vocabulary, listening, and attention skills have improved. The most significant improvement in speech and language development was shown in the area of social communication: 80% were ahead of development ). Suggests "the natural forest school environment, had enabled children to develop their speech and language skills in a positive manner." Quotations from children indicated that adult interaction "were a pivotal aspect in their memories, and therefore their verbal recollection of the experiences."	JBI score 17 out of 20. 85%
Richardson and Murray (2017) Are young children's utterances affected by characteristics of their learning environments? A multiple case study. <i>Early Child</i>	UK	Mixed methods	Learning environment development ; outdoor play; forest schools;	Small scale-case study involving four 4-5-year-olds	Data from three different learning environments – an indoor classroom, an outdoor classroom, and a natural environment	Covers natural environments and language development explicitly	Type/Token ratio analysis showed that: a) Lexical diversity was richer in the natural environment for three out of four children; b) Verb usage was higher for all four children in the natural environment; c) Exclamation usage was higher for three of four children in the natural environment; d) Noun usage was higher for two of the four children in the two classroom environments. Thematic	JBI score 20 out of 20. 100%

<p><i>Development and Care</i>, Vol. 187 (3-4), 457-488</p>	<p>Canada</p>	<p>Qualitative</p>	<p>children's everyday literacy lives, curriculum, language arts, multimodalit y, narrative, pedagogy, outdoor education, forests, environment s, kindergart en</p>	<p>15 x 5-6 year olds</p>	<p>Indoor</p>	<p>Not overly relevant – study focuses on children's drawings as a means to share experiences and drawings showed that children were most interested in natural outdoor environments</p>	<p>analysis of transcripts from voice recordings showed that children's excitement and enjoyment were more evident in the natural environment. The authors conclude that their findings "support an argument that children's experiences in natural environments affect the quality of their SL development more positively than their experiences in indoor and outdoor classrooms, and present a number of likely reasons for this. Paper explores children's views and preferences about their school environment, using multi-modality. Argued that this research method develops literacy and communication about the natural outdoors.</p>	<p>JB I score 16 out of 20. 80%</p>
<p>Sundberg, B., Sofie Arelljung, Karin Due, Kenneth Ekström, Christina Ottander &amp; Britt Teilgren (2018) Opportunities for and obstacles to science in preschools: views from a community perspective. <i>International Journal of Science Education</i>, 40:17, 2061+2077.</p>	<p>Sweden</p>	<p>Qualitative</p>	<p>early years/early childhood, qualitative research, teacher beliefs, activity theory</p>	<p>observations with video recording and fieldnotes in 14 preschools (children majority aged 3-6), video recall sessions and individual semi-structured interviews with staff</p>	<p>Physical contexts not well described but it appears very little of the activity analysed takes place in nature</p>	<p>how cultural factors interact with teachers' shaping of science activities in preschools but focus on cultural rather than natural influences and focus predominately on science.</p>	<p>Three types of setting identified. Type I : children are afforded purposefully framed learning opportunities offering content knowledge, a scientific vocabulary, sensory experiences and discussions of clearly defined phenomena' p2071 / Type IIa: 'Science learning opportunities are seen instead as something to be 'caught in the moment', when the children show an interest in, or explicitly ask questions about, something that is connected to science.' p2071/ Type IIb: 'common desire to provide the children with science learning opportunities, however, with different views of how.' Conclusion: 'to afford children with visible science learning opportunities, a strong community has to be combined with an educational culture in which child-centred activities are linked to a teacher-led focus on the science content.'</p>	<p>JB I score 16/20. 80%</p>

Of the 12 papers reviewed, only four (Richardson, 2014; Richardson and Murray (2017); Norling and Sandberg, 2015; Hackett *et al.*, 2021) intentionally discussed language development in nature. The other eight papers mentioned language development as a by-product of their research study. Three of the four papers focused on language development *per se* set out to explore the impact of nature on language development in children directly (Richardson, 2014; Richardson and Murray, 2017; Hackett *et al.*, 2021, while the fourth (Norling and Sandberg, 2015) offered adults' perspectives of the effect of outdoor environments on language. This is depicted in figure two below:

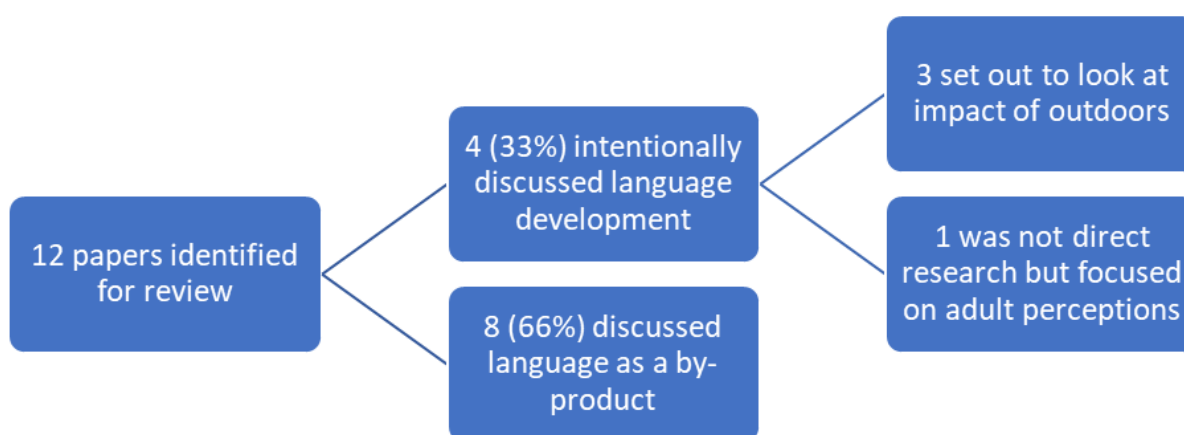


Fig.2: The relevance of articles to overall review

Through thematic analysis (Braun and Clarke, 2006) the following initial codes and subsequent themes were identified:

Code	Papers claiming this to be a benefit of their study	Total number of papers within code	Theme
Recognising and using symbols	Miller (2007)	1	Literacy skills
Naming, range of vocabulary	Bucholz and Pyles (2018) Flannigan and Dietze (2017) French (2004) Miller (2007) Richardson (2014) Streelasky (2019)	8	Communication skills

	Richardson and Murray (2017) Moffatt (2016)		
Telling stories	Canning (2013) Miller (2007)	2	Literacy skills
Spelling	Miller (2007)	1	Literacy skills
Reading	Miller (2007)	1	Literacy skills
Creating pledges, poems, songs	Canning (2013) Hackett <i>et al.</i> (2021) Miller (2007)	3	Literacy skills
Conversing with adults and children	Bucholz and Pyles (2018) French (2004) McVittie (2018) Miller (2007) Norling and Sandberg (2015) Richardson (2014) Moffatt (2016)	7	Communication skills
Recognising that print has meaning	Miller (2007)	1	Literacy skills
Clarity of speech	Richardson (2014)	1	Communication skills
Listening	Richardson (2014)	1	Communication skills
Attention skills	Richardson (2014)	1	Communication skills
Increased motivation	Hackett <i>et al.</i> (2021) Norling and Sandberg (2015) Richardson and Murray (2017)	3	Desire to communicate
Rich experiences	Flannigan and Dietze (2017) Canning (2013) French (2004) Hackett <i>et al.</i> (2021) Norling and Sandberg (2015) Moffatt (2016) Richardson and Murray (2017)	7	Desire to communicate

Table 3: Codes and themes identified and prevalence of codes

Table 3 above indicates that through the thematic analysis process three themes were identified; the desire to communicate (with 10/37 code occurrences), communication skills (with 18/37 code occurrences), and literacy skills (with 9/37 code occurrences). These themes will now be discussed further in the section that follows.

### **Desire to communicate**

With 10/37 code occurrences in this theme, the theme around a desire to communicate was a substantial finding of this systematic literature review. 6 of

the 12 papers reported that the desire to communicate could be enhanced within a natural environment. Richardson and Murray (2017) point to several reasons for the positive effects of natural environments; there are fewer boundaries and deeper involvement in open-ended play, natural environments lead to greater excitement and enjoyment of their surroundings, there are better opportunities to experience activities in smaller groups, encouraging social interaction rather than passive learning and there is enhanced sensory learning. French (2004) concurs with their argument that 'children need to be in an environment that is both experience-rich and language-rich. An experience-rich environment fuels development by providing events and materials that can be comprehended, represented, and further processed by the child and..... includes ample opportunities for authentic communication with adults and the adults' (French, 2004:147). Hackett *et al.* (2021) tested this theory and found that the intervention of moving part of the daily routine outdoors to a tepee appeared 'to have been a marked change in the children's language practices' (Hackett *et al.*, 2021:918). Previously many children, when indoors, were silent, but after moving outdoors 'nearly all children were speaking during "tepee time"' (Hackett *et al.*, 2021:918).

Norling and Sandberg (2015) also recognise the importance of an environment which inspires language however at the same time recognise that this can be difficult to define. What was noted by Norling and Sandberg (2015) was that the space that is afforded to children in a natural environment can result in adults being too far away to support language learning in the way that can be done indoors and adults may become more passive when in a natural environment as they do not see it as formal learning as they would in an indoor classroom environment.

This lack of adult engagement can be seen as a benefit however of play and learning in an outdoor, natural environment. Hackett *et al.* (2021) suggest that reducing the performance expectations that many children experience when communicating in formal contexts by relocating outdoors can free up their use of language and increase utterances by restoring lively movement of language through bodies. This 'incidental' support for language while the focus may be on other learning or play within nature is a common theme across several papers (Hackett *et al.*, 2021; Flannigan and Dietze, 2017; Richardson and Murray, 2017). This serendipitous side effect may be particularly valuable for children who are hesitant to speak in class because there is less pressure to 'perform'. It seems to be linked to the natural environment offering authentic and material reasons for communication, where children wish to enact desires, ideas and emotions and need to speak, engage in dialogue and extend their vocabulary to explain these to others.

This review found that curiosity appears to play a pivotal role in supporting language development in the natural environment (Canning, 2013; Moffatt, 2016) and contributes to the rich experiences that the environment provides. Flannigan and Dietze (2017), through a study exploring the addition of loose parts to a natural environment, argue that awe and wonder can be used to enhance language through the use of provocations, they state:

The outdoor environment provides a rich context that supports children in developing language and communication skills. A peaceful area

surrounded by nature and free of background noise can motivate children to express themselves. Children can use their voice in a variety of ways, including pitches and volumes, without the usual constraints imposed in the indoor environments. The addition of loose parts in an outdoor environment provides further language development through the use of unfamiliar objects, new experiences, and the array of play possibilities.

Flannigan and Dietze, 2017:57

This theme within this systematic literature review provides evidence that natural environments can provide increased motivation and a rich experience for children to develop their language skills. It is asserted that this is probably one of the most important aspects when encouraging speech and language development as in order to progress in this area, a child will need to be motivated, they will need to be inspired and they will need an environment that provides the rich experiences to promote this. Once this has been instilled then can come the communication skills, which will be discussed further in the section that follows.

### **Communication skills**

The skills needed to communicate, such as the ability to pay attention, to listen, to make speech sounds and then to communicate with others are recognised as the building blocks to receptive language (Hayes, 2016). Throughout this literature review 10 out of the 12 papers found the natural environment to be beneficial to the development of these skills. 8 papers noted that by engaging in nature, it gave children the chance to expand their vocabulary. This vocabulary increase occurs, it is argued, due to the exposure to new context-specific words and experiences such as that which Bucholz and Pyles (2018) discuss through the use of illustrated bird guides or, as Moffatt (2016) suggests comes through exposure to new experiences. When considering vocabulary benefits, Richardson (2014) and Richardson and Murray (2017) note that vocabulary usage differs within different environments, with the natural environment elucidating greater usage of verbs, more exclamation and richer lexical diversity

Giving children the vocabulary enables children to share their learning (Streelasky 2019), their emotions (Miller, 2007) and their experiences by communicating with others (Moffatt, 2016), engaging in conversation (Richardson, 2014) and in turn expanding vocabulary. This conversational benefit was highlighted by 7 out of the 12 papers. 58% of papers purported the benefits of engaging in natural environments to include more opportunities to communicate with adults and other children, and therefore enhancing language development accordingly. This finding paradoxically contradicts the point made in the section above that noted that children benefited from the distance between themselves and close adult supervision. It could be argued that when considering the theme above, the desire to communicate, that this is best done with space and freedom as is suggested above, but once this desire is instilled then the children need the support of others to continue to develop further.

Richardson (2014) asserts that 80% of the children within her study were seen to improve in their social communication skills, suggesting that 'the natural

environment, and the experiences offered by a forest school environment, had enabled children to develop their speech and language skills in a positive manner' (Richardson, 2014:10). Quotations from children indicated that adult interactions 'were a pivotal aspect in their memories, and therefore their verbal recollection of the experiences' (Richardson, 2014:11), again highlighting the need for the support of others within the environment. French (2004) concurs, recognising that children are learning vocabulary best when children are active learners who construct knowledge through participation in hands on experience with adult support and that teachers and parents provide positive reinforcement around new vocabulary acquired and its transfer to other situations. Although McVittie's (2018) study emphasised the importance of embodied learning, this paper also recognised the need for social interactions with adults and peers to share learning and scaffold accordingly.

It is important that children have secure language skills before they are able to confidently read and write and develop the key literacy skills required. The section that follows will discuss how the theme of literacy manifested itself throughout this review.

### **Literacy skills**

Although literacy skills were not recognised throughout the papers as frequently as the other themes (with 9/37 code occurrences), it is important to report on this theme as it was an element that was found to impact on children's language development in nature. Miller (2007), in particular, noted the natural world to be a positive influence on language skills through the development of skills regarding naming, telling stories, spelling, reading and the formation of words. When studying pre-schooler's learning during hands on outdoor activities, children were designated 'plant doctors' (Miller, 2007:55) with a view to increasing ownership of the natural space. This in turn, according to Miller (2007), resulted in improved literacy skills, which she argues allows 'children to communicate what they know in a very different way than they might in a traditional classroom' (2007:64). Canning (2013) and Hackett *et al.* (2021) also assert that the use of storytelling and rhymes in a natural environment can prompt imagination and creativity, enhancing conversation and language usage. These papers therefore recognise the importance of the natural environment to support children in a holistic manner and argue the need to consider all environments when planning for learning and development.

### **Discussion**

The aims of the twelve papers were varied but all selected papers shed some light on the potential impacts of natural environments on language development. Emphasis includes bridging gaps between out of school and in school experiences (Bucholz and Pyles), the role of loose parts/den making (Flannigan and Dietze, 2017), supporting more child-initiated experiential learning as factors that encourage motivation (Miller, 2007), creativity and imaginative engagement with the environment that in turn appears to stimulates a desire to express feelings (McVittie, 2015), thinking, intentions and actions, and communicate these to others. This diversity in focus highlights that research specifically examining early language development in nature is very scarce indeed.



Streelasky's study (2019) provides support for the often-assumed view that the natural environment is an interesting site about which children wish to express and communicate their preferences and feelings. Nature play is seen as a means of stimulating communication between children. Norling and Sandberg (2015) asked preschool teachers about their use of the natural environments as a stimulating language learning environment and found that most opportunities for language learning mentioned were about interaction between peers outside and that teachers were often either too far away to extend the potential for language development or unaware of possibilities. Nevertheless, playing games outside, the open-ended nature of natural features and opportunities for conversations about natural phenomena seemed to encourage children's talk. Norling and Sandberg (2015) also suggested that the freedom of natural spaces seemed to allow children more choice in how they interacted. They propose that adults scaffolding children's exploration with questions might further expand children's understanding.

The novelty that is provided by change and loose parts encourages language development to express new discoveries (Flannigan and Dietz, 2017). It is also suggested that the larger spaces in nature also promote a spectrum of possible voice pitches from loud to very quiet that might not be achievable inside classrooms (Norling and Sandberg, 2015). Several studies (Buchholz and Pyles, 2018; French, 2004; Moffatt, 2016) point to the fact that Science can be a valuable vehicle for developing language, harnessing children's curiosity about the natural world and how things grow through hands-on activity in gardens or other natural environments. French (2004), for example, in her article evaluating the ScienceStart! Curriculum, comments that language as a medium for conveying information is foundational to all academic subjects. She notes that children's innate curiosity about the world around them through hands-on direct exploration outside the classroom in planned play in nature, can be supported by teachers' expansion upon their questions through interactions, building their knowledge of grammar, vocabulary and academic language alongside scientific skills.

Norling and Sandberg (2015) state that teachers attribute the impact of natural environments on language to greater opportunities afforded for freedom and space for children to play and interact with others, including adults, to support dialogue. In most of the included studies, the adult support is oral, for example French (2004) suggests that adults can help children to understand and build upon language and knowledge from personal discoveries in nature in a language, and experience rich, environment. Buchholz and Pyles (2018), however, use an illustrated bird guide to support children's identification and accurate naming of birds and Streelasky (2019) suggests children's drawings of nature can help to mediate expression in language by children.

Although the aims and the outcomes of the papers are all so different, what they all agree on is the need for the natural environment to promote language development in some way, be it by instilling the desire to communicate, developing communication skills or through enhancing literacy skills, all of which, it is argued, are important skills for maximising an individual's wellbeing and life chances.

*Implications for practice*

In several papers (n=8), it seems that the link to positive language development outcomes is made retrospectively. Nevertheless, an analysis and increased awareness of associated factors that have resulted in these outcomes may enable teachers to use these factors skilfully to achieve multiple beneficial outcomes for children. As this review has highlighted it is paramount that educators instil into children the desire to communicate, providing a language rich environment that supports, encourages and nurtures children within this area. By providing children with provocations and to create awe and wonder, by giving the space to talk in a non-threatening manner and by allowing children to wallow in their play and their environment this will then lead to a situation where children feel confident to communicate socially and develop the vocabulary needed to do so. It is important that educators establish these building blocks so that children can then flourish when it comes to the development of literacy learning.

### *Implications for further research*

We found in our systematic search for literature about early language development in nature, that there was very little available research specifically focused on language development in nature. The term *natural environment* in the language development field tended to refer to the home/family environment and not to natural outdoor environments such as forests, meadows, rivers, etcetera. The studies selected included some reference to language development in nature but often only as a side effect of another focus.

Given the fundamental importance of language to mediate other beneficial life chances, and the valuable role that nature appears to play in supporting language, further research with this specific focus is warranted. Greater attention to the pedagogies associated with nature would also help to explain the processes and what specific qualities of the natural environments that are beneficial for different aspects of language development.

### **Strengths and limitations of the review process**

As the research team were situated in various Higher Education Institutions (HEIs) in both England and Sweden, slight differences existed between the database systems across institutions and countries. It could be said that this was a limitation of the study; however, we would argue that this strengthens our review as it widened our net and yielded more initial search results. Our different assigned keyword combinations and library systems frequently identified the same articles; potential duplication was eliminated by entering results on a shared spreadsheet. This helped to ensure that we were not missing anything nor double counting, and aligned the resultant hits across institutions.

We set out a written protocol for the process before we began but part of our intention was to explore issues with systematic reviews that can result in a very small number of acceptable articles for synthesis. This is particularly problematic and constraining when the research topic is under researched. We therefore decided to meet to discuss the process on a monthly basis reflecting on our findings thus far. This enabled reflection on action and in action (Schon, 1991) and was a strength of the study for it allowed the team to discuss the way forward at regular intervals and make any sensible adjustments to the process, whilst ensuring the systematic and transparent nature of the review was maintained.

It is noted that all papers studied children speaking English as a first language and although this provides a comparable set of research papers, it could be argued that this is a limitation of this study. Conversely however, it is recognised that language development is a universal concept (Saxton, 2017) and therefore should not impact on the findings. Also the systematic literature review process did not highlight papers that researched with children speaking languages other than English, hence indicating an additional gap in the research.

Although the research team did not include any quantitative research experts, the peer review system for publishing articles and the detailed guidance of the QRAT checklist helped mitigate this limitation of our study. In the event, out of the final 12 papers, none were solely quantitative in nature.

## **Conclusion**

This systematic literature review has found that there is very little available research which focuses on the importance of engaging in nature in order to enhance speech and language development. Given the issues around speech and language development, we would argue that this is an area that urgently needs further research.

## **References**

Beitchman, J., Nair, R., Clegg, M., and Patel, P. (1986) Prevalence of speech and language disorders in 5 year old kindergarten children in the Ottawa Carleton region. *Journal of speech and hearing disorders*. **51**(1), pp.98-110.

Braun, V. and Clarke, V. (2006) Using thematic analysis in psychology. *Qualitative Research in Psychology*. **3**(1), pp.77-101.

Bronfenbrenner, U. (1979) *The ecology of human development: experiments by nature and design*. London: Harvard University Press.

Bruce, T. (2004) *Developing learning in early childhood*. London: Sage publications.

Bucholz, B.A. and Pyles, D.G. (2018) Scientific Literacy in the Wild: Using Multimodal Texts in and out of School. *The Reading Teacher*. **72**(1), pp. 61-70.

Canning, N. (2013). "Where's the bear? Over there!" - creative thinking and imagination in den making. *Early Child Development and Care*. **183**(8), pp.1042–1053. <https://doi.org/10.1080/03004430.2013.772989>

Child Care and Early Education Research Connections (CCEERC) (2022) Quantitative research assessment tool. [online] Available from: Research Assessment Tools | Research Connections (cceerc.net) [Accessed 11<sup>th</sup> October 2022].

Clegg, J., Hollis, C., Mawhood, L. and Rutter, M. (2005) Developmental language disorders – a follow up in later adult life. *Journal of psychology and psychiatry*. **46**(2), pp.128-149.

Dockrell, E. J., Bakopoulou, I., Law, J., Spencer, S., & Lindsay, G. (2015) Capturing communication supporting classrooms: The development of a tool and feasibility study. *Child Language Teaching and Therapy*. **31**(1), pp.271–286.

Dyment, J., and M. Green. (2018) Everyday, Local, Nearby, Healthy Childhoodnature Settings as Sites for Promoting Children's Health and Well-Being. In: *Research Handbook on Childhoodnature: Assemblages of Childhood and Nature Research*, edited by A. Cutter-Mackenzie, K. Malone, and E. Barratt Hacking, pp.1155–1180. Singapore: Springer.

ELaDiNa (2020) ELaDiNa - Early Language Development and Nature Project. [online]. Available from: [Cšod - ELaDiNa project \(www-csod-si.translate.google\)](http://www-csod-si.translate.google) [Accessed 21<sup>st</sup> March 2023]

Finnegan, J. and Warren, H. (2015) *Ready to read: closing the gap in early language skills so that every child in England can read well*. London: Save the Children Fund.

Flannigan, C. and Dietze, B. (2017) Children, outdoor play and loose parts. *Journal of Childhood Studies*. **42**(4), pp. 53-60.

French, L. (2004) Science as the Center of a Coherent, Integrated Early Childhood Curriculum. *Early Childhood Research Quarterly*. **19**(1), pp.138-149.

Gomersall, J., Jadotte, Y., Xue, Y., Lockwood, S., Riddle, D. and Preda, A. (2015) Conducting Systematic Reviews of Economic Evaluations. *International Journal of Evidence-Based Healthcare*. **13**(3), pp. 170–78.

Gomes, J., Almeida, S.C., Kaveri, G., Mannan, F., Gupta, P., Hu, A. and Sarkar, M. (2021) Early Childhood Educators as COVID Warriors: Adaptations and Responsiveness to the Pandemic Across Five Countries. *International Journal of Early Childhood*. **53**(1), pp.345–366.

Green, M. and Rayner, M. (2022) School ground pedagogies for enriching children's outdoor learning. *Education 3-13*. **50**(2), pp. 238-251. DOI: 10.1080/03004279.2020.1846578

Hackett, A., MacLure, M. and MacMahon, S. (2021) Reconceptualising early language development: matter, sensation and the more human. *Studies in the cultural politics of education*. **2**(6), 913-929. DOI: <https://doi.org/10.1080/01596306.2020.1767350>

Halliday, M. (1975) *Learning how to mean*. London: Edward Arnold.

Hayes, C. (2016) *Language, literacy and communication in the early years*. Northwich: Critical Publishing.

Hughes, F. (2010) *Children, play and development*. London: Sage publications.

Joanna Briggs Institute (JBI) (2020) JBI critical appraisal checklist for qualitative research. [online] Available from: EMT Report (jbi.global) [Accessed 11<sup>th</sup> October 2022].

Lame, G. (2019) Systematic literature reviews: an introduction. *International Conference on engineering Design*. Delft: Netherlands.

Law, J., Rush, R., Schoon, I. and Parsons, S. (2010) Modelling developmental language difficulties from school entry into adulthood. *Journal of speech, language and hearing research*. **52**(1), pp.1401-1416.

Law, J., Boyle, J., Harris, F., Harkness, A. and Nye, C. (2000) Prevalence and natural history of primary speech and language delay: findings from a systematic review of the literature. *International journal of language & communication disorders*. **35**(2), pp.165-188.

Levy Y. and Ellis T. (2006) A Systems Approach to Conduct an Effective Literature Review in Support of Information Systems Research. *Informing Science Journal*. **9**, pp. 182-212.

Macmillan, M. (1919) *The nursery school*. London: J.M. Dent and Sons.

Marshall, J. and Lewis, E. (2013) 'It's the way you talk to them.' The child's environment: early years practitioners' perceptions of its influence on speech and language development, its assessment and environment targeted interventions. *Child language teaching and therapy*. **30**(3), pp.337-352

McLeod, S. and Harrison, L. (2009) Epidemiology of speech and language impairment in a nationally representative sample of 4 to 5 year old children. *Journal of speech, language and hearing research*. **52**(1), pp.1213-1229.

McVittie, J. (2018) Sensuous and languaged learning: Children's embodied and playful connections to nature. *The International Journal of Early Childhood Environmental Education*. **6**(1), pp.21-34.

Miller, D. (2007) The Seeds of Learning: Young Children Develop Important Skills through Their Gardening Activities at a Midwestern Early Education Program. *Applied environmental education and communication*. **6**(1), pp.49-66.

Moffatt, L. (2016). Start with a Seedling: Uncovering the Kindergarten Language and Literacy Curriculum One Leaf at a Time. *Language & Literacy (Kingston, Ont.)*. **18**(3), pp. 89–105. <https://doi.org/10.20360/G2RC84>

Neaum, S. (2012) *Language and literacy for the early years*. London: Learning Matters.

Norling, M., & Sandberg, A. (2015) Language Learning in Outdoor Environments: Perspectives of preschool staff. *Nordisk barnehageforskning*. **9**. <https://doi.org/10.7577/nbf.749>

Nwosu, N. (2015) Systemic review of the prevalence of speech and language disorders in Nigeria. *International journal of humanities and social science*. **5**(5), pp.130-133.

O'Brien, L. and Murray, R. (2006) *Forest school: a marvellous opportunity to learn*. Forest Research: Social and Economic Research Group.

Okoli C. and Schabram, K. (2010) A Guide to Conducting a Systematic Literature Review of Information Systems Research. *Sprouts: Working Papers on Information Systems*. **10**(26).

Petticrew, M. (2001) Systematic reviews from astronomy to zoology: myths and misconceptions. *British Medical Journal*. **322**(7278), pp.98-101.

Pretty, J., Angus, C., Bain, M., Barton, J., Gladwell, V., Hine, R., Pilgrim, S., Sandercock, G. and Sellens, M. (2009) *Nature, childhood, health and life pathways*. Interdisciplinary Centre for Environment and Society Occasional Paper 2009-02: University of Essex.

PRISMA (2020) PRISMA: Transparent reporting of systematic reviews and meta-analyses. [online] Available from: PRISMA (prisma-statement.org) [Accessed 11<sup>th</sup> October 2022].

Richardson, T. (2014) *Speech and language development in a forest school environment: an action research project*. London: SAGE Research Methods Cases. [online] Available from: <http://srmo.sagepub.com/view/methods-case-studies-2013/n342.xml> [Accessed 2<sup>nd</sup> April 2016]

Richardson, T. and Murray, J. (2017) Are young children's utterances affected by characteristics of their learning environments? A multiple case study. *Early Child Development and Care*. **187**(3-4), pp.457-468

Richardson, T. (2019) Children as communicators. In: Fitzgerald, D. and Maconochie, H. (eds.) *Early Childhood Studies: A student's guide*. London: Sage Publications.

Saxton, M. (2017) *Child language: acquisition and development*. 2<sup>nd</sup> ed. London: Sage Publications.

Schon, D. (1991). *The reflective practitioner: How professionals think in action*. Aldershot: Ashgate Publishing Ltd.

Streelasky, J. (2019) A forest-based environment as a site of literacy and meaning making for kindergarten children. *Literacy*. **53**(2), pp.95-101.

Sutterby, J. and Frost, J. (2006) Creating play environments for early childhood: indoors and out. In: Spodek, B. and Saracho, O. (eds) *Handbook of research on the education of young children*. 2<sup>nd</sup> ed. Mahwah NJ: Lawrence Erlbaum Associates.

Swarbrick, N., Eastwood, G. and Tutton, K. (2004) Self-esteem and successful interaction as part of the forest school project. *Support for learning*. **19**(3), pp.142-146.

UNICEF (2014) *The state of the world's children 2014 in numbers*. [online] Available from: <https://www.unicef.org/sowc2014/numbers/> [Accessed 19<sup>th</sup> December 2016]

Wellings, E. (2012) *Forest school national governing body business plan 2012*. Cumbria: Institute for outdoor learning.

Wren, Y., Miller, L., Peters, T., Edmond, A. and Roulstone, S. (2016) Prevalence and predictors of persistent speech sound disorder at eight years old: findings from a population cohort study. *Journal of speech, language and hearing research*. **59**(1), pp.647-673.

Xiao, Y. and Watson, M. (2019). Guidance on Conducting a Systematic Literature Review. *Journal of Planning Education and Research*. **39**(1), pp. 93–112. <https://doi.org/10.1177/0739456X17723971>

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This work is entirely theoretical, there is no new data underpinning this publication and the way that the existing data was analysed is detailed at length in the paper.