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Quantifying plasticity of children's visions of nature

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Abstract

Visions of nature underlie how people behave toward the environment. It is often assumed that environmental education can nudge positive visions of nature and thus contribute to transformative change in individuals and ultimately societies. However, little is known about the effectiveness of educational activities. Here, we present an approach that quantifies these effects and how they depend on factors such as previously held visions. We demonstrate the approach assessing the normative, expressive, and cognitive dimensions of the visions of nature held by school children (11–12 years old, $n = 120$ children) before and after a full day of outdoor educational activities, including environmental measurements and games, in the Venice Lagoon, Italy. To quantify children's visions of nature, we used questionnaires and art they produced, and which we analyzed in quantitative ways. Results revealed that 75% of the children had a nature-centered perspective of the natural world before the outdoor educational activities. Most children maintained their perspective, but proportionally more children shifted from a human-centered to a nature-centered perspective than vice versa. Children with a nature-centered perspective of the natural world became more environmentally aware and "connected to" the lagoon after the field excursion, as suggested by increases in: (1) selection of environmental elements to describe the lagoon, (2) words associated with positive emotions, and (3) recognition of environment-friendly activities. In contrast, children with human-centered perspectives before the excursion tended to maintain associations of the lagoon with anthropogenic elements and mechanized activities. These results suggest that environmental education can consolidate the development of environmental awareness in children that already have nature-centered perspectives. While the current questionnaires and activities were customized to the Venice Lagoon, our approach measuring multiple dimensions of the visions of nature before and after educational interventions is generic and applicable to socio-ecological systems across the Global North and South.

KEYWORDS
citizen science, environmental education, nature connectedness, nature perceptions, pro-environmental behavior, restoration ecology, transformational change

INTRODUCTION

In the face of Earth's environmental crisis, massive collective action is needed to safeguard and restore the planetary functions that sustain nature and societies (Rockström et al., 2009). Such Earth Stewardship requires a transformational change in the ways individuals, institutions, and societies understand and engage with the natural world (Chapin, 2024; Ostrom, 2017). Fostering this transformational change relies, among other things, on developing shared common values, beliefs, and understanding of nature and the environmental problems (Anderies & Folke, 2024; Ortiz-Riomalo et al., 2023).

Although public perceptions on human–nature relationships have been studied using different theoretical frameworks, assessment instruments, and disciplinary perspectives (Flint et al., 2013), there is an emergent convergence toward recognizing "friendliness toward nature" as an attitude that is held universally across cultural contexts (Van den Born et al., 2025). A quantitative comparison of empirical studies revealed that, across the Global North and South, most people reject the idea that humans can do as they please to nature and, instead, associate themselves with more friendly human–nature relational images (Calderón Moya-Méndez et al., 2022; Van den Born et al., 2025). This does not mean that all cultures or individuals conceive nature equally. For example, indigenous communities often have more nature-centered perspectives (Salmón, 2000). Also, how individuals conceptualize nature and their relationship with it depends on their cultural backgrounds (Buijs et al., 2009; Calderón Moya-Méndez et al., 2022; Ducarme & Couvet, 2020; Kloek et al., 2018) and personal experiences (Kals et al., 1999). For example, environmentally responsible individuals often associate early life outdoor experiences as a catalysator of their behavior and actions later in life (Ernst et al., 2021; Ewert et al., 2005).

One approach to study the ideas people have on what the natural world is and how they relate to it uses the concept of "Visions of Nature" (De Groot et al., 2006). In this framework, three complementary dimensions of the individual conceptualization of nature are distinguished: (1) normative, (2) expressive, and (3) cognitive (Buijs et al., 2011; Keulartz et al., 2004; Kloek et al., 2013). The *normative* dimension refers to how individuals perceive the relationships between humans and other beings along a gradient from human-centered (i.e., anthropocentric) to nature-centered (i.e., eco-centric) interactions. Anthropocentric views emphasize the superiority of humans over other beings and the use of nature to satisfy people's needs, whereas eco-centric views recognize other beings' needs and rights beside humans to varying extents (De Groot et al., 2006). The *expressive* dimension refers to the emotions and associations individuals experience toward nature. The *cognitive* dimension refers to the knowledge individuals have on the natural environment (De Groot et al., 2011; Keulartz et al., 2004).

It is generally believed that the normative and expressive dimensions of the nature vision are built early on in life, while the cognitive dimension is more flexible (Louv, 2005). Environmental education of children widely recognizes the importance of interacting with nature as essential for developing a nature-centered perspective and early positive emotions toward the natural environment (Adams & Savahl, 2017; Ardoin & Bowers, 2020; Chawla, 2015; Drissner et al., 2010). The idea is that such normative and expressive attitudes form a sense of connectedness to nature that may in turn become the foundation of the cognitive dimension by triggering curiosity toward the natural world that facilitates gaining more knowledge on how it functions (Drissner et al., 2010). Environmental education assessments are increasingly recognizing the complex interactions between people's sense of connectedness to nature and environmental knowledge that ultimately guides environmentally responsible behavior (Cheng & Monroe, 2012; Otto & Pensini, 2017; Roczen et al., 2014) and views on nature conservation (Chan et al., 2016; Van Den Born et al., 2018).

From a practical point of view, a key question is which educational and outreach approaches are most effective for nudging individuals toward a higher affinity for nature and more environment-friendly behavior. A recent meta-analysis summarizing five decades of research on environmental education with children and adolescents worldwide demonstrated that there is an enormous variability in the extent to which environmental education improves environmental knowledge, attitudes, intentions, and self-reported behavior toward the environment (Van De Wetering et al., 2022). This high variability in the effect size of environmental educational programs could not be explained by the characteristics of the educational approach (e.g., group learning, nature

experience, duration of the intervention) or the participants' sample (e.g., age or gender ratio). These results suggest that the effects of environmental education on young people's environmental outcomes could be related to other individual characteristics.

One possibility we explore in the current research is that part of the variability found in the effects of environmental education may be explained by the visions of nature that the participants had before engaging in the environmental educational programs. So far, integrated assessments of the three components of the visions of nature (normative, expressive, cognitive) have been mostly studied with adult populations (Van den Born et al., 2025). Here we explore the plasticity of the three dimensions of visions of nature in children exposed to different outdoor educational activities. The mechanisms involved in the formation and change of attitudes and beliefs are studied in a range of disciplines including neurosciences, psychology, and social sciences (Scheffer et al., 2022). Environmental education is rooted in the theories of experiential learning in which learning is conceived as a continual process where ideas are formed and reformed by experience and interaction with the environment (Kolb, 1984). Plasticity, in this context, is the capacity of individuals to modify concepts, attitudes, and behavior in response to environmental exploration and information. In the field of education, the concept of *functional plasticity* is defined as the ability to change behavior as a result of experiences and is measured by assessing rates of observed changes in behavior (Thomas, 2012). In this vein, we will use the term plasticity to refer to the capacity of individuals to change their perception of nature when experiencing outdoor environmental education. Specifically, we studied how outdoor exploration and games influenced the responses of children to exercises designed to measure normative, expressive, and cognitive components of their visions of nature. We assessed scores on each of those dimensions before and after children took part in educational activities to assess how flexible these different aspects of their nature perception were and how they influence each other. As far as we know, this is the first study that quantifies the impact of environmental education on the three components of the visions of nature in children. The specific research questions were: (1) How do outdoor environmental education activities influence the normative, expressive, and cognitive dimensions of children's visions of nature?; (2) Does the initial normative perspective (human-centered vs. nature-centered) affect the plasticity of these dimensions?; (3) How do the three dimensions interact in response to a single-day educational intervention?

METHODS

Venice Lagoon as a socio-ecological system

The Venetian Lagoon is the largest coastal wetland of Italy at 55,000 hectares (ha) bordering the NE Italian peninsula and the upper Adriatic Sea. It hosts a unique range of biotypes including salt marshes, reed beds, seagrass meadows, mudflats, and is especially significant on a Mediterranean scale in terms of biodiversity and socio-ecological interrelationships. It is characterized by a tidal system and centuries of human interventions that were explicitly planned and executed to change the fate of the lagoon system. Initially, the main rivers flowing into the lagoon were diverted to prevent the channels used by ships from silting up, and more recent port developments have moved the system much further onto an erosive trajectory (Brambati et al., 2003). Venice and the Lagoon were designated a UNESCO World Heritage site in 1987, but since 2014, it has risked being assigned to UNESCO's list of endangered sites (UNESCO, 2014). Unsustainable activities, such as increasingly large ships being served by the Port of Venice, as well as intense local water traffic, have resulted in extensive loss of salt marsh and ongoing erosion that is exacerbated by the lack of sediment inputs from rivers and large volumes of sediments exported to the Adriatic Sea.

Ecological restoration of the lagoon's natural capital has been identified as a priority in national laws since 1973 and by European Directives for Habitat and Bird protection, to protect this unique socio-ecological system in the face of pollution, infrastructure developments, biodiversity loss, sea-level rise, and other changes as climate change progresses (Da Mosto, Smith, & Ruszkowska, 2020). Attention on Venice's cultural heritage and tourism pressures is widely reported and discussed (Settis, 2016). Reinforcing awareness that the fate of the city and the encircling lagoon is interconnected is essential to finding and implementing effective long-term policies (Lund, 2023).

Restoration efforts to date have been strongly informed by coastal engineering, focusing on morphological reconstructions to attenuate hydrological dynamics, such as increasingly large ships as well as intense local water traffic. Nature regeneration could instead be coupled with wetland reconstruction with a more resilient outcome using a more holistic approach that actively recognizes the central role of ecosystems in sediment retention, attenuation of lagoon hydrodynamics, enhanced biodiversity, and provision of other ecosystem services (Da Mosto, Bertolini, et al., 2020). For example, the creation of ecologically functional saltmarshes in the

Venetian Lagoon could reduce sediment loss and ameliorate the impacts of sea-level rise (Zoccarato & Da Lio, 2021). It could also increase biodiversity and carbon sequestration, maintaining the provisioning and cultural services that have been historically important for people (Rova et al., 2022). However, the lack of an integrated ecosystem approach that recognizes the role of saltmarsh vegetation as an ecological engineer is a major barrier to effective ecological restoration that helps build ecosystem resilience to climate change.

Educational activities

We developed an environmental education program for school children from the greater Venice area aimed at increasing awareness of the ecological functioning of the lagoon ecosystem as a complex socio-ecological system with saltmarshes in different ecological conditions (i.e., good, degraded, and under ecological restoration), interactions between abiotic and biotic elements (i.e., sediments, water, plants, and animals), and the presence of diverse human activities (i.e., boat traffic, and fishing). The program was developed by an interdisciplinary team of scientists, artists, schoolteachers, and educators and embedded within the curriculum for the school classes involved. After a consultation phase with a wide range of institutions in Venice, we developed a combination of educational activities (Figure 1), involving an excursion to the Venice lagoon and environmentally oriented games, building on the previous nature education experience of the Natural History Museum of Venice (MSN).

We conducted outdoor educational activities with 120 school children (11–12 years old) from six classes of three public secondary schools in Venice (Francesco Morosini from Venice, Giuseppe Volpi from Favaro Veneto, and Lazzaro Spallanzani from Mestre). In the Italian school system, 11–12-year old children are typically in the first or second year of Scuola Media (lower secondary school), also known as Scuola Secondaria di Primo Grado. This stage of education is compulsory for all pupils and lasts for 3 years, starting at age 11. Participation in the outdoor activities was authorized by the children's custodians, followed safety protocols, and was always guided by the children's teachers. The objective of the outdoor educational activities was to observe the Lagoon landscape, but also its anthropogenic and

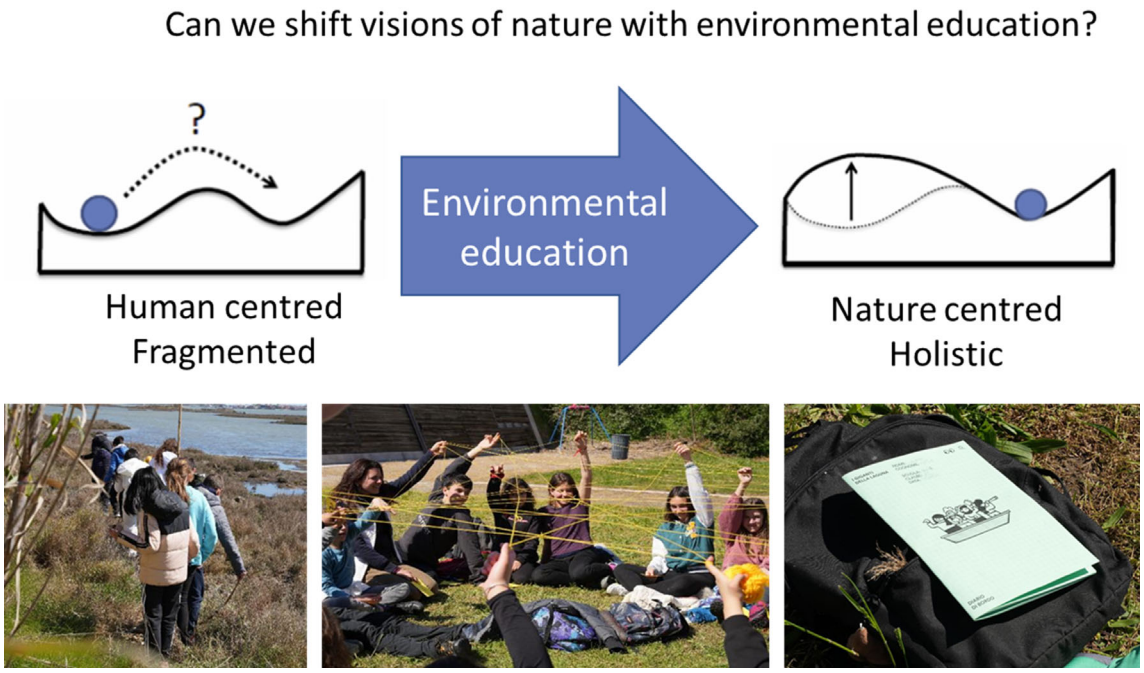

FIGURE 1 Environmental education as an instrument to nudge people's visions of nature. Visions of nature have three complementary dimensions: normative, expressive, and cognitive, that underlie the relationships and interactions between people and nature (Keulartz et al., 2004). Environmental education can influence these different dimensions of people's visions of nature by facilitating shifts from human-centered to nature-centered views of nature (normative dimension), building positive emotions and associations with nature (expressive dimension), and increasing the understanding of nature functioning (cognitive dimension). We conducted outdoor educational activities with school children that included working in teams to take environmental observations, play games to explore ecological interactions, and make personal observations and drawings. Pictures by E. Sovrani.

natural elements to understand the interrelationships between them. School classes were divided into smaller groups accompanied by an adult to collect observations on sediments, plants, animals, and human activities along a water-land gradient in the saltmarshes, on a beach, and on the adjoining terrestrial areas (partly wild, partly agricultural). All children received a personal logbook to write down their thoughts and observations; some also had small boxes to collect things as well as magnifying glasses, binoculars, and cameras to stimulate exploration from different perspectives and at multiple levels of detail. After the observation phase, each group had about 20 min to prepare a brief presentation on the assigned habitat, which was then presented collectively by group representatives.

Children also played a network game designed to highlight ecological interactions between abiotic and biotic components of the wetland system based on two existing games used for raising awareness on interconnections among elements (American-Museum-of-Natural-History, 2023; Project-Learning-Tree, 2023). The first part of the game was a treasure hunt, where every child had to find a Lagoon element's drawing, hidden outdoors in a huge green space near the saltmarsh. For the second part, children formed groups of about 8–10 students each. Each team received a skein of thread. Every child was asked to represent the element of the Lagoon he found during the treasure hunt. Then they were asked to throw the ball to a child representing an element they thought had an ecological interaction with them. The child receiving the thread would then throw the ball in turn. This simple game resulted in ecological networks of elements, represented by the children, and connected through a thread. After the game, supervisors facilitated the conversation among children to highlight the reasons for the connections that were formed.

Assessing visions of nature

We assessed individual visions of nature before and after the educational activities. We adapted and designed three short exercises to measure normative, expressive, and cognitive dimensions of a child's vision of nature (see Supporting Information). Every child completed, individually, the same exercises before and after the educational activities. Exercises were presented in two separate bundled sheets printed with different colors to facilitate pairing the answers per child during the data processing phase. Exercises were first completed in the classrooms, prior to a presentation explaining the lagoon and the planned excursion. The second time, exercises were completed on the boat, on the way back after the outdoor excursion.

The normative domain was assessed first by presenting two contrasting images of the position of humans in relation to other living beings. The human-centered perspective was represented by a pyramidal figure with a man on top of a highly hierarchical organization of life. Here, plants, invertebrates, and fungi were at the bottom, followed by vertebrate animals and humans on top. The nature-centered perspective was represented by a circular image where plants, animals (invertebrates and vertebrates), and humans were positioned everywhere within the circle. The assignment asked: "Which one of the two images you feel closer to? Circle the selected image" (Figure S1; including original question in Italian). These two contrasting images are often used for representing the intrinsic perception people have of how humans and other beings are related to each other (Lehmann, 2023; Lucero & Gonzalez Cruz, 2020). We adapted the images to reflect the organisms commonly found in the Lagoon, using a drawing style familiar and accessible to children. We chose the word "feel" (could also be translated as "appeal," from "senti" in Italian) because it refers to the deeper relationships people have with their environment (De Groot et al., 2011).

The expressive domain was assessed by presenting three separate columns listing words related to either elements, emotions, or recreational activities associated with the lagoon. The columns were not labeled and had 10 words alphabetically ordered. The first column contained words associated with contrasting types of elements (i.e., anthropogenic, abiotic, and wildlife). The second column listed words associated with emotions (i.e., positive or negative associations related to beauty and state of mind, and contrasting associations with peacefulness and action). The third column listed types of human activities performed in the ecosystem (i.e., consumptive, mechanized, recreational, and environmentally friendly). The assignment asked, "Imagine the lagoon: which words come to your mind? Select one word for each column" (Figure S2; including original question in Italian).

In addition, each child was invited to make a personal drawing before the introductory presentation on the educational program and field excursion in response to the question "What does the lagoon look like? Make a sketch of the most important elements." Drawings are a useful approach to assess children's perceptions of nature (Howlett & Turner, 2023). We used the drawings to complement the assessment of the expressive dimension of the children's visions of nature.

The cognitive dimension was assessed by presenting disconnected components of the lagoon and asking "Which elements are interconnected in the lagoon? Draw lines to link them." Elements included abiotic elements (e.g., sand and mud), organisms (e.g., fish, birds, crab, a worm, and saltmarsh plants), and human activities (e.g., a human fishing and a boat). This assignment was designed to measure the knowledge on how components of the coastal wetland interact and, particularly, the central role of saltmarsh plants as ecological engineers (Figure S3; including original question in Italian).

Data processing and statistical analysis

Assessments before and after the educational activities were anonymized, and the data were managed following protocols for protecting personal information. Missing answers or answers that did not follow the assignment instructions were not considered for further statistical analysis.

For Assignment 1, assessing the normative dimension, we used Fisher's Exact Test, a variation of the X^2 contingency tests for small sample sizes, to test if the outdoor activities changed the nature perspective of the children (i.e., from human-centered to nature-centered, or vice versa), and whether this change depended on their initial nature perspective, as identified before the outdoor activities.

For Assignment 2, assessing the expressive dimension, we used word-cloud analysis (Gupta, 2024) to visualize the frequency of words chosen before and after the outdoor educational activities, using free available software (wordcloud.com). We used constrained Redundancy Analyses and Canonical Correlation Analysis (CCA) using CANOCO 5.0 software (Ter Braak & Smilauer, 2002) to relate word selection of the children to the moment of assessment (before or after the outdoor activity) and their initial normative perspective (human-centered or nature-centered), as identified before the outdoor activity. For both the RDA and CCA, we binarized and centered the response data before analysis to improve data distribution (Ter Braak & Smilauer, 2002). We used the CCA to explore variance partitioning between normative nature perspective, the moment of the survey, and school class, downweighing the influence of rare word selections. Finally, we ran a second CCA in which we zoomed in on the impact of nature perspective, using school class as a covariable.

The drawings were analyzed quantitatively and compared with the words selection in Assignment 2 to have an assessment of the expressive dimension through visual and text forms. We counted the elements and activities reflected in every drawing and compared the frequency of the words chosen by the children in the expressive assignment (i.e., column "elements" and column "human activities") described previously. If a drawing portrayed an element or activity that was not listed in the word exercise, we classified it into one of the categories of elements (i.e., anthropogenic, abiotic, and wildlife) or type of activity (i.e., consumption, mechanized, recreational, and environmentally friendly). A total of 117 drawings were analyzed, of which 95 could be linked to individuals. We used word clouds to illustrate the relative abundance of elements drawn by the children, using the same settings as for Assignment 2.

For Assignment 3, we explored if the outdoor activities influenced the children's knowledge on ecological relationships between different elements of the lagoon, using network analysis (Freeman, 2002). In order to compare the embedding of each element within the drawn networks before and after the outdoor educational activities, we calculated the degree and the closeness centrality (Freeman, 2002) per element (i.e., node within a network), per student. Degree is a measure of the connectivity of a node. The degree of a node within a network is the number of pairwise interactions of that node with other nodes. Closeness centrality is a measure of the centrality of a particular node in the entire network. The more central a node is, the closer it is to all other nodes. It is calculated as the reciprocal of the sum of the length of the shortest paths between the node and all other nodes in the network (Beauchamp, 1965).

To detect changes in the embedding of the different nodes in the network, we calculated the average degree and closeness centrality per node for all students before and after the outdoor educational activities, and the relative change in average degree and closeness centrality after the outdoor activities compared to before. To visualize the networks, we calculated the frequency of pairwise connections (links) between elements (nodes) based on all students, before and after the outdoor activities, directly programmed in Python.

RESULTS

Assessment 1: Normative dimension

Before the outdoor excursions with field educational activities, 77% of the children chose the encircled image reflecting a nature-centered perspective, whereas 23% of the children chose the pyramidal image representing the human-centered perspective ($n = 95$ of valid sheets). Most of the children maintained their views after the

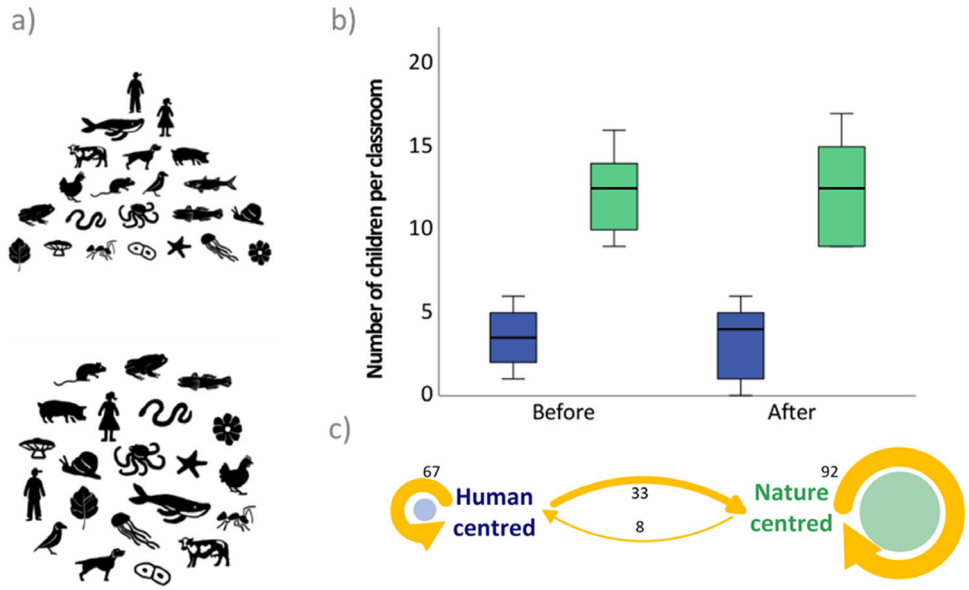

FIGURE 2 Normative dimension of visions of nature. Graphical representation of human-centered vs. nature-centered visions of nature (a). Children show mostly nature-centered views before and after the outdoor educational activities (b). Shifts from human-centered to nature-centered visions of nature occurred more often than vice versa after the outdoor education (c). Data show %.

educational activity. Of the children who had chosen a nature-centered image before the field excursion, 92% maintained their choice afterward, whereas 8% chose the human-centered image after the outdoor activities. Of the children who chose a human-centered image before the outdoor activities, 65% maintained this choice, while 35% switched to a nature-centered image after the outdoor educational activities. While school classes varied in the number of children with human-centered perspectives, there was no systematic effect on the shift in perspective associated with school or class. Overall, the results show that after the outdoor educational activities, a larger proportion of children switched toward a nature-centered than to a human-centered perspective, as defined in Assignment 1 (Fisher Exact Test Statistic = 0.0055; $p < 0.01$; Figure 2).

Assessment 2: Expressive dimension

The outdoor excursion significantly influenced the words chosen by the children to describe the elements, emotions, and human activities associated with the Venice Lagoon (Figure 3a; CCA, pseudo$F_{4.1}$, $p = 0.006$). The impact was most evident for children associating with a nature-centered normative perspective, who significantly changed their word choice for elements and recreational activities (CCA, pseudo$F_{4.7}$, $p = 0.006$). For children associating with a human-centered perspective, the response was strongest for the emotions, but this was not statistically significant (Figure S4, Table S1).

Elements characterizing the lagoon

Overall, 47% of the children selected anthropogenic elements to define the Venetian Lagoon before the field excursion. After the activity, this dropped to 32% of the students. In contrast, the use of environmental concepts to define the lagoon increased from 28% before the activity to 46% after the field activities (Figure 3b). Most of this shift occurred in children with nature-centered views. For this group, the use of anthropogenic elements to characterize the lagoon was almost halved, while the recognition of abiotic environmental elements doubled after the outdoor activities. Also, negative emotions associated with the lagoon prior to the activities were replaced by positive ones (Figure S4, Table S1). In contrast, children that associated with a human-centered image of nature slightly increased the use of anthropogenic elements (14%) and abiotic elements (25%) to describe the lagoon after the outdoor activities.

Emotional associations with the lagoon

Positive associations with the lagoon increased after the outdoor excursion (Figure 3c). The increase was more pronounced for children with a human-centered perception of nature than for children with a nature-centered perspective (50% vs. 30%, respectively). Most of the children with negative associations of nature before the excursion shifted toward positive associations. We also detected a higher association with action words after the outdoor excursion.

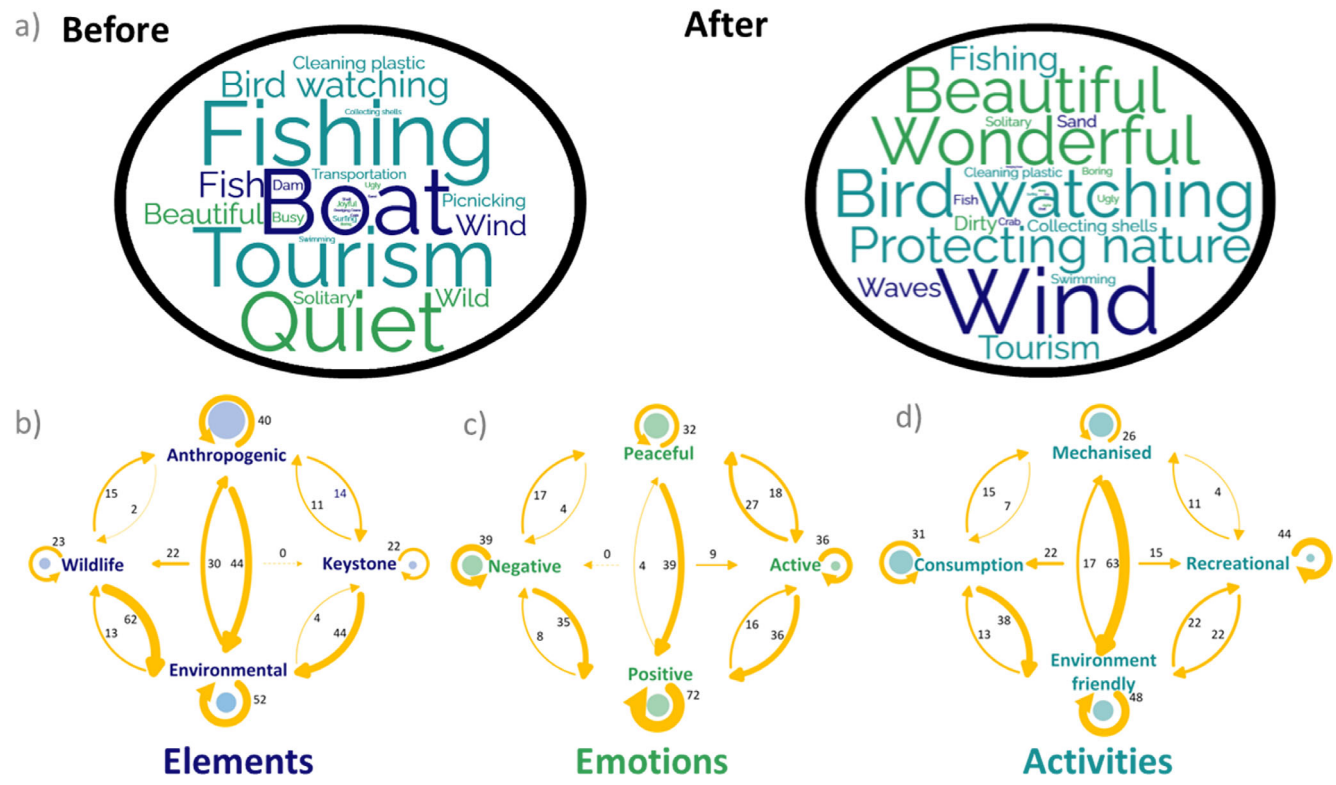

FIGURE 3 Expressive dimension of visions of nature. Word clouds of terms selected by children to characterize elements, emotions, and activities associated with the Venice Lagoon before and after the outdoor educational activities (a). Shifts in the type of elements (b), emotions (c), and activities (d) associated with the lagoon after the outdoor activity. Arrows indicate the direction and frequency of shifts between categories. Data show %.

Activities associated with the lagoon

The outdoor excursion shifted children's associations of the lagoon from predominantly activities related to consumption and mechanized activities to recreational and environmentally responsible activities (Figure 3d). But this shift was strongly driven by children with nature-centered perspectives. These children reduced associations of consumption (47%) and mechanized activities (50%) and increased associations with recreational activities (37%) and environmentally responsible activities (118%). In contrast, children with human-centered views hardly changed their ideas on what activities could be performed in the lagoon, and the small changes went from consumption to mechanized activities mostly. These children had increases in appreciative activities but reduced the associations with pro-environmental ones.

Analysis of the drawings

The frequency of elements portrayed in the children's drawings echoes the words used by the children to characterize the lagoon before the excursion (Figure 4). Human-related elements were most depicted in the drawings (43%), followed by wildlife (36%) and abiotic elements (21%). The most common human-related elements were boat (60%), followed by bricole (31%) and buildings (17%). "Bricole" is a Venetian word referring to wooden posts in the water that mark the navigable canals. Wildlife was reflected more commonly through fish (51%), bird (25%), seagrass (20%) and algae (19%). The more common abiotic environmental elements were waves (41%), sun (20%) and clouds (13%). Interestingly, 45% of the drawings combine underwater and terrestrial elements.

Assessment 3: Cognitive dimension

The structure of the children's perceived ecological networks changed with the outdoor excursions. After the excursion, children drew ecological networks containing nodes with more connections (i.e., higher degree) and higher importance (i.e., centrality) of natural elements. This is illustrated by the shift in the average number of pairwise connections drawn between the elements of the network, with average degree 16.3 before the excursion,

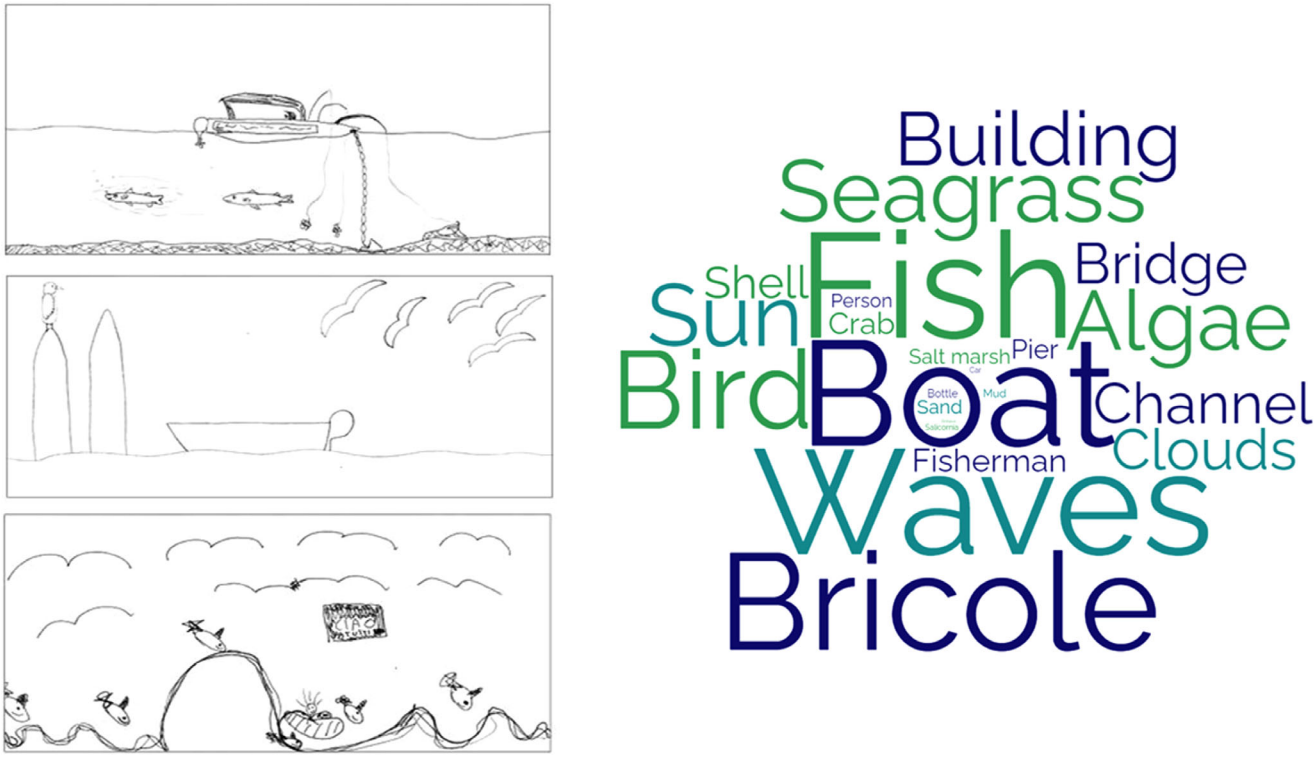

FIGURE 4 Artistic representation of the Venice Lagoon. Children's drawings before the outdoor excursion. The word cloud reflects the frequency of elements and types of activities represented in 117 children's drawings. Bricole = thick wooden poles indicating the navigational water channels.

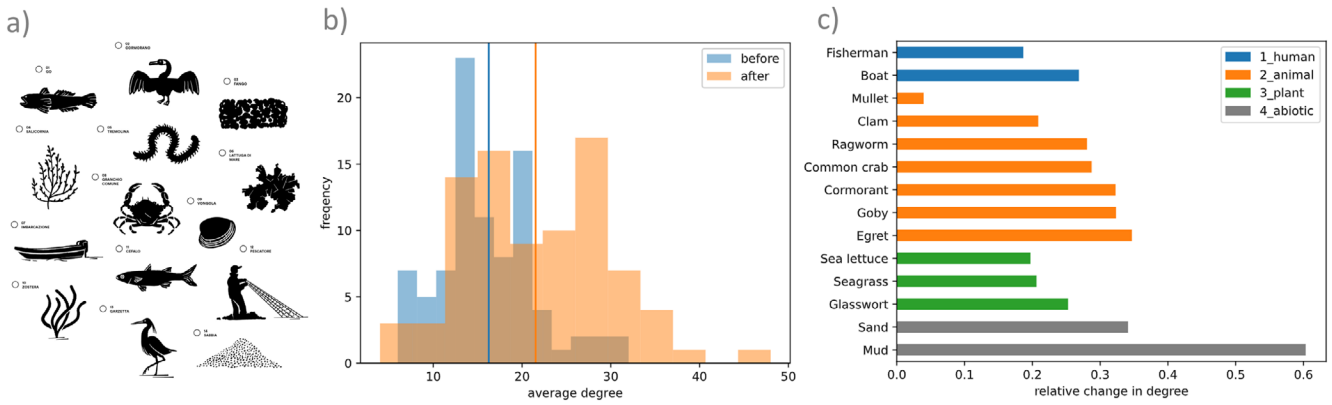

FIGURE 5 Cognitive dimension of visions of nature. Exercise as presented to the children asking them to link connected elements (a). The frequency distribution of the total number of connections drawn (the degree) between elements before and after the outdoor educational activities and activities (b). The relative change in the centrality of elements (nodes) within the networks after the outdoor excursion and activities compared to before the educational activities (c).

and 21.5 after the excursion (Figure 5a). Within the two groups with different normative views of nature, the observed patterns were similar. Within the human-centered group, the average degree increased from 15.1 to 20.3, and within the nature-centered group, it increased from 16.5 to 21.6. The centrality of each node also increased after the outdoor educational activities, especially that of natural elements (Figure 5b).

DISCUSSION

Environmental education aims to foster people's relationships and understanding of nature to nudge friendly environmental behavior that can address environmental problems and build more sustainable futures. There is increasing awareness that people's actions and decisions toward the environment are deeply rooted in relational

values (Chan et al., 2016) and visions of nature (Van den Born et al., 2025). Understanding the plasticity of visions of nature to environmental education is essential for the transformational change needed in individuals and societies.

We assessed the plasticity of the normative, expressive, and cognitive dimensions of children's visions of nature influenced by outdoor excursions collecting environmental data and playing environmentally themed games in the Venice Lagoon. The plasticity of children's visions of nature depended on their overall perspective on the relationships between humans and other beings. Only 16% of the children switched their normative image of nature after the outdoor activity, but proportionally more children switched from a human-centered to a nature-centered perspective (35%) than vice versa (8%). Our results show a significant interaction between the normative and expressive dimensions held by young school children. Children with a nature-centered perspective became more environmentally aware and connected to the lagoon after the outdoor educational activities, whereas children with a human-centered image of nature maintained their earlier associations of the lagoon with human-related elements and consumptive or mechanized activities. Nevertheless, all children, regardless of their normative image of nature, had more positive emotional associations with the lagoon (i.e., beauty and joy) after the field activities. We found that outdoor education increased children's appreciation of ecological interactions, the knowledge dimension, regardless of children's normative image of nature before the educational activities. It is possible that the positive effects of the outdoor education on the emotional associations children expressed about the lagoon may be more long-lasting and influential on their behavior than the effects the environmental education had on the cognitive dimension. Evidence is growing that people's deeper sense of connectedness to nature has stronger effects than knowledge on pro-environmental behavior (Barragan-Jason et al., 2022; Cheng & Monroe, 2012; Otto & Pensini, 2017; Roczen et al., 2014). For example, early childhood outdoor experiences with nature around appreciative recreational activities, such as bird watching or enjoying the scenery, contributed to having a nature-centered perspective later in life, whereas consumptive activities in nature, such as mushroom collecting or gold panning, contributed more to the development of a human-centered view of the environment (Ewert et al., 2005). Comparable patterns have been found in other studies (Wells & Lekies, 2006). Our results indicate that environmental educational activities are more likely to be successful with children that already have a nature-centered perspective of the world. Since two thirds of the children had nature-centered perspectives before the field activities, engaging these children in direct contact with nature can further contribute to nurturing positive emotional associations toward nature and increasing their awareness toward the environment. Building a nature-centered view very early in life thus seems a strong prerequisite for effective educational programs aiming to promote environment-friendly attitudes (Ardoin & Bowers, 2020).

The clear impact of a single outdoor educational activity on the image of nature, the emotional associations, and the ecological understanding of the lagoon of children aged 11–12 is noteworthy. However, this was a unique intervention assessing short-term changes in visions. The duration of an environmental educational program influences the outcomes of the interventions. For example, Drissner et al. (2010) assessed the environmental attitudes of children, within this same age range, before and after one morning of outdoor learning and found positive shifts toward pro-environmental attitudes on nature exploitation but not on nature conservation. More profound changes in environmental attitudes have been found by expanding the educational interventions to 5 days (Bogner, 1998; Braun & Dierkes, 2017).

Also, the age of children influences the effects of environmental education (Świątkowski et al., 2024). Children younger than 11 years old respond more positively to environmental education than older children (Braun & Dierkes, 2017; Liefländer et al., 2013). Environmental education seems also to have stronger effects on children following academically focused tracks than children with more general educational tracks (Liefländer et al., 2013). Further research on the longer-term effects of environmental education could help understand how early shifts in visions of nature may cascade into actual attitudes and behavior toward nature. Even one elementary school environmental education field trip was powerful enough to affect environmental attitude for at least 1 year after the event (Farmer et al., 2007). Long-lasting effects of environmental education are self-reported by environmentally responsible adolescents and adults, who often associate early life outdoor experiences as a catalysator of their behavior and actions later in life (Ernst et al., 2021; Ewert et al., 2005; Hoover, 2021; Wells & Lekies, 2006).

Ideally, long-term studies would follow cohorts of individuals to better understand how the environment they grew up in (i.e., academic, cultural, ecological, and socioeconomic) and the environmental education they were exposed to translate into different types of environmental attitudes. The call for longitudinal studies has been echoed frequently; however, due to operational challenges, attempts to quantify longer-term effects remain limited to studies of self-reported behavior of participants over a few years (Olsson et al., 2022; Shephard

et al., 2015). Clearly, following the attitudes of children over longer periods is logistically challenging as well as ethically delicate. Nonetheless, developing appropriate ways of measuring the impacts of different kinds of environmental education on attitudes toward nature will be important for designing evidence-based approaches. Such assessments need to go beyond the traditional way of assessing cognitive understanding only.

The approach we have presented in this study provides a practical starting point for such work. The methodology (assessing the normative, expressive, and cognitive dimensions of visions of nature before and after educational interventions) can be applied to study the impacts of environmental education across regions, social groups, and individual life stages. Of course, the particular exercises that measure these three components of how people conceptualize nature should be tailored to the particular ages, social groups, cultures, and ecosystems, as well as the particular research questions. Such follow-up work is in progress. For example, we have adapted the approach presented in this paper to study the effects of involving children in ecological restoration on their perceptions of nature in the peatlands of Ireland and the saltmarshes of Venice. Meanwhile, a comparable set-up is now used in an ongoing study of the impacts of citizen science with adults in England and Estonia.

Results of those follow-up studies are not in yet. However, it seems reasonable to assume that the overall approach may be applied across a range of contexts. Indeed, recent evidence demonstrates that generic approaches to assess people's connectedness to nature may deliver results that are comparable regardless of the region of Earth we live in (Van den Born et al., 2025). Clearly, demonstrating effects will require designing programs that contextualize the learning instruments and document the impacts properly (Ardoin et al., 2020). While this may be challenging, our findings suggest that it should be possible to assess the impact of education not just on knowledge, but also on other components of people's visions of nature.

From children environmental education to society

We presented the results of this outdoor educational project in an open event celebrating the Centennial of the Museum of Natural History of Venice in the presence of all children, teachers, and parent. Children and teachers also presented the results of their extended indoor projects inspired by the field excursion to the Venice Lagoon (Figure 6). Each class gave an oral presentation on different aspects of European wetlands. Children had also developed new games related to wetlands including crossword puzzles, board games, card games. Some teams also showed to the public how to conduct water quality measurements to highlight how salinity changes in different locations of the Venice Lagoon. Teachers had facilitated this process by adapting course schedules and encouraging creativity. In summary, the project had been fully embraced by children and teachers independently of the initial organizers. The project results were further

FIGURE 6 Children's presentations at the Centennial of the Museum of Natural History of Venice showcasing self-developed games and projects inspired by the educational field activities in the Venice Lagoon, illustrating legacy effects of the activities and embedding within the school curriculum. Pictures by M. Holmgren.

shared in two additional outreach activities, one exhibiting the children's drawings of the Venice Lagoon to the public, and one directed specifically to primary schools. The project has now been running for two additional years and has more than doubled the number of participants and schools involved. We are currently exploring how to include outdoor educational activities comparable to the one described in this study as part of the standard student curricula of all children schools of Venice. Besides reaching an ever-increasing number of children, the project has also reached their parents, including key stakeholders and decision makers in Venice, giving first signals of potential cascading effects of environmental education into organizations responsible for the management and conservation of the Venice lagoon.

Engaging school children in environmental activities and understanding the potential effects of this engagement on their vision toward nature could potentially contribute to developing long-term social capital for environment-friendly behavior. Recent climate activism led by children has demonstrated the cascading effects of children's actions in mobilizing actions in the rest of society (Thunberg, 2019). These cascading effects on social norms and behavior can be manifested at the level of families (Damerell et al., 2013), communities (Trott, 2019), and society at large (Trott, 2021).

CONCLUSIONS

Our work with children 11–12 years old shows that the three components forming children's visions of nature respond to environmental education in different degrees, illustrating the value of an integrative assessment of the effectiveness of education activities. Of all aspects assessed, both the emotional associations and ecological knowledge responded most strongly to the outdoor educational activities, suggesting that the expressive and cognitive dimensions are more plastic than the normative image of nature. These results imply that environmental education is a powerful instrument in building nature connectedness and understanding.

AUTHOR CONTRIBUTIONS

Milena Holmgren: Conceptualization; data curation; formal analysis; funding acquisition; methodology; project administration; supervision; validation; writing – original draft; writing – review and editing. **Jane Da Mosto:** Investigation; resources; supervision; validation; writing – review and editing. **Matthijs G. C. Schouten:** Methodology; writing – review and editing. **Eleonora Sovrani:** Investigation; resources; supervision; validation; visualization; writing – review and editing. **Ingrid van de Leemput:** Formal analysis; visualization; writing – review and editing. **Juul Limpens:** Conceptualization; data curation; formal analysis; funding acquisition; methodology; project administration; supervision; validation; visualization; writing – review and editing.

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ETHICS STATEMENT

The authors declare compliance with the ESA Code of Ethics.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available in the public repository DANS https://doi.org/10.17026/SS/RXSHVG.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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