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Trees, forests, and recycled paper: art–science approaches to ecological understanding in Northern Finland

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ABSTRACT

The escalating environmental concerns highlight the need for educational approaches that engage children with ecological relations in everyday environments. The integration of art and science can connect learners with natural processes through experiential and multimodal practices. This study examines how children articulated ecological understanding through embodied, material, and imaginative engagement in art–science integrated activities during a 'Nature and Science' summer camp in Northern Finland. The camp was situated in a forest-rich region where forests are integral to everyday life and debates on sustainability and resource use. The study draws on art-based action research, in which artistic activity functions as both pedagogy and research data. The analysis approaches learning situations as embodied, material, and collaborative processes in which artworks and interpretations developed through activity. The camp included recycled papermaking, sensory forest activities, and exploration at a science center. Data included observations, children's artworks, field notes, photographs, and teacher interviews. The analysis identified three recurring forms of articulation: (1) sensory encounters with forest environments, (2) the transformation of recycled paper through collaborative making, (3) connections described across activities during interdisciplinary exploration. Ecological understanding developed through engagement with materials, places, and activities, as pupils connected experiences across forest exploration, recycled papermaking, artistic creation, and science-center investigations. The children's artworks and reflections referred to continuity, renewal, vulnerability, and care, while positioning themselves as participants, protectors, and co-inhabitants in relation to forest environments. The findings show how art–science activities can support children's ecological meaning-making through material engagement, imagination, and interdisciplinary exploration.

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1. Introduction

The escalating global environmental crisis has intensified discussions within environmental education research concerning how children come to know and understand forest environments and ecological processes. Environmental education has long sought to foster human–environment relations. However, contemporary childhood is increasingly shaped by urbanized and technologically mediated environments in which sustained and sensory engagement with natural environments is limited. This situation has been described as an 'extinction of experience' (Beery et al. 2023, 473), highlighting a decline in embodied and affective encounters with nature that are central to ecological understanding and care (Whitburn, Abrahamse, and Linklater 2023). When children's understanding of ecological processes is limited or remains disconnected from lived experience, environmental issues may be perceived as abstract concepts. This disconnection can reduce opportunities to develop a sense of responsibility, care, and agency in relation to environmental challenges. For this reason, environmental education increasingly emphasizes learning experiences that support meaningful engagement with local environments and ecological processes.

Forests are places where ecological, social, and cultural meanings intersect. In Northern Finland, they function as everyday landscapes that are closely connected to local livelihoods, biodiversity conservation, and debates concerning sustainability and resource use. The coexistence of these multiple and sometimes conflicting roles makes forests particularly relevant contexts for exploring how children come to understand ecological processes and human–environment relations. Industrial forestry has contributed to biodiversity loss, while debates surrounding forest protection influence how forests are understood and valued by communities, families, and children. These tensions make forests significant sites for exploring how children come to understand ecological processes, environmental responsibility, and human–environment relations. Recent research has increasingly emphasized embodied, experiential, and affect-oriented approaches that support children's engagement with specific environments through direct interaction (Hallam, Gallagher, and Owen 2022; Whitburn, Abrahamse, and Linklater 2023). In this study, affect-oriented approaches refer to the emotional and relational dimensions of children's engagement with environments.

Within environmental art education, artistic processes have long been used to engage with natural environments through sensory, material, and place-based interaction (Jokela, Hiltunen, and Härkönen 2015). These practices emphasize direct encounters with materials and sites, supporting forms of learning that emerge through perception, manipulation, and reflection (van Boeckel 2013). While scientific approaches contribute knowledge about ecological systems and environmental processes, artistic practices offer opportunities for sensory engagement, imagination, and interpretation. Integrating science and art can support ecological understanding by connecting conceptual knowledge with embodied and personal experience, enabling learners to engage with environmental phenomena from multiple perspectives. In the forest, art-based activities invite attention to textures, material transformations, and ecological interdependencies. Forest-based outdoor activities further support embodied engagement by offering open-ended contexts for play, experimentation, and collaboration (Huhmarniemi and Lande 2025; Whitburn, Abrahamse, and Linklater 2023). In this

study, art is approached as a material and interpretive practice through which children engage with trees, fibers, soil, and water in situated learning activities. Drawing on perspectives from environmental art education and arts-based learning (Eisner 2002; Inwood 2008), interpretive practice in this study refers to the ways children make meaning from environmental experiences through observation, material engagement, artistic creation, and reflection.

This article examines how children articulated ecological understanding through embodied, material, and imaginative engagement in forest-based art–science practices. Ecological understanding is approached as a situated process through which children make sense of ecological processes, material cycles, and connections between forest environments and everyday life (Desmarais 2024). Empirical material derives from an art-based action research project conducted during a 'Nature and Science' summer camp in Northern Finland, forming part of an ongoing multi-cycle longitudinal study on interdisciplinary education (Zhang and Hiltunen 2025; Zhang and Huhmarniemi 2026). The research question is: How did children articulate ecological understanding and their own roles in relation to forest environments through embodied, material, and imaginative engagement in art–science activities?

2. Research and the theoretical background

This study is situated at the intersection of environmental education and art–science integrated learning. Environmental education provides the broader context, while art–science integration offers a pedagogical approach that combines scientific inquiry with artistic exploration. Visual art contributes sensory, material, and interpretive dimensions to environmental learning. The following sections outline the perspectives informing the analysis.

2.1. Art–science integration in environmental education

In environmental and sustainability education, visual art practices have increasingly been approached as pedagogical practices that support learners' engagement with ecological issues through sensory, emotional, and participatory forms of learning (Ison and Bramwell-Lalor 2023). Dewey (1934) described aesthetic experience as learning grounded in human–environment interaction, where perception, emotion, and action are integrated through direct engagement with the world. Eisner (2002) extended this idea by emphasizing how artistic processes support perception, interpretation, and meaning-making, which is central to the present study's focus on learning through engagement with environmental phenomena. Research in environmental and art–science education highlights the role of artistic practices such as drawing, creative work with natural materials, and visual reflection in supporting experiential and inquiry-oriented learning. These practices enable learners to engage with materials, observe processes, and develop interpretations through making and reflection (Barone & Eisner, 2012; van Boeckel 2013).

In these fields, interdisciplinary approaches have become increasingly important for connecting artistic, scientific, and environmental ways of knowing (Perignat and Katz-Buonincontro 2019). Art–science approaches combine scientific observation

with artistic exploration and are often associated with interdisciplinary or phenomenon-based learning organized around real-world processes (Sochacka, Guyotte, and Walther 2016). Within these contexts, artistic practices function as ways of investigating and interpreting environmental processes (Glass and Wilson 2016; Marshall 2014), including attention to transformation and material change (Kewalramani and Veresov 2022; Macdonald, Malone, and Firth 2022). Visual art practices introduce interpretive, imaginative, and affective dimensions that enable learners to engage with ecological phenomena in personally meaningful ways. In this sense, art provides opportunities to explore ecological relationships through sensory experience, creative interpretation, and emotional engagement, extending approaches that rely primarily on scientific explanation alone. Research emphasizes that the educational value of art depends on pedagogical framing, task openness, and the degree of agency afforded to learners (Cremin and Chappell 2021; Illeris 2016). In art–science integrated settings, visual arts practices such as drawing support observation, material engagement, and the investigation of environmental processes and transformations (Sochacka, Guyotte, and Walther 2016; van Boeckel 2013). These processes are linked to creativity as a dimension of learning, where artistic practices provide opportunities for situated meaning-making through engagement with materials, environments, and experiences.

In art–science integrated environmental learning, interdisciplinary approaches are further developed through place-based and experiential pedagogies (Inwood 2008; Jokela, Hiltunen, and Härkönen 2015). Visual arts have been closely associated with environmental education that emphasizes place-responsive and materially situated learning (Jokela, Hiltunen, and Härkönen 2015; van Boeckel 2013). Within these place-responsive approaches, artistic practices support situated engagement with materials and experiences. Artistic activities such as drawing and creative work can support observation and interpretation of environmental phenomena. Children's drawings, when emerging from open-ended and exploratory processes, function as visual articulations of environmental experiences and understandings (Hiltunen, Kallio-Tavin, and Sohlman 2021). Previous research has identified challenges within art–science integrated environmental education. Interdisciplinary projects may privilege scientific content, and connecting creative activities with deeper ecological understanding remains a continuing challenge (Perignat and Katz-Buonincontro 2019).

2.2. Embodied and multimodal perspectives on learning

Learning in environmental and art–science contexts is closely connected to embodied and multimodal processes (Anttila 2015). Understanding develops as learners engage with materials, environments, and situations through sensory experience and participation (Thomas Jha and Price 2022). Artistic practices such as drawing, making, and collaborative experimentation open up ways for learners to work across visual, verbal, and bodily modes (Wright 2010). Through this engagement, learning begins to take shape in relation to materials and environments, as perception and action become intertwined in the exploration of phenomena (Ingold 2013). Bodily movement and material manipulation support this process by enabling learners to encounter and make sense of phenomena through direct experience (Wilson 2002).

As learners move within and across these modes, meaning develops through continuous shifts between perception, action, and representation (Kewalramani and Veresov 2022). Multimodal engagement allows learners to revisit and reorganize their experiences, gradually forming more complex understandings through interaction with materials and environments (Dunn and Wright 2014). In art–science integrated contexts, this process extends into inquiry, as learners begin to investigate and interpret phenomena through both artistic exploration and scientific thinking (Sochacka, Guyotte, and Walther 2016). Artistic and material practices support this development by creating opportunities to test ideas, reconsider observations, and explore alternative interpretations (Guyotte et al. 2014). Through this engagement, attention is directed toward processes such as transformation, causality, and material change as they emerge in practice (Hadzigeorgiou, Fokialis, and Kabouropoulou 2012).

As the learning process develops through engagement with materials, experiences, and environmental phenomena, imagination becomes increasingly significant in shaping how learners engage with and interpret phenomena. Through this development, engagement extends beyond immediate perception, as learners explore possibilities and form connections between materials, experiences, and ecological processes (Vecchi 2010). In this process, meaning-making involves the reinterpretation of phenomena through narrative, transformation, and personal experience (Beghetto 2010). Through the interplay of perception, action, and imagination, interpretations emerge that are grounded in experience while remaining open to new possibilities (Thomas Jha, Price, and Motion 2020). Embodied and multimodal perspectives frame learning as a dynamic process shaped by interaction, inquiry, and imaginative engagement in art–science contexts (Anttila 2015). Embodied and multimodal perspectives guide the analysis of how children make sense of ecological phenomena and inform the design of the summer camp activities. Forest exploration, recycled papermaking, drawing, and science-center investigations engaged children through sensory, visual, and verbal modes, encouraging movement between observation, material experimentation, artistic expression, and discussion.

2.3. Developing ecological understanding in place-based art–science learning contexts

Ecological understanding has become an important concern in environmental education as contemporary environmental challenges increasingly require learners to understand relationships between human activities and ecological systems (Stone and Barlow 2005; United Nations 2015; Vesterinen and Ratinen 2024). Recent studies have highlighted the role of situated and experiential engagement in supporting children's ecological understanding (Kiviranta et al. 2024). Place-based perspectives contribute to ecological understanding by connecting learning to specific environments, local experiences, and material encounters. From this experiential and place-based perspective, ecological understanding is examined as developing through engagement with place, materials, and ecological processes (Inwood 2008; Jokela and Coutts 2018). Participation in environmentally situated activities enables direct encounters with seasonal change and material transformation (Huhmarniemi 2023;

Jokela, Hiltunen, and Huhmarniemi 2019). Ecological understanding is also closely connected to broader aims of sustainability education (UNESCO 2017).

Art–science perspectives guide the examination of how children interpret ecological processes through engagement with materials and environments (Perignat and Katz-Buonincontro 2019). Arts-based and material-oriented pedagogies support ecological understanding by fostering sensory and imaginative engagement with ecological phenomena through visual and tactile practices that cultivate attentiveness and care. Ecological learning concerns how learners connect everyday experiences with broader environmental processes through situated activities (Thomashow 1996). In this study, the analytical focus is placed on how such connections are articulated through children's engagement with materials and environments in art–science learning situations. This study examines ecological understanding primarily through an art–science and embodied learning perspective. Place-based and multimodal perspectives provide complementary lenses for understanding how such processes develop in specific educational contexts.

3. Methodology

Art-based Action Research (ABAR) combines the cyclical structure of action research with creative and reflective practices (Jokela, Hiltunen, and Härkönen 2015; Jokela, Hiltunen, and Huhmarniemi 2019). Emerging from Finnish community and environmental art education, it links artistic practice with educational and social development across school and ecological contexts (Jokela, 2019). It has been described as a collaborative process integrating art, participatory action, and place-based learning through iterative cycles of planning, creation, and reflection. In a previous ABAR cycle using bilberry-based pigments (Zhang and Huhmarniemi 2026), pupils explored color changes and expressed them visually, demonstrating the learning potential of natural material experimentation.

In this study, ABAR operated as a mode of knowledge production in which artistic activity generated the research material, guided interpretation, and shaped the progression of the research process. This was realized through artistic practice functioning simultaneously as pedagogy, data production, and an analytical process. Artistic practice shaped the learning activities, generated visual and material data through pupils' creative work, and informed the interpretation of these expressions during analysis. Children's artworks were approached as interpretive material through which ecological understanding became visible, and interpretations developed through attention to visual, material, and interactional processes. Art was conceptualized primarily as children's visual and material making, including drawing and recycled papermaking. The study was conducted in forest environments because forests constitute an important local environment in Northern Finland and provided opportunities to examine ecological understanding through direct engagement with natural materials. The study followed a cyclical process in which pedagogical planning, artistic activity, and reflection informed one another. Zhang worked in a dual role as educator and researcher, allowing pedagogical decisions to be shaped by children's actions, material engagements, and emerging meanings.

3.1. Data collection and analysis methods

Data collection employed arts-based research methods (Leavy 2009, 2017) combined with qualitative inquiry, incorporating visual, verbal, and observational materials. The dataset consisted of 34 children's drawings, photographs, field notes, and reflective records documenting workshop activities, outdoor explorations, and material experimentation. Semi-structured interviews were conducted with four participating teachers to explore pupils' engagement, interdisciplinary collaboration, and the integration of art and science practices. All procedures followed TENK (2019) ethical guidelines. Written informed consent was obtained from 31 guardians, and participant anonymity was ensured throughout the study.

An inductive content analysis was conducted, grounded in an arts-based research framework (Barone & Eisner, 2012) and informed by visual methodologies (Leavy 2017). The analysis focused on how children expressed creative and ecological understanding through artistic and sensory processes. Attention was given to the pupils' use of texture, color, and material transformation in their artworks. Visual data were examined through a process of close looking, adapted from Manarin's (2018) approach to close reading and extended to visual materials. The analysis integrated observational notes, photographic documentation, and the pupils' verbal descriptions. A purposive selection of artworks was analyzed in depth to illustrate representative and diverse examples of learning through the creative process. To ensure credibility and trustworthiness, another researcher specialized in environmental education reviewed a subset of the data. Interpretations were discussed until agreement was reached on key themes. Methodological triangulation across visual, verbal, and observational sources (Denzin 1978; Patton 2002) strengthened the reliability and depth of the analysis. Three overarching analytical dimensions were identified: (1) sensory and affective engagement with natural materials, (2) the creative transformation of recycled resources into artistic expressions, (3) ecological understanding through interdisciplinary experience. Although these dimensions were informed by the organization of the camp activities, they served as analytical categories for examining recurring patterns in pupils' experiences, expressions, and interpretations across different data sources.

3.2. The research context and case study

In Northern Finland, forests play a central role in everyday life and in debates concerning sustainability and resource use. This action research cycle was implemented as a summer camp integrating arts, science, and environmental education. The camp aimed to support children's sensory engagement with forest environments and to explore ecological themes through material-based art–science practices. The first author collaborated with the LUMA Center Lapland, the Pilke Science Center, the Junnu Science Education Center, and pre-service teachers from the University of Lapland. A total of 34 children aged 7–9 and 5 teachers participated.

The camp comprised three phases (see Figure 1): forest-based sensory activities, collaborative papermaking and drawing using recycled materials, and interdisciplinary exploration at the Pilke Science Center. The participants were second- and third-grade pupils from local primary schools. Approximately 60% of the pupils had participated



Figure 1. The phases of the activities with the pupils in the summer camp.

in an earlier action research cycle involving embodied engagement with natural materials, which may have supported their familiarity with material-based exploration. At the beginning of the camp, the first author introduced themes related to trees, forests, and environmental art to establish a shared starting point for the activities.

4. Findings and analysis

The findings show how children articulated ecological understanding through the activities of the summer camp. Pupils expressed relationships with forest environments and positioned themselves through sensory, material, and creative engagement. Teachers supported these processes through open-ended prompts that encouraged observation, reflection, and discussion. The following sections explore how these understandings emerged through sensory engagement, material-based artistic practices, and interdisciplinary exploration.

4.1. Sensory and affective engagement with natural materials

The Nature and Science summer camp began with outdoor activities designed to cultivate children's sensory awareness and emotional connection with the natural environment. In the first phase, the pupils participated in forest games and the collective act of 'tree hugging' (see Figure 2). By touching bark and noticing shifting patterns of light and shadow, the pupils encountered the pine trunk through embodied sensory engagement with texture, leaves, air, and the surrounding forest environment. The teachers encouraged them to describe what they felt, heard, and saw. This approach prompts reflection on how trees and other living materials breathe, grow, and change.

During these activities, the pupils engaged in tactile and sensory exploration that supported the expression of affective and imaginative relationships with the forest environment. Within the encounter, the particular tree they held was articulated as a breathing being through the combined presence of touch, stillness, and shared language. The pupils noted how bark 'holds the warmth of the sun,' describing trees as responsive and meaningful beings. One pupil stated:

> The tree feels warm. It feels as if it is breathing slowly. When I put my arms around the trunk and stood still, I could feel the tree being alive in a quiet way, even though it was not moving like people do. (Pupil A)



Figure 2. Sensing the forest through the body. Photograph by Xiaowei Zhang, 2025.

The sense of the tree as living emerged through bodily contact with the bark, focused attention, and shared talk. These expressions were shaped by teachers' prompts, peer interaction, and moments of stillness that influenced what pupils attended to and expressed. Some pupils extended these encounters into imaginative possibilities, such as living 'with the animals in a tree house.' Forests were understood in multiple ways, including care, play, protection, and imaginative identification. These relations were situational and shaped by materials, tasks, and social interaction. The teachers similarly observed that sensory attentiveness accompanied more elaborated descriptions:

> When the children hugged the trees or stood still to listen, they didn't just describe what they saw. They started imagining how the forest feels and what it means to live among the trees. That sense of belonging made them more attentive and expressive. (Teacher A)

The teacher's observation situates the activity as a guided sensory encounter. Pupils were encouraged to attend to touch, sound, and stillness while working together around the trees. Talk, movement, and shared attention formed the conditions within which different ways of relating to trees were articulated during the activity. As they moved into creative work, many demonstrated greater care in handling materials, sensitivity to form and texture, and a desire to represent their relationship with the forest.

4.2. The creative transformation of recycled resources into artistic expressions

At the beginning of the papermaking activity, the teacher briefly introduced the connection between paper and trees. Pupils initially expressed this in simple terms, such as 'paper comes from trees.' The second phase focused on recycled papermaking and art creation (see Figure 3). Pupils collaboratively transformed discarded paper into new sheets through tearing, soaking, blending, and pressing. Through working with pulp, fibers, water, and pigment, they explored material transformation while discussing the relationship between trees, paper, and recycling. Pupils frequently referred to material origins and renewal, suggesting that recycling could support ecological continuity.



Figure 3. Exploring material transformation through recycled papermaking. Photograph by Xiaowei Zhang, 2025.



Figure 4. Cycles of decay and renewal. Photograph by Xiaowei Zhang, 2025.

The artworks produced in this phase reflected shared ecological orientations alongside varied emotional and imaginative responses. Many pupils represented forests, lakes, and animals as interconnected systems, often through references to seasonal change and continuity. One example is a drawing of a tree beside a lake (see Figure 4), which points to themes of endurance and renewal. During the storytelling stage, one pupil described it as:

> The tree looks bare, with only some yellow leaves at the tops, but it is not dead because when there is water and it stays there for a long time, the tree can grow again, even if it looks very quiet right now. (Pupil B)

The visual composition of the artwork and the pupil's explanation reflect a conceptualization of nature as dynamic and continuous. The tree was understood through processes of change. The pupil described seasonal transformation in terms of continuity.

Other pupils expressed ecological belonging and affective attachment through imaginative integration of humans and more-than-human life. In one drawing (Figure 5), a flowering branch rises between sea and land while children and animals coexist



Figure 5. The harmony of land, sea, and life. Photograph by Xiaowei Zhang, 2025.

in play. The composition conveys harmony and interdependence, where nature was described as dynamic within the drawing and storytelling encounter. This interpretation was further supported during the group discussion, when the pupil explained that:

> The branch grows in the middle because everyone can be together there. The animals and children are playing because the place is safe, and nobody is alone in nature, even if they are different. (Pupil C)

This explanation shows how the pupil framed environmental relations through ideas of togetherness, safety, and shared space. While this drawing emphasized togetherness and safety through images of play and shared space, other pupils expressed environmental concern through more action-oriented and dramatic narratives. Another drawing (Figure 6A) depicted a superhero protecting forest tree houses, presenting environmental care as both imaginative action and hopeful responsibility. The pupil who created the drawing explained:

> The superhero is there to help the trees because they cannot run away when something bad happens. The hero has to stay and protect the tree houses all the time because trees need someone to look after them when they are in danger. (Pupil D)

This explanation frames environmental care as an active and protective response to perceived vulnerability in the natural world. Meanwhile, another drawing shows a burning tree and a child attempting to extinguish the flames (Figure 6B), depicting urgency and empathy, showing awareness of ecological fragility and human agency.

The artworks show how pupils explored different meanings associated with forest environments through visual expression. Recurring motifs such as trees, animals, and



Figure 6. (A) Sky Island. (B) Acting to save the forest. Photograph by Xiaowei Zhang, 2025.

acts of care reflected different ways of engaging with ecological themes. Pupils positioned themselves in relation to the forest as participants, protectors, and co-inhabitants, with imagination extending engagement beyond direct perception and supporting narratives of coexistence and care. The transformation of recycled paper into artistic compositions further encouraged ideas of reuse, continuity, and ecological connection, demonstrating how ecological meaning-making developed through both experience and imagination.

4.3. Ecological understanding through interdisciplinary experience

The third phase of the camp took place at Science Center Pilke (see Figure 7), where pupils connected experiences across activities through interdisciplinary engagement with art, science, and environmental themes. When examining river water and discussing forest ecosystems, they linked these observations to earlier papermaking experiences. Wood fibers, water, and paper were understood as part of the same cycle, as pupils revisited prior encounters with fibers, pressing, and water. Comments such as 'The paper was trees before' and 'everything changes and comes back' indicate how cyclical transformation was articulated as a key ecological idea. This understanding extended into collaborative wooden block constructions, where many pupils created structures resembling 'forest villages,' exploring spatial organization and balance. Several pupils noted that the wooden blocks 'used to be trees,' linking construction materials back to the forest. These observations suggest that ecological understanding developed across activities through repeated engagement with materials.

A teacher further observed that moving between papermaking, water testing, and construction supported pupils in recognizing connections across natural processes.



Figure 7. Interdisciplinary exploration at the science center. Photograph by Xiaowei Zhang, 2025.

This phase highlighted how art–science integration enabled pupils to engage with ecological themes through experimentation, construction, and reflection. Pupils expressed their roles as makers, observers, and caretakers, indicating how participation in activities shaped their understanding of ecological processes. These expressions were also shaped by the pedagogical context, including guidance and shared expectations. Following Hackett et al. (2025), they can be interpreted as situated responses emerging through interaction and activity. From this perspective, ecological understanding appears as a process developing through embodied participation, material engagement, and collaborative interpretation.

5. Discussion

The discussion examines how ecological understanding developed through art–science and embodied learning processes in the camp activities. Ecological meaning-making emerged through pupils' sensory encounters with forest environments and their engagement with materials and peers. Touching bark, listening to sounds, and moving within the forest shaped how they noticed and interpreted ecological processes, supporting awareness of environmental relationships (Beery and Jørgensen 2018). As the activities developed, recycled papermaking extended these experiences through material transformation. Pupils connected changing materials with broader ecological ideas of continuity, renewal, vulnerability, and care. These findings suggest that ecological understanding in art–science contexts develops through the interplay of material engagement, sensory experience, and collaborative interpretation. Ecological learning emerged through direct encounters with nature and through opportunities to revisit and reinterpret ecological meanings across different materials and activities (Kewalramani and Veresov 2022; Thomashow 1996). This process deepened pupils' emotional and interpretive connections with environmental phenomena.

Engagement with ecological themes was closely connected to sensory, imaginative, and embodied encounters with the forest environment. Embodied learning research shows that understanding develops through interaction between perception and action (Anttila 2015). When pupils touched tree bark, listened to forest sounds, or described trees as 'breathing,' they expressed interpretations grounded in bodily

sensation and attention *in situ* (Hallam, Gallagher, and Owen 2022). The environment provided as an active setting shaping sensory and imaginative engagement. The forest functioned as an active source of sensory, material, and ecological experiences, allowing ecological meanings to emerge through direct engagement with local surroundings. Pupils moved between living trees and processed materials such as pulp and paper. This movement illustrates how meaning developed through engagement with materials and shifts between experience and representation (Ingold 2013; Kewalramani and Veresov 2022). During the papermaking activity, pupils adjusted their actions in response to the behavior of wet pulp, while their comments connected ideas about trees with material properties. Expressions such as 'the paper was trees before' referred to material origins and cycles. Through collaborative experimentation, prior knowledge was reworked as pupils interpreted transformation by handling fibers and observing change, highlighting the role of material engagement in understanding transformation processes (Barone & Eisner, 2012; Sochacka, Guyotte, and Walther 2016). While previous studies have highlighted the importance of embodied and multimodal engagement in environmental learning (Anttila 2015; Thomas Jha and Price 2022), the present findings provide a more detailed account of how ecological understanding developed through movement across different learning situations and material transformations. The study demonstrates how ecological meanings were revisited and reformulated through successive encounters with trees, fibers, paper, and forest-related systems.

The interdisciplinary activities at the science center extended these processes, as pupils explored connections among wood, water, and paper while engaging with ecological systems. The science-center exhibition introduced perspectives on forestry and sustainability within managed systems, complementing earlier sensory and creative engagements. Experiential and system-oriented perspectives were brought together, as pupils discussed knowledge, feelings, and responsibility, and meaning developed across different forms of representation (Wright 2010). In this context, interdisciplinary learning supported engagement across multiple modes of understanding (Perignat and Katz-Buonincontro 2019), and ecological understanding developed through interconnected experiential dimensions (Stone and Barlow 2005). A distinctive feature of this study was the way ecological understanding emerged across interconnected activities. Pupils revisited ecological ideas through forest exploration, recycled papermaking, artistic creation, and science-center investigations. These findings highlight the value of connecting multiple experiences within interdisciplinary environmental learning.

The study also draws attention to the role of pedagogical framing in shaping ecological understanding. Teacher guidance and task structure directed pupils' attention toward particular ecological themes while still allowing space for their own interpretations (Illeris 2016). Pupils positioned themselves in relation to the forest as participants, protectors, and co-inhabitants, suggesting that ecological understanding developed not only as knowledge of environmental processes but also as a relational way of locating oneself within ecological systems (Vecchi 2010). Although several common themes emerged across the activities, pupils did not approach ecological understanding in identical ways. Some emphasized sensory and affective relationships with trees and forest environments, whereas others focused on protection, coexistence, or material transformation.

The participant, protector, and co-inhabitant positions reflected different ways of relating to forest environments through exploration, responsibility, and coexistence. These positions suggest that ecological understanding involved both knowledge of environmental processes and relational ways of locating oneself within ecological systems. From a pedagogical perspective, this suggests the importance of designing learning environments that allow movement between exploration, making, and interpretation. This also points to challenges in supporting such open-ended and interpretive processes within structured educational settings, especially where curricular goals and assessment frameworks are more prescriptive. This tension points to the need for further research on how art–science approaches can balance guidance and openness while supporting meaningful ecological learning. The findings also invite critical reflection on the pedagogical design itself. The activities encouraged pupils to engage with forests through themes of care, coexistence, and sustainability. Some pupils also recognized that forests involve both care and use, suggesting an emerging awareness of balancing environmental protection with the use of natural resources. Broader issues related to industrial forestry and competing land uses received less attention, highlighting how pedagogical choices shape the ecological meanings available for learners to express.

Ecological understanding developed across interconnected activities. Pupils linked experiences of touching trees, transforming recycled paper, and exploring forest-related exhibits at the science center, indicating that ecological meaning-making emerged through repeated engagement across different contexts. This highlights how interdisciplinary art–science approaches structure the conditions under which ecological understanding develops in situated educational contexts (Perignat and Katz-Buonincontro 2019). One unexpected finding was the extent to which pupils connected experiences across activities and materials. These extend existing work on embodied and multimodal learning by showing how sensory, material, and imaginative engagement become intertwined in practice. This highlights the importance of designing learning environments that support both experiential engagement and interpretive depth. It also points to future research examining how these processes unfold over longer periods in educational contexts.

6. Conclusion

This study shows how ecological understanding and children's roles in relation to forest environments became visible in art–science learning situations. Pupils expressed this through engagement with materials, sensory experiences, and imagination, as well as through movement between different ways of interpreting the forest. These processes show how pupils interpreted ecological relations by connecting direct experience with broader environmental ideas and meanings. The findings further demonstrate how pupils reworked material processes in diverse ways during the activities. Their responses extended beyond repeating given information, taking shape as varied expressions of continuity, care, vulnerability, and coexistence through drawings, narratives, and collaborative interactions. This perspective contributes to environmental education research by examining how ecological understanding develops as a situated and interpretive process within art–science learning contexts.

Interdisciplinary art–science approaches supported connections between experience, interpretation, and ecological understanding. Ecological learning emerged as a situated and interpretive process shaped by engagement with materials, environments, and shared activity. Although grounded in a specific educational context, the findings may inform other art–science and environmental learning settings. They suggest the value of learning environments that support sensory engagement, creative exploration, and interpretation. A limitation of the study is its focus on a short-term educational intervention and specific learning activities. Future research could examine how these processes develop over longer periods and in different educational contexts.

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Author contributions

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References

Anttila, E. 2015. Embodied learning in the arts. In *International yearbook for research in arts education 3: The wisdom of the many—Key issues in arts education*, edited by S. Schonmann, 372–377. Waxmann Verlag.

Barone, T., & Eisner, E. 2012. "Arts-Based Educational Research." In *Handbook of Complementary Methods in Education Research*, edited by J. L., Green, J. Green, G. Camilli, P. B. Elmore, & P. Elmore, 95–109. New York, NY: Routledge.

Beery, T., and K. A. Jørgensen. 2018. "Children in Nature: Sensory Engagement and the Experience of Biodiversity." *Environmental Education Research* 24 (1): 13–25. https://doi.org/10.1080/13504622.2016.1250149.

Beery, Thomas, Anton Stahl Olafsson, Sandra Gentin, Megan Maurer, Sanna Stålhammar, Christian Albert, Claudia Bieling, et al. 2023. "Disconnection from Nature: Expanding Our Understanding of Human–Nature Relations." *People and Nature* 5 (2): 470–488. https://doi.org/10.1002/pan3.10451.

Beghetto, R. A. 2010. "Creativity in the Classroom." In *The Cambridge Handbook of Creativity*, edited by J. C. Kaufman & R. J. Sternberg, 447–463. New York, NY: Cambridge University Press. https://doi.org/10.1017/CBO9780511763205.027.

Cremin, T., and K. Chappell. 2021. "Creative Pedagogies: A Systematic Review." *Research Papers in Education* 36 (3): 299–331. https://doi.org/10.1080/02671522.2019.1677757.

Denzin, N. K. 1978. *The Research Act: A Theoretical Introduction to Sociological Method*. New York, NY: McGraw-Hill.

Desmarais, R. 2024. "Ecological Literacy: Definition, Early Articulations, Frameworks and Empirical Research." *The Journal of Sustainability Education* 29: 1-19. https://www.susted.com/wordpress/content/ecological-literacy-definition-early-articulations-frameworks-and-empirical-research_2024_04/.

Dewey, J. 1934. *Art as Experience*. New York, NY: Minton, Balch & Company.

Dunn, J., and S. Wright. 2014. "Signs, Meaning and Embodiment: Learning and Pedagogy in the Early Years." In *The Routledge International Handbook of the Arts and Education*, edited by S. Wright, 223–233. New York, NY: Routledge.

Eisner, E. W. 2002. *The Arts and the Creation of Mind*. New Haven, CT: Yale University Press.

Glass, D., and C. Wilson. 2016. "The Art and Science of Looking: Collaboratively Learning Our Way to Improved STEAM Integration." *Art Education* 69 (6): 8–14. https://doi.org/10.1080/00043125.2016.1224822.

Guyotte, K. W., N. W. Sochacka, T. E. Costantino, J. Walther, and N. N. Kellam. 2014. "STEAM as Social Practice: Cultivating Creativity in Transdisciplinary Spaces." *Art Education* 67 (6): 12–19. https://doi.org/10.1080/00043125.2014.11519293.

Hackett, A., M. Hall, K. Pahl, and P. Kraftl. 2025. "Giving up the 'Good Research Child'." *Qualitative Research* 25 (4): 805–823. https://doi.org/10.1177/14687941241264490.

Hadzigeorgiou, Y., P. Fokialis, and M. Kabouropoulou. 2012. "Thinking about Creativity in Science Education." *Creative Education* 03 (05): 603–611. https://doi.org/10.4236/ce.2012.35089.

Hallam, J., L. Gallagher, and K. Owen. 2022. "The Secret Language of Flowers: Insights from an Outdoor, Arts-Based Intervention Designed to Connect Primary School Children to Locally Accessible Nature." *Environmental Education Research* 28 (1): 128–145. https://doi.org/10.1080/13504622.2021.1994926.

Hiltunen, M., M. Kallio-Tavin, and A. Sohlman. 2021. "Toward Place-Specific and Situational Arctic Visual Culture Learning in Finnish Art Teacher Education." *Studies in Art Education* 62 (3): 266–285. https://doi.org/10.1080/00393541.2021.1936428.

Huhmarniemi, M. 2023. "Participatory Art with Trees: Pedagogical Approach." In *Art, Sustainability and Learning Communities: Call to Action*, edited by R. Vella & V. Pavlou, 217–226. Bristol, UK: Intellect. https://doi.org/10.1386/9781789388978_15.

Huhmarniemi, M., and A. K. Lande. 2025. "Observation of Change as a New Genre Arctic Art." In *Artistic Dialogues with the Arctic North: Environmental Change and Identity in Transition*, edited by A. Sohns, 13–26. London: Routledge.

Illeris, H. 2016. "Learning Bodies Engaging with Art: Staging Aesthetic Experiences in Museum Education." *International Journal of Education Through Art* 12 (2): 153–165. https://doi.org/10.1386/eta.12.2.153_1.

Ingold, T. 2013. *Making: Anthropology, Archaeology, Art and Architecture*. London: Routledge. https://doi.org/10.4324/9780203559055.

Inwood, H. J. 2008. "At the Crossroads: Situating Place-Based Art Education." *Canadian Journal of Environmental Education* 13 (1): 29–41.

Ison, M., and S. Bramwell-Lalor. 2023. "The Arts in Environmental Education: Connecting Learners with Their Talents and Nature." *Environmental Education Research* 29 (7): 964–979. https://doi.org/10.1080/13504622.2023.2205062.

Jokela, T 2019. "Arts–Based Action Research in the North." In *Oxford Research Encyclopedia of Education*, edited by G. W. Noblit. New York, NY: Oxford University Press. https://doi.org/10.1093/acrefore/9780190264093.013.522.

Jokela, T., & Coutts, G., eds. 2018. *Relate North: Art & Design for Education and Sustainability*. Rovaniemi, Finland: University of Lapland Press.

Jokela, T., M. Hiltunen, and E. Härkönen. 2015. "Art-Based Action Research: Participatory Art for the North." *International Journal of Education Through Art* 11 (3): 433–448. https://doi.org/10.1386/eta.11.3.433_1.

Jokela, T., M. Hiltunen, and M. Huhmarniemi. 2019. "Art-Based Action Research: Participatory Art Education Research for the North." In *Provoking the Field: International Perspectives on Visual Arts PhDs in Education*, edited by A. Sinner, R. L. Irwin & J. Adams, 45–56. Bristol: Intellect.

Kewalramani, S., and N. Veresov. 2022. "Multimodal Creative Inquiry: Theorising a New Approach for Children's Science Meaning-Making in Early Childhood Education." *Research in Science Education* 52 (3): 927–947. https://doi.org/10.1007/s11165-021-10029-3.

Kiviranta, L., E. Lindfors, M.-L. Rönkkö, and E. Luukka. 2024. "Outdoor Learning in Early Childhood Education: Exploring Benefits and Challenges." *Educational Research* 66 (1): 102–119. https://doi.org/10.1080/00131881.2023.2285762.

Leavy, P. 2009. *Method Meets Art: Arts-Based Research Practice*. New York, NY: Guilford Press.

Leavy, P. 2017. *Research Design: Quantitative, Qualitative, Mixed Methods, Arts-Based, and Community-Based Participatory Research Approaches*. New York, NY: Guilford Press.

Macdonald, I., E. Malone, and R. Firth. 2022. "How Can Scientists and Designers Find Ways of Working Together? A Case Study of Playful Learning to co-Design Visual Interpretations of Immunology Concepts." *Studies in Higher Education* 47 (9): 1980–1996. https://doi.org/10.1080/03075079.2021.2020745.

Manarin, K. 2018. "Close Reading: Paying Attention to Student Artifacts." In *SoTL in Action: Illuminating Critical Moments of Practice*, edited by N. L. Chick. Bristol, UK: Routledge.

Marshall, J. 2014. "Transdisciplinarity and Art Integration: Toward a New Understanding of Art-Based Learning across the Curriculum." *Studies in Art Education* 55 (2): 104–127. https://doi.org/10.1080/00393541.2014.11518922.

Patton, M. Q. 2002. *Qualitative Research and Evaluation Methods*. 3rd ed. Thousand Oaks, CA: Sage Publications.

Perignat, E., and J. Katz-Buonincontro. 2019. "STEAM in Practice and Research: An Integrative Literature Review." *Thinking Skills and Creativity* 31: 31–43. https://doi.org/10.1016/j.tsc.2018.10.002.

Sochacka, N. W., K. W. Guyotte, and J. Walther. 2016. "Learning Together: A Collaborative Autoethnographic Exploration of STEAM (STEM + the Arts) Education." *Journal of Engineering Education* 105 (1): 15–42. https://doi.org/10.1002/jee.20112.

Stone, M. K., & Barlow, Z. (Eds.). 2005. *Ecological Literacy: Educating Our Children for a Sustainable World*. San Francisco, CA: Sierra Club Books.

Thomas Jha, R., and S. Price. 2022. "Embodying Science: The Role of the Body in Supporting Young Children's Meaning Making." *International Journal of Science Education* 44 (10): 1659–1679. https://doi.org/10.1080/09500693.2022.2089366.

Thomas Jha, R., S. Price, and A. Motion. 2020. "Designing 'Embodied' Science Learning Experiences for Young Children." In *Learning and Collaboration Technologies* (pp. 207–225). Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-030-50513-4_16.

Thomashow, M. 1996. *Ecological Identity: Becoming a Reflective Environmentalist*. Cambridge, MA: MIT Press.

UNESCO. 2017. *Education for Sustainable Development Goals: Learning Objectives*. Paris, France: UNESCO Publishing.

United Nations. 2015. "*Transforming Our World: The 2030 Agenda for Sustainable Development*." United Nations Publishing. https://sdgs.un.org/2030agenda

van Boeckel, J. 2013. "At the Heart of Art and Earth: An Exploration of Practices in Arts-Based Environmental Education." Doctoral dissertation. Helsinki, Finland: Aalto University.

Vecchi, V. 2010. *Art and Creativity in Reggio Emilia: Exploring the Role and Potential of Ateliers in Early Childhood Education*. New York, NY: Routledge. https://doi.org/10.4324/9780203854679.

Vesterinen, M., and I. Ratinen. 2024. "Sustainability Competences in Primary School Education–a Systematic Literature Review." *Environmental Education Research* 30 (1): 56–67. https://doi.org/10.1080/13504622.2023.2170984.

Whitburn, J., W. Abrahamse, and W. Linklater. 2023. "Do Environmental Education Fieldtrips Strengthen Children's Connection to Nature and Promote Environmental Behaviour or Wellbeing?" *Current Research in Ecological and Social Psychology* 5: 100163. https://doi.org/10.1016/j.cresp.2023.100163.

Wilson, M. 2002. "Six Views of Embodied Cognition." *Psychonomic Bulletin & Review* 9 (4): 625–636. https://doi.org/10.3758/BF03196322.

Wright, S. 2010. *Understanding Creativity in Early Childhood: Meaning-Making and Children's Drawing*. Los Angeles, CA: SAGE Publications. https://doi.org/10.4135/9781446251447.

Zhang, X., and M. Hiltunen. 2025. "Integrating Art into Chemistry Class: Exploring pH Reactions through Creative Expression." *International Journal of Education Through Art* 21 (3): 483–493. https://doi.org/10.1386/eta_00213_3.

Zhang, X., and M. Huhmarniemi. 2026. "The Bilberry Experiment for Arctic STEAM Education." *Scandinavian Journal of Educational Research* 1–15. https://doi.org/10.1080/00313831.2026.2623292.