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An innovative non-formal learning model based on nature and science: content, pedagogy and continuous professional development

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The current education model is gradually shifting away from its traditional framework, evolving towards a more informal, out-of-brick, outdoor learning culture. In this context, the topic of non-formal out-of-school learning environments, which bridge education with real-life experiences and enhance individuals' learning through daily activities, requires further examination and clarification within relevant frameworks. To this end, this study aims to clarify a framework for "nature and science-based out-of-school learning environments" encompassing content, pedagogy, continuous professional development by achieving a consensus based on expert opinions. This Delphi study employs an exploratory sequential design, a type of mixed-method research. By incorporating the insights of trainers, the study provides significant perspectives on non-formal outdoor learning, particularly in the areas of definition, content, pedagogy, professional development and education technology. The findings highlight the importance of effectively integrating content, pedagogy, professional development, and the pedagogical application of education technology in non-formal learning settings.

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Introduction

In the field of education, the traditional method of memorizing information and learning without active participation has gradually given way to more interactive and interdisciplinary hands-on approaches (Kyere, 2017). One such approach is nature-based or outdoor learning pedagogy, which leverages natural and outdoor environments to enhance learning (Barrable, 2022). This pedagogical approach addresses several factors, some of which are enhanced learning quality, experiential learning, and pro-environmental behavior, thereby creating a holistic and engaging experience for students (Baird et al., 2022; Kuo et al., 2019; Wu et al., 2023). Learning in outdoor environments enhances students' abilities to make observations, collect data, and interpret results by stimulating scientific curiosity, providing first-hand experiences, and helping students connect real-life situations with school learning (Erten and Tasci, 2016). Furthermore, this nature-based learning offers measurable benefits for students' socio-emotional development, academic performance, and overall well-being. That is why some programs address trauma and promote mental well-being through nature-based activities, which are vital components of experiential learning (Bobilya et al., 2024). These environments promote affective learning, which is often neglected in traditional educational settings (Meredith et al., 1997).

In confined classrooms, conventional educational models often rely on repetitive drills and memorization methods. These techniques have limitations regarding long-term retention and deeper understanding (Tutal and Yazar, 2021). Moreover, these traditional methods contribute to boredom, decreasing student engagement and motivation (La Marca and Longo, 2017). In contrast, nature-based and outdoor learning pedagogy, when guided by competent teachers, offers a dynamic alternative to traditional classroom instruction. This approach emphasizes holistic learning by engaging multiple senses and creating meaningful connections during educational experiences (Heide, 2022; Schoeb, 2021). A landmark study by Dettweiler et al. (2015) substantiates this pedagogical approach, finding that students participating in outdoor learning programs demonstrated significantly higher levels of knowledge retention compared to those in traditional classroom settings. To illustrate, studying the life cycle of plants in a classroom may provide learners with a superficial grasp of the concepts. However, witnessing the growth of a seed into a plant in a garden can lead to a much deeper and more profound understanding of the process. This observation of nature not only enhances comprehension but also fosters a sense of wonder and curiosity about the natural world (Driscoll and Lownds, 2007). Recognizing these compelling benefits, researchers argue that this learning approach should become an integral component of every child's educational experience (Norwood et al., 2022). Critically, such experiential learning should be thoughtfully tailored to the unique environmental and cultural contexts of local environment (Mann et al., 2022).

Research suggests that direct interaction with nature is essential for fostering a paradigm shift in education and promoting sustainable living (Ameli, 2022). Diverse natural experiences offer young students various benefits, including increased self-esteem, self-efficacy, resilience, stimulation of wonder, improved academic and cognitive outcomes (Mygind et al., 2019; Schilhab, 2021). According to Kellert (2002), this type of experiential learning fosters critical thinking and problem-solving skills, as learners encounter real-world challenges and develop strategies to solve them. These skill sets are considered essential for lifelong learning and success in an ever-changing world. A study by Wells and Lekies (2006) found that children who had frequent and positive experiences in outdoor settings were more likely to develop pro-environmental attitudes and engage in environmentally friendly behaviors. This means nature-based outdoor learning cultivates a sense of wonder, curiosity, and environmental stewardship among learners, preparing them to become active participants in creating a sustainable present and promising future (Wattchow and Brown, 2011).

The out-of-school learning, global challenges, and science education

As environmental and sustainable development issues have become a priority for many countries, out-of-school science programs closely intertwined with nature are increasingly favored for offering active, hands-on experiences that positively influence students' environmental perceptions and foster their ability to generate solutions to these pressing challenges (Kaçar et al., 2020). As classrooms may not adequately equip students with real-life experiences, particularly in areas critical to sustainable living and development (Aslan et al., 2023), out-of-school learning environments are getting recognized as highly effective channels for achieving educational outcomes related to a sustainable future (Achiam, 2023).

Outdoor learning environments, which can be categorized as formal, non-formal, and informal settings (Yıldırım, 2020), have strong potential to promote sustainability and prepare citizens for a sustainable future (Evans and Achiam, 2021). Furthermore, these environments positively affect students' attitudes toward school courses (Duatepe-Paksu et al., 2022) and are valuable for fostering students' interest in science, technology, engineering, and mathematics (Neher-Asylbekov and Wagner, 2023), which can, in the long run, contribute to solutions for climate change and the energy crisis. However, the current science courses, confined to school environments, are often boring, irrelevant, and outdated, designed primarily to educate a minority of future scientists (Braund and Reiss, 2006, p. 1373). However, research indicates that out-of-school learning environments significantly influence the development of students' science skills, serving as a supportive strategy for a broad range of students (Faber Taylor et al., 2022). The integration of these environments into science education has been shown to profoundly boost students' motivation to learn science (Yıldırım, 2020).

Effective science education can be realized through various venues such as field trips, museums, zoos, aquariums, planetariums, theme parks, sports centers, botanical and nature gardens, hospitals, industrial institutions, factories, libraries, and various other outdoor learning environments, including online tools (Yıldırım, 2018; Oktay, 2022). These venues offer active learning experiences that are challenging to replicate within the school setting (Taylor and Caldarelli, 2004) and have been found to support the learning achievement of outdoor learners more effectively compared to their classroom-based peers (Avcı and Gümüş, 2020; Sontay and Karamustafaoğlu, 2018). Well-structured out-of-school education opportunities can shift the source of learning motivation from external to intrinsic, thereby encouraging a deeper engagement with the subject matter (Salmi et al., 2023), contributing to high-quality and interdisciplinary science education.

Teacher leadership for out-of-school learning environments

Out-of-school education environments provide rich and concrete experiences that complement traditional classroom settings (Aslan et al., 2023; Bozdoğan et al., 2015; Ertuğrul and Karamustafaoğlu, 2020). As educational systems recognize the shortcomings of test-dominated education, they realize that out-of-school learning experiences enhance students' physical and mental health, listing many other positive effects (Mann et al., 2022). However, teachers often face challenges in recognizing the potential of outdoor learning while confined to indoor settings; therefore, they must be actively encouraged to step outside, explore, and engage with out-of-school education opportunities through hands-on learning experiences (van Dijk-Wesselius et al., 2020). To maximize the benefits of these environments, teachers should focus on providing concrete experiences, defined as spontaneous, in-the-moment encounters where learners take full or shared responsibility for the learning process, engaging socially, cognitively, and physically (Lesseig et al., 2023).

Despite their frequent involvement in field trips, many teachers often lack the pedagogical knowledge and experience necessary to fully leverage these opportunities (Tal and Morag, 2009). This gap highlights the critical need for teacher leadership that extends beyond the classroom—leadership that is essential for cultivating a new culture of education characterized by creativity and ingenuity. Teachers who embody an entrepreneurial mindset and strong leadership qualities can maintain deep connections with their students while leading initiatives beyond the classroom, thereby developing and disseminating the best policies and practices for 21st-century teaching and learning (Berry, 2013, p. 309).

Interestingly, non-formal learning environments are not solely confined to physical places; recent developments in the non-formal learning field have increasingly leveraged digital platforms to facilitate human-computer-human interactions, which help bridge formal and informal learning spaces. This approach emphasizes the creation of digital learning communities where educators and learners collaborate as co-participants (Prestridge et al., 2024). Indeed, elderly students need flexibility in learning, demonstrating the need for learning environments that allow participation without the need to come to the school for face-to-face meetings (Valtonen et al., 2020). To broaden outdoor learning to this scope, schools need teacher leaders who learn, grow, and go beyond the existing confinements, not just changing their teaching practices in class and outside the classroom.

Nature and science based out-of-school learning environment (NaSOSLE)

NaSOSLE programs include structured after-school, weekend, and summer activities focusing on nature and science. These programs involve visits to nature centers, botanical gardens, forests, rivers, and other natural settings, encouraging students to question their experiences, engage in meaningful conversations, and make observations of the natural world. Furthermore, nature and science-integrated programs, guided by effective teacher leadership and aligned with updated curriculums, foster critical thinking and responsible attitudes toward the natural environment (Braund and Reiss, 2006).

Learners benefit most from an interdisciplinary, thematic approach to learning, where they engage actively and collaboratively (Demiralp, 2007). Thus, the NaSOSLE approach should be carefully structured around thematic, outdoor, practice-based activities, allowing students to connect curriculum subjects with their everyday lives (Aslan and Demircioğlu, 2018). As a result, these environments promote the development of social and collaborative skills while strengthening self-concept factors (Mann et al., 2022). Additionally, NaSOSLE programs directly move students into active roles. Rather than being passive recipients of information, students in this approach are actively engaged with their surroundings, which allows for a deeper understanding of the concepts and topics they encounter (Beames et al., 2023). For example, instead of merely reading about ecosystems in textbooks, students can explore a local forest or garden to directly observe the relationships between the diversity of organisms, their habitats, and other living things.

NaSOSLE: content and pedagogy perspectives

To enhance science and nature education, it is essential to have a strong understanding of teaching approaches, methods, and techniques from a pedagogical perspective. Li et al. (2005) emphasize the importance of a multi-disciplinary approach informed by current learning theories, advocating that students learn concepts more effectively as an integrated whole rather than as fragmented ideas. Wistoft (2013, p.125) further highlights that outdoor learning environments, when paired with dedicated teaching, can foster a strong desire to learn in students. To cultivate this desire and ensure holistic concept acquisition, outdoor learning environments provide firsthand opportunities for students to see, touch, play, and listen in a concrete manner. Accordingly, increasing visits to these environments, coupled with the proper subject matter knowledge and effective teacher leadership, can significantly contribute to the development of students' cognitive, affective, and physical skills, as well as their socialization (Yıldırım, 2018). However, if out-of-school learning is too limited and lacks the appropriate pedagogical strategies, the potential benefits of these resources may be lost (Schauble et al., 2003; Tal, 2012). Therefore, it is crucial to guide teachers in adopting a pedagogical mindset that encourages students to fully explore and engage with out-of-school learning environments.

NaSOSLE from continuous professional development perspectives

Effective teacher education enhances science teaching and learning, particularly when integrating out-of-school activities with theoretical and practice-based experiences (Wallace and Loughran, 2012). Teachers equipped with strong NaSOSLE strategies can help students grasp science concepts and engage in scientific inquiry as outdoor education promotes diverse perspectives, authentic problem-solving, real-world environments, inquiry-based learning, and scaffolding (Ratinen et al., 2021).

Ensuring ongoing support through continuous professional development is a priority to effectively facilitate nature and science-based out-of-school learning opportunities. Such a development program, supported by experts and relevant stakeholders, can greatly empower both in-service teachers and students in out-of-school learning environments (Burridge and Carpenter, 2013).

Teachers should be supported on four main pillars of out-of-school education: extension (taking learning to natural environments that are more relevant to the subject being taught), development (personal growth through problem-solving), content (topics such as natural environments and traditional subject matter related to outdoor activities), and teaching methodology (methods used in out-of-school activities to teach related subjects and concepts) (Bunting, 2006; McComas, 2014).

With ongoing professional development rooted in out-of-school learning research, teachers can employ numerous pedagogical practices that support immersive outdoor learning experiences. Neville et al. (2023) propose an evidence-based model to enhance outdoor teaching practices, emphasizing three key themes: (i) the environment, (ii) the learner, and (iii) the educator, each of which should be examined in detail to develop teachers' pedagogical repertoire.

Teachers can consider the model's three interconnected domains while developing and organizing outdoor learning activities, which can serve as a nexus for nature and science-based out-of-school learning settings from the standpoint of continuing professional development.

NaSOSLE from education technology and its perspectives

Recent advancements in technology, such as augmented reality (AR) and virtual reality (VR), are transforming out-of-school learning environments, particularly in science education. AR has shown promise in enhancing motivation and academic achievement across various educational settings at home and outside. Studies demonstrate that integrating AR with mobile technologies can bridge the gap between formal and informal learning environments, enhancing student engagement and knowledge retention (Hsiao et al., 2016). AI technologies also present new opportunities for enhancing non-formal science learning experiences. AI has been used to create contingent interactions in educational media, improving students' engagement and understanding of scientific concepts (Xu et al., 2022). By simulating real-world environments, AI can help model complex scientific phenomena, creating "microworlds" that provide interactive learning experiences (Good, 1987). AI can complement traditional teaching methods, making educational experiences more personalized and human-centric (North et al., 2024).

In addition to AI, the integration of mobile technologies in non-formal learning environments has been shown to support science education by providing students with flexible, on-the-go learning tools (Scanlon et al., 2005). Mobile devices can facilitate access to educational content, enabling students to engage with science learning in informal settings like museums, zoos, and nature reserves. While research on mobile technologies in informal science education is still limited, initial findings suggest they hold significant potential for enhancing student engagement and fostering deeper connections to scientific concepts (Scanlon et al., 2005).

The integration of mixed reality technologies—such as Embodied Mixed Reality Learning Environments (EMRELEs)—has also demonstrated learning gains in science subjects like chemistry and disease transmission (Johnson-Glenberg et al., 2014). These technologies create immersive, interactive learning experiences that support both cognitive and affective learning, as they engage students in hands-on, inquiry-based activities. The eLuna Framework, which combines mixed reality with narrative game-based learning, has been extended to improve science learning outcomes, particularly in science centers (Breien et al., 2022). Similarly, immersive AR simulations in science centers have been found to support social learning, with parents guiding their children through scientific reasoning and problem-solving (Tscholl and Lindgren, 2016).

In conclusion, while education technology holds great promise for enhancing outdoor and adventure education, its integration into these settings must be approached with caution and responsibility. Educators and researchers must work collaboratively to ensure that education technology tools are used in ways that enhance the learning experience without compromising the core values of outdoor education, such as experiential learning, physical activity, and social-emotional development.

Research questions

The purpose of this study is to develop and validate a comprehensive framework for Nature and Science-Based Out-of-School Learning Environments (NaSOSLE). This framework encompasses three key aspects: Content, Pedagogy, and Continuous Professional Development. By gathering expert opinions through a Delphi study, we aim to achieve consensus on these aspects and provide a robust foundation for implementing NaSOSLE in educational settings.

To accomplish this aim, the study addresses the following research questions:

1. How do experts conceptualize and define NaSOSLE?
2. What specific content areas and pedagogical approaches should be included in the NaSOSLE framework?
3. In what ways, does NaSOSLE contribute to the professional development of teachers?

Methods

This study employs a mixed-methods approach, specifically the exploratory sequential design, as illustrated in Fig. 1. This design allows for the integration of both qualitative and quantitative data (Creswell, 2014), providing a comprehensive understanding of NaSOSLE.

The sample of delphi study. The sample of research was determined by criterion sampling, which is one of the non-random sampling types. Sampling criteria were determined as "to have experience of out-of-school learning environment", "to have worked in the profession for at least 5 years", "to have trained in

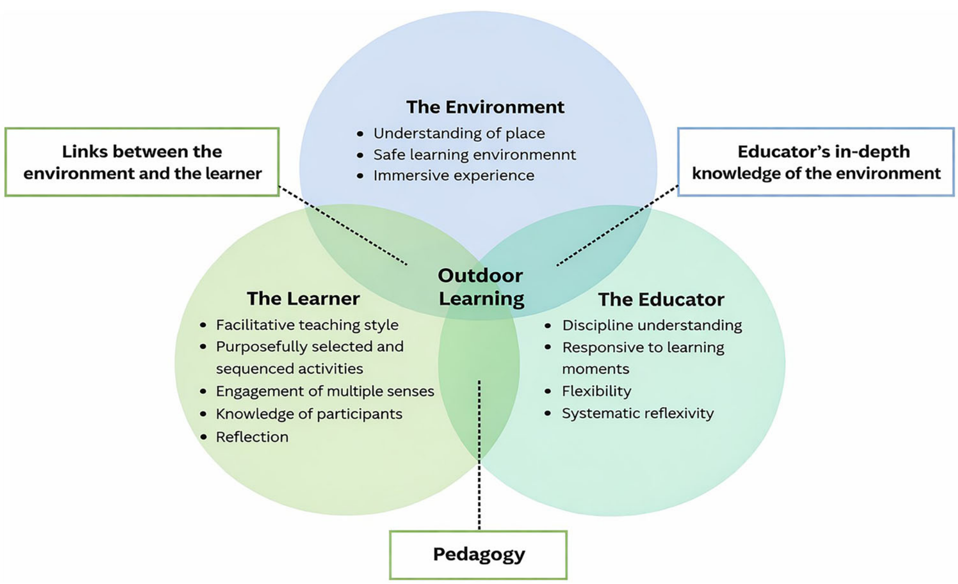

Fig. 1 Components of Outdoor Learning. Pedagogical practices that support outdoor learning experiences (Directly taken from Neville et al. 2023, p.6).

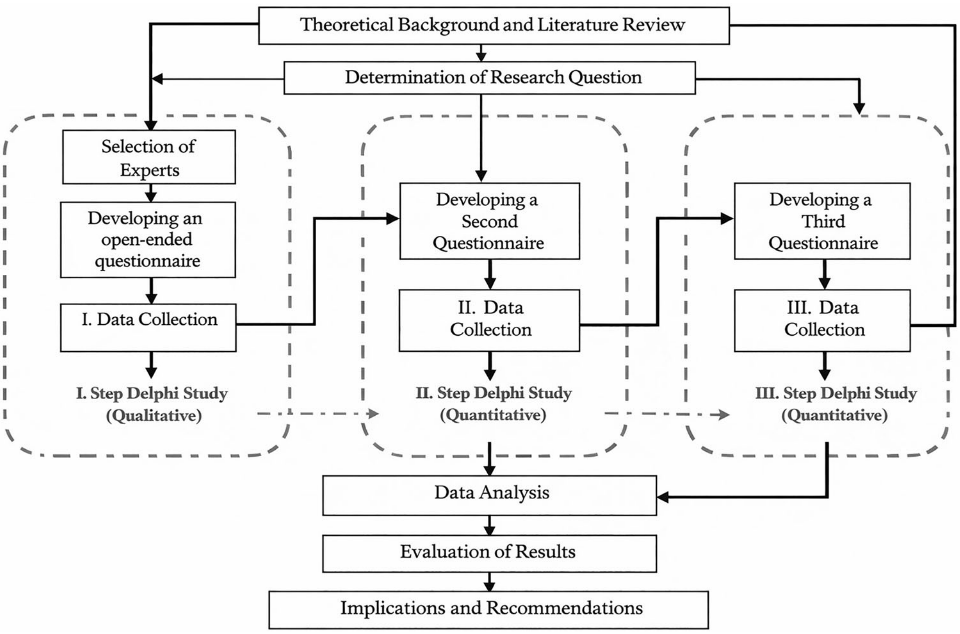

Fig. 2 Theoretical Background and Research Methodology. Exploratory design and process of the delphi study (based on Creswell and Clark 2006, p. 73; Kaya and Elster, 2019, p. 9).

out-of-school learning environments" and "being a volunteer to take part in work on this study".

The study's working group consists of a diverse panel of experts, including mentor teachers, educators, and academicians from various disciplines. This diverse group was deliberately selected to ensure maximum variation in perspectives and to collect rich, multifaceted data on NaSOSLE. Including experts from different backgrounds allows for a more comprehensive and nuanced understanding of the framework's potential applications and impacts.

The experts included in the sample of the study are selected according to specific criteria (work experience, work status (like educators, academicians and mentor teachers) and are from different disciplines. Although the size of sample is determined to be of ideal size before the study, it is observed that the size of expert participation is varied when data are collected based on a voluntary. The sample size of participants in this study to be adequate according to the literature. It is seen that the sample size in similar studies is also a certain number. For instances, Zawacki-Richter (2009) conducted a Delphi study with a final expert panel comprising 25 individuals from Nineteen of these experts participated in both rounds of the study, with data collection spanning 4 months. Another study is to conduct a Delphi study in the field of nursing, involving 12 respondents who self-identified as having expertise in various areas such as nursing education, administration, research, clinical practice, theory, and policy (Davis et al., 2014).

The process of delphi study. As shown in Fig. 1, the exploratory sequential design, aligned with the Delphi study, was employed to elicit expert opinions regarding the concept of NaSOSLE.

In this study, as depicted in Fig. 2, the Delphi study was conducted in three consecutive steps. First, qualitative data was collected. Following the analysis of the first Delphi study, an online quantitative data tool was developed in the second step. After analyzing the data collected in this step, the final quantitative data tool was prepared for the third step of the Delphi Study.

First round. The sample of the first step Delphi study was carried out with the participation of 15 experts who work as mentor teachers, educators, and academicians. Upon the feedback of two field experts/academics (communicative validation), the final version of the semi-structured interview form consisting of ten questions was used. To reveal expert consensus, the themes and subthemes of each question in both the 2nd and 3rd rounds were used from the results obtained from the interviews. Each question was treated as a theme. The subthemes of each (question) theme formed the substructure as items.

Table 1 Demographic characteristics.

Demographic characteristics		*N*
Gender	Female	9
	Male	6
Major	Pre-School Education	4
	Elementary School Education	4
	Subject-Matter Education	7
Work experience	6–10 Years	5
	11–15 Years	7
	16 years and above	3
Having published related to out-of-school learning	Yes	5
	No	10

As seen in Table 1, in the sample of the first round of the Delphi study, 60% were women, and 40% were men. In this round, the opinions of experts working at different education levels (approximately 53% pre-school and classroom teachers, 47% branch teachers) were taken, and approximately 33% of experts had research on out-of-school learning.

Second round. Before conducting the second round of the Delphi study, a pilot study was carried out to evaluate validity and reliability. Responses collected from the first round were transformed into Likert-scale items, utilizing a 7-point Likert scale ranging from "Strongly agree" (7) to "Strongly disagree" (1). Additionally, experts were invited to provide feedback on each item in the questionnaire, which helped determine endorsement levels. To ensure the validity and reliability of the questionnaire, feedback was solicited from two academics in environmental

Table 2 Reliability analysis summary (Cronbach's alpha and omega coefficients).

Reliability statistics

Questions	Cronbach's Alpha	Omega	*N* (number of items)
Question 1: Definition of Nature and Science Based Out-of-School Learning (NaSOSLE)	0.79	0.80	10
Question 2: Features of NaSOSLE	0.81	0.79	13
Question 3: Examples of Nature and Science Based Out-of-School Learning	0.74	0.73	5
Question 4: Importance of NaSOSLE	0.91	0.94	11
Question 5: Contexts related to NaSOSLE	0.87	0.86	10
Question 6: Teaching methods for NaSOSLE	0.88	0.87	20
Question 7: Materials in NaSOSLE	0.91	0.92	7
Question 8: Importance of NaSOSLE for Continuing Professional Development	0.94	0.94	7

Table 3 Indicator of consensus (Şahin, 2009).

Consensus	Indicator of consensus
Consensus Criteria	If median ≥ 5 and DBQ ≤ 1.5, If median ≥ 5 and DBQ ≤ 1.5 and 5-7 frequencies ≥ % 70
Not reach the consensus	If median ≤ 3 and DBQ ≤ 1.5., If median ≤ 3 and DBQ ≤ 2.5 and 1-3 frequencies ≥ % 70

education and one linguist. A pilot study involving 33 experts was then conducted, with the reliability results presented in Table 2.

As a result of the analysis, Cronbach's Alpha and Omega coefficients were calculated. In addition, a question with an internal consistency of less than 0.70 was completely removed from the questionnaire. The general summary of the validity and reliability coefficients of the questionnaire is seen in Table 2. Cronbach's Alpha coefficients are between 0.74 and 0.94. Omega coefficients are between 0.73 and 0.94. The results indicate that the statistics are reliable. After a pilot study (reliability analysis), the second round of the Delphi study involving 14 experts was conducted.

Third round. The items in the second and third questionnaires were identical. The statistical data, such as standard deviation, arithmetic mean, and quartile difference, taken from the second-round questionnaire were shared with 20 experts in the third-round questionnaire. This allowed the experts to interpret each item while evaluating the statistical data from the second round.

Data analysis. In the first step of the Delphi study, a final version of the semi-structured interview form consisting of ten questions was utilized, following feedback and review from two scientists (communicative validation). The content analysis method was used to analyze the data obtained in the first round.

In the second and third steps of the Delphi study, statistical analysis was conducted to determine if consensus was reached. The tables present mean (x), median (med), standard deviation (sd), the difference between quarters (DBQ), consensus difference between the second and third round analyses (cons. dif.), response percentage, consensus (cons). According to Table 2, consensus is considered achieved if the median is equal to or greater than 5, the DBQ is equal to or less than 1.5, and the frequencies of "agree" (Likert-scale between 5 and 7) are equal to or greater than 70% (as shown in Table 3).

Results

The results from the first round were utilized in both the 2nd and 3rd rounds. Each question represents a theme, and each item represents a code. Consequently, the first-round results are not included in this section. Percentage and frequencies were calculated and presented for the second and third rounds. Expert responses on the 7-point Likert scale were categorized into three groups: 1–3 (no consensus), 4 (neutral), and 5–7 (consensus). Furthermore, the number of experts participating in the second and third Delphi rounds was 14 and 20, respectively.

At the end of the Delphi study, as indicated in Table 4, a consensus was seen on seven items related to views on the definition of nature and science based out-of-school learning. However, there was no consensus on the remaining four items (moving beyond traditional learning, enables curriculum-based learning, and it is a self-directed and self-managed process, and students are happy).

As shown in Table 5, there occurred a consensus on all items except for "a place where children spend time outside of school.", "this environment is structured or semi-structured" and "an environment without a specific space (unstructured)." While there was an agreement about "any place where there is a connection with nature", there was no agreement in second round of Delphi.

As shown in Table 6, a consensus was spotted on all items except for the science museum. When the results of the second and third Delphi rounds are compared, the percentage agreement on all items increased.

As shown in Table 7, there was a consensus on all items regarding the importance of nature and science-based out-of-school learning.

As indicated in Table 8, at the conclusion of the Delphi study, a consensus was reached on all items regarding the contexts related to nature and science-based out-of-school learning.

As indicated in Table 9, a consensus was seen on all items regarding the contexts related to teaching methods for nature and science based out-of-school learning. However, there was no agreement about project-based learning in the second round of Delphi.

As shown in Table 10, a consensus was seen on all items except for laboratory materials and technological tools. When comparing the results of the second and third Delphi rounds, the percentage agreement on all items, except for the first-aid kit, increased.

As indicated in Table 11, at the end of the Delphi study, a consensus was seen on all items regarding the contexts related to the importance of nature and science based out-of-school learning environments for continuing professional development.

Discussion and conclusions

This Delphi study offers significant insights into outdoor learning, addressing its definition, content, pedagogy, professional

Table 4 Views on the definition of nature and science-based out-of-school learning (questionnaire results).

Item	Round	x̲	Sd	Med	DBQ	Responses f (%)			Cons based on criteria
						Cons.	Neut.	No Cons.	
Realized in the natural space	**2.R**.	6.50	1.09	7.00	0.25	12(85.7)	2 (14.3)	-	**Yes**
	3.R.	6.45	0.24	7.00	1.00	19 (95.0)	-	1 (5.0)	
Learning through living	**2.R**.	6.79	0.80	7.00	0.00	13 (92.9)	1 (7.1)	-	**Yes**
	3.R.	6.85	0.08	7.00	0.00	20 (100)	-	-	
Moving beyond traditional learning	**2.R**.	6.71	0.83	7.00	0.00	13 (92.9)	1 (7.1)	-	**Yes**
	3.R.	6.10	0.26	7.00	2.00	17 (85.0)	3 (15.0)	-	**No**
Observing nature	**2.R**.	6.79	0.43	7.00	0.25	14(100)	-	-	**Yes**
	3.R.	6.70	0.16	7.00	0.00	19 (95.0)	1 (5.0)	-	
Learning by exploring nature	**2.R**.	6.86	0.54	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.95	0.05	7.00	0.00	14 (100)	-	-	
Learning that takes place in spaces without four walls	**2.R**.	6.71	1.07	7.00	0.00	13 (92.9)	-	1 (7.1)	**Yes**
	3.R.	6.30	0.25	7.00	1.00	17 (85.0)	3 (15.0)	-	
Learning emerges from certain patterns	**2.R**.	6.43	1.09	7.00	1.00	12 (85.7)	2 (14.3)	-	**Yes**
	3.R.	6.35	0.24	7.00	1.00	17 (85.0)	3 (15.0)	-	
Enables curriculum-based learning	**2.R**.	5.86	1.61	7.00	2.00	12 (85.7)	-	2 (14.3)	**No**
	3.R.	5.60	0.32	6.00	2.00	16 (80.0)	1 (5.0)	3 (15.0)	
Different disciplines are considered as a whole.	**2.R**.	6.71	0.83	7.00	0.00	13 (92.9)	1 (7.1)	-	**Yes**
	3.R.	6.65	0.13	7.00	1.00	20 (100)	-	-	
It is a self-directed and self-managed process.	**2.R**.	6.07	1.54	7.00	2.00	12 (85.7)	1 (7.1)	1 (7.1)	**No**
	3.R.	6.10	0.23	6.00	1.75	18 (90.0)	2 (10.0)	-	
Students are happy	**2.R**.	-	-	-	-	-	-	-	**No**
	3.R.	6.10	0.32	7.00	1.75	17 (85.0)	2 (10.0)	1 (5.0)	

Table 5 Features of NaSOSLE (questionnaire results).

Item	Round	x̲	Sd	Med	DBQ	Responses f (%)			Cons based on criteria
						Cons.	Neut.	No Cons.	
Learning through living	**2.R**.	7.00	0.00	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.90	0.07	7.00	0.00	20 (100)	-	-	
Allowing individuals to learn through their own observations.	**2.R**.	6.92	0.27	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.80	0.09	7.00	0.00	20 (100)	-	-	
An environment where students are more open to learning	**2.R**.	7.00	0.00	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.65	0.24	7.00	0.00	18 (90.0)	1 (5.0)	1 (5.0)	
A place where children spend time outside of school	**2.R**.	5.86	1.41	6.00	2.00	13 (92.9)	-	1 (7.1)	No
	3.R.	5.58	0.40	6.00	2.00	16 (80.0)	1 (5.0)	3 (15.0)	
It should complement learning in school	**2.R**.	6.57	0.85	7.00	0.50	14(100)	-	-	Yes
	3.R.	6.45	0.20	7.00	1.00	19(95.0)	1 (5.0)	-	
This environment is structured or semi-structured	**2.R**.	5.93	1.14	6.00	2.00	12(85.7)	2(14.3)	-	No
	3.R.	5.80	0.34	6.00	2.00	17(85.0)	-	3 (15.0)	
An environment without a specific space (unstructured)	**2.R**.	5.14	1.83	5.50	3.00	8 (57.1)	4 (28,6)	2 (14.3)	**No**
	3.R.	6.05	0.27	6.50	2.00	18 (90.0)	1(5.0)	1 (5.0)	
Any place where there is a connection with nature	**2.R**.	6.14	1.23	7.00	2.00	13 (92.9)	-	1 (7.1)	**No**
	3.R.	6.30	0.21	6.00	1.00	19 (95.0)	-	1 (5.0)	**Yes**
An environment in which achievements are transferred more effectively.	**2.R**.	6.36	1.08	7.00	1.00	12 (85.7)	2 (14.3)	-	**Yes**
	3.R.	6.30	0.24	7.00	1.00	19 (95.0)	-	1 (5.0)	
An environment that supports sustainable living	**2.R**.	7.00	0.00	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.85	0.08	7.00	0.00	20 (100)	-	-	
An environment that supports sustainable development.	**2.R**.	6.79	0.58	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.35	0.26	7.00	1.00	18 (90.0)	1 (5.0)	1 (5.0)	
It is an environment that allows science to be learned anywhere	**2.R**.	7.00	0.00	7.00	0.00	14(100)	-	-	**Yes**
	3.R.	6.65	0.15	7.00	0.75	20 (100)	-	-	
A place provides freedom for students	**2.R**.	6.93	0.27	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.80	0.09	7.00	0.00	20 (100)	-	-	

development, and methodological approaches. The research aimed to establish a clear framework for the NaSOSLE concept and sought to achieve expert consensus on its core elements. Utilizing the Delphi technique, the study involved multiple rounds of iterative questionnaires. While consensus was achieved on the majority of items, 6 out of 86 items remained with non-consensus, highlighting areas requiring further investigation or discussion.

The three-step Delphi process demonstrated that outdoor learning experiences in nature foster critical thinking and problem-solving skills. These experiences encourage learners to ask questions, make observations, work with others, solve problems, and analyze their findings. Additionally, they promote a sense of discovery and exploration. A related study that complements these findings is a systematic literature review on out-

Table 6 Examples of nature and science-based out-of-school learning (questionnaire results).

Item	Round	x	Sd	Med	DBQ	Responses f (%)			Cons based on criteria
						Cons.	Neut.	No Cons.	
Forests	**2.R**.	6.71	0.61	7.00	0.25	14 (100)	-	-	Yes
	3.R.	6.75	0.12	7.00	0.00	20 (100)			
National Parks	**2.R**.	6.71	0.73	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.55	0.19	7.00	1.00	19 (95.0)	1 (5.0)	-	
Nature and Science based Camping	**2.R**.	6.79	0.58	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.70	0.11	7.00	1.00	20 (100)	-	-	
Science Museums	**2.R**.	5.79	1.37	6.00	2.00	12 (85.7)	-	2 (14.3)	No
	3.R.	5.90	0.29	6.00	2.00	18 (90.0)	1 (5.0)	1 (5.0)	
Museums of Natural History	**2.R**.	6.21	1.19	7.00	1.25	13 (92.9)	-	1 (7.1)	Yes
	3.R.	6.20	0.20	6.00	1.00	19 (95.0)	1 (5.0)	-	

Table 7 Importance of nature and science-based out-of-school learning (questionnaire results).

Item	Round	x	Sd	Med	DBQ	Responses f (%)			Cons based on criteria
						Cons.	Neut.	No Cons.	
It allows learning to take place in natural environments.	**2.R**.	6.93	0.27	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.58	0.19	7.00	1.00	19 (94.7)	1 (5.3)	-	
It allows students to support their curiosity.	**2.R**.	6.86	0.53	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.68	0.13	7.00	1.00	19 (100)	-	-	
It allows students to develop their cognitive, emotional and social skills.	**2.R**.	6.93	0.27	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.80	0.92	7.00	0.00	20 (100)	-	-	
Students have the opportunity for self-discovery.	**2.R**.	6.93	0.27	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.45	0.19	7.00	0.75	19 (95.0)	1 (5.0)	-	
It offers the opportunity to work collaboratively.	**2.R**.	7.00	0.00	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.65	0.17	7.00	0.75	19 (95.0)	1 (5.0)	-	
Allows students to develop awareness of nature	**2.R**.	7.00	0.00	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.70	0.13	7.00	1.00	20 (100)	-	-	
Support students' interests.	**2.R**.	6.57	0.85	7.00	0.50	14 (100)	-	-	**Yes**
	3.R.	6.55	0.11	7.00	0.75	20 (100)	-	-	
Makes students more motivated to learn	**2.R**.	6.93	0.27	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.60	0.18	7.00	1.00	19 (95.0)	1 (5.0)	-	
Enables peer learning	**2.R**.	6.86	0.53	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.45	0.22	7.00	0.75	19 (95.0)	-	1(5.0)	
Enables the establishment of a daily life relationship	**2.R**.	6.79	0.58	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.70	0.13	7.00	0.75	20 (100)	-	-	
Enables the concretization (memorability) of training experiences	**2.R**.	6.93	0.27	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.80	0.09	7.00	0.00	20 (100)	-	-	

of-school science learning environments by Neher-Asylbekov and Wagner (2023). This study focuses on the factors that influence students' interest in out-of-school science programs, aligning with the present study's emphasis on engaging students in nature and science-based experiences. It highlights that factors such as autonomy, relevance, hands-on activities, and social interactions contribute to students' interest in out-of-school science learning environments.

In this study, the framework of NaSOSLE consists of three interconnected spheres: *Content, Pedagogy*, and *Continuous Professional Development*. Content refers to the specific knowledge and skills learners are expected to acquire in outdoor learning environments. Pedagogy emphasizes the teaching and learning strategies most effective in these settings. Continuous Professional Development focuses on the ongoing learning and development of educators, enhancing their abilities to facilitate outdoor learning experiences. The study also underscores the importance of environmental literacy and sustainability in outdoor learning. Environmental literacy entails understanding and valuing the environment while equipping learners with the knowledge, skills, and attitudes needed to address environmental challenges. Sustainability and sustainable development are pivotal concepts, as they inspire learners to cultivate a lifelong commitment to sustainability and nature conservation.

Overall, the study highlights the numerous benefits and importance of outdoor learning in nature and provides key insights into the framework of NaSOSLE. It emphasizes the necessity of ongoing professional development for educators and the critical integration of environmental literacy and sustainability into outdoor learning experiences. However, despite these benefits, outdoor learning faces several challenges, such as accessibility, limited resources, and the demand for high-quality and adaptive teacher training. Additionally, societal perceptions and institutional regulations may also influence the successful implementation of non-formal learning programs (Grindheim et al., 2021). The study emphasizes the growing need for further research to identify the ideal conditions and best practices for outdoor learning, ensuring diverse educational goals and contexts are effectively met (Mann et al., 2022).

On the aspect of its *definition* in the study, NaSOSLE are defined as educational settings outside of traditional school environments that incorporate nature and science-related activities. These environments offer students opportunities for hands-on learning experiences, fostering a deeper understanding of the

Table 8 Contexts related to NaSOSLE (questionnaire results).

Item	Round	x̲	Sd	Med	DBQ	Responses f (%)			Cons based on criteria
						Cons.	Neut.	No Cons.	
Sustainability (sustainable development and life, etc.)	**2.R**.	6.71	0.61	7.00	0.25	14 (100)	-	-	Yes
	3.R.	6.50	0.21	7.00	1.00	18 (90)	2 (10)	-	
Global and local environmental problems	**2.R**.	6.64	0.93	7.00	0.00	13 (92.9)	1 (7.1)	-	Yes
	3.R.	6.65	0.11	7.00	1.00	20 (100)	-	-	
Socio-scientific issues	**2.R**.	6.57	0.76	7.00	1.00	14 (100)	-	-	Yes
	3.R.	6.50	0.15	7.00	1.00	20 (100)	-	-	
Scientific Process Skills	**2.R**.	6.71	0.61	7.00	.25	14 (100)	-	-	**Yes**
	3.R.	6.50	0.19	7.00	1.00	19 (95.0)	1 (5.0)	-	
Environmental Education	**2.R**.	6.86	0.54	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.75	0.10	7.00	0.75	20 (100)	-	-	
Recycling	**2.R**.	6.93	0.27	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.60	0.13	7.00	1.00	20 (100)	-	-	
Social perspectives (interrelationship of environment, society, and technology, etc.)	**2.R**.	6.64	0.75	7.00	0.25	14 (100)	-	-	**Yes**
	3.R.	6.50	0.14	7.00	1.00	20 (100)	-	-	
Development of environmentally-friendly behavior (Energy Saving, Use of Renewable Energy, Protection of Nature, Respect for Living Things)	**2.R**.	6.86	0.54	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.80	0.09	7.00	0.00	20 (100)	-	-	
First-aid	**2.R**.	6.93	0.27	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.70	0.13	7.00	0.75	20 (100)	-	-	
Multi-Perspectives Thinking	**2.R**.	7.00	0.00	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.75	0.12	7.00	0.00	20 (100)	-	-	

natural world. Notably, views on the definition of nature- and science-based out-of-school learning draw attention due to their distinctiveness from broader perspectives, which often associate outdoor learning exclusively with natural environments (Miller et al., 2021). However, the experts in this study expand the definition of NaSOSLE, characterizing it as learning that occurs outside traditional settings, beyond the confines of four walls, and independent of rigid, top-down models or curriculum-based instruction. The study highlights NaSOSLE as encompassing learning through various disciplines, encouraging self-regulated learning, and creating environments where students feel happy and engaged. Examples of nature- and science-based out-of-school learning settings also deserve mention, as experts identified diverse locations that extend beyond traditional natural or forested areas.

In terms of *content*, NaSOSLE includes topics related to the natural environment, sustainability, and traditional subject matter connected to outdoor education. It aims to integrate curricular subjects with students' daily lives and foster their understanding of the environment. The content is purposefully aligned with the school curriculum, emphasizing interdisciplinary and thematic learning approaches. Topics related to Nature- and Science-Based Out-of-School Learning extend beyond learning for the sake of learning, integrating practical applications in social, economic, psychological, and environmental issues within communities. Experts identified key contexts, including sustainability, environmental issues, socio-scientific challenges, recycling, social and societal concerns, energy-saving, eco-friendliness, first aid, and analytical thinking skills. This aligns with research highlighting outdoor education's potential to influence societal progress and address community issues (Priest, 1986). Such contexts position NaSOSLE as more than a conventional learning model, demonstrating its ability to transcend traditional boundaries. This approach bridges theoretical knowledge with practical, real-world experiences, enhancing both learning outcomes and retention (Sari et al., 2023; Berek and Mau, 2024). The content of outdoor learning emphasizes ecological and environmental themes, fostering awareness and appreciation of nature. It encourages students to explore and understand natural resources, cultivating a heightened sense of responsibility towards environmental conservation (Tracana et al., 2018; Colaci, 2018).

With regards to *pedagogy*, the approach in NaSOSLE emphasizes active, experiential learning strategies. Students learn by engaging with the natural environment, observing and interacting with living organisms, and exploring different ecosystems. The pedagogical practices include authentic problem-solving activities, inquiry-based learning, and scaffolding techniques. Teachers adopting a thematic approach and out-of-school learning strategies can effectively help students absorb science concepts and develop scientific inquiry skills. A comprehensive review by Waite et al. (2022) examines the benefits of outdoor learning for children's development and well-being, highlighting positive effects on physical health, mental well-being, cognitive and social skills, and environmental awareness. These findings support the argument in the present study regarding the benefits of nature-based out-of-school learning environments, including enhanced self-concept, academic performance, and responsible attitudes towards the environment. Moreover, teaching methods for nature- and science-based out-of-school learning include interdisciplinary teaching, learning by doing, active learning, inquiry-based learning, problem-solving, collaborative learning, contextual and situated learning, project-based learning, the question-and-answer method, game-based learning, drama, and storytelling. In addition to leveraging materials from natural settings, nature-based pedagogy promotes the use of outdoor spaces to support experiential learning, a key factor in developing character and environmental stewardship (Rahmawati, 2017). This pedagogical strategy nurtures values such as environmental care, social responsibility, and cooperation, engaging students meaningfully while connecting activities to their lives. Teachers may also adapt this pedagogy based on local wisdom to ensure relevance and resonance with learners (Rahmawati, 2017). Curricula in this domain are often designed to instill moral compassion, logical thinking, leadership, and entrepreneurial skills. These aim not only to enlighten students, particularly rural youth, about their rights but also to foster independence and social responsibility (Supriyoko et al., 2022). Nature-based pedagogy closely aligns with education for sustainability, aiming to develop students' capacities to critically engage with environmental and social issues. To achieve this, it is

Table 9 Teaching methods for NaSOSLE (questionnaire results).

Item	Round	x	Sd	Med	DBQ	Responses f (%)			Cons based on criteria
						Cons.	Neut.	Cons.	
Teaching approach that will allow different disciplines to be associated with each other	**2.R**.	6.93	0.27	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.65	0.13	7.00	1.00	20 (100)	-	-	
Teaching approach by considering different disciplines as a whole	**2.R**.	6.36	0.93	7.00	2.00	14 (100)	-	-	**No**
	3.R.	6.55	0.17	7.00	1.00	20 (100)	-	-	**Yes**
Learning through living	**2.R**.	6.86	0.53	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.80	0.09	7.00	0.00	20 (100)	-	-	
Invention learning	**2.R**.	6.93	0.27	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.75	0.10	7.00	0.75	20 (100)	-	-	
Active learning	**2.R**.	6.93	0.27	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.85	0.08	7.00	0.00	20 (100)	-	-	
Constructivist Approach	**2.R**.	6.64	0.84	7.00	0.25	13 (92.9)	1 (7.1)	-	**Yes**
	3.R.	6.40	0.27	7.00	1.00	19 (95.0)	-	1 (5.0)	
Inquiry-based learning	**2.R**.	6.86	0.54	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.75	0.10	7.00	0.75	20 (100)	-	-	
Problem-based learning	**2.R**.	7.00	0.00	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.80	0.09	7.00	0.00	20 (100)	-	-	
Collaborative learning	**2.R**.	7.00	0.00	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.75	0.12	7.00	0.00	20 (100)	-	-	
Different methods of discussion (Like argumentation...)	**2.R**.	6.79	0.58	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.65	0.13	7.00	1.00	20 (100)	-	-	
Context-based Learning	**2.R**.	6.71	0.47	7.00	1.00	14 (100)	-	-	**Yes**
	3.R.	6.55	0.15	7.00	1.00	20 (100)	-	-	
Exploring/Learning by Exploring	**2.R**.	6.93	0.27	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.80	0.09	7.00	0.00	20 (100)	-	-	
Hands-on experience	**2.R**.	6.86	0.54	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.70	0.11	7.00	1.00	20 (100)	-	-	
Trip-Observation	**2.R**.	7.00	0.00	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.75	0.10	7.00	0.75	20 (100)	-	-	
Questioning	**2.R**.	6.79	0.43	7.00	0.25	14 (100)	-	-	**Yes**
	3.R.	6.35	0.20	7.00	1.00	19 (95.0)	1 (5.0)	-	
Learning through presentation	**2.R**.	5.36	1.78	6.00	3.25	8 (57.1)	3 (21.4)	3 (21.4)	**No**
	3.R.	5.25	0.45	5.50	3.00	14 (70.0)	2 (10.0)	4 (20.0)	
Project Based Learning	**2.R**.	6.00	1.41	7.00	2.25	11 (78.5)	2 (14.3)	1 (7.1)	**No**
	3.R.	6.10	0.27	6.00	1.00	18 (90)	-	2 (10)	**Yes**
Gamification	**2.R**.	6.86	0.54	7.00	0.00	14 (100)	-	-	**Yes**
	3.R.	6.65	0.11	7.00	1.00	20 (100)	-	-	
Drama/Creative Drama	**2.R**.	6.79	0.80	7.00	0.00	13 (92.9)	1 (7.1)	-	**Yes**
	3.R.	6.70	0.13	7.00	0.75	20 (100)	-	-	
Storytelling	**2.R**.	6.71	0.83	7.00	0.00	13 (92.9)	1 (7.1)	-	**Yes**
	3.R.	6.65	0.13	7.00	1.00	20 (100)	-	-	

Table 10 Materials needed in NaSOSLE (questionnaire results).

Item	Round	x	Sd	Med	DBQ	Responses f (%)			Cons based on criteria
						Cons.	Neut.	Cons.	
Everything encountered in nature	**2.R**.	6.93	0.27	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.80	0.09	7.00	0.00	20 (100)	-	-	
Magnifier	**2.R**.	6,29	1.00	7.00	1.25	13 (92.9)	1 (7.1)	-	Yes
	3.R.	6.50	0.21	7.00	1.00	20 (100)	-	-	
Telescope	**2.R**.	6.29	1.14	7.00	1.00	13 (92.9)	-	1 (7.1)	Yes
	3.R.	6.40	0.22	7.00	1.00	19 (95.0)	-	1 (5.0)	
Microscope	**2.R**.	6.50	0.94	7.00	1.00	13 (92.9)	1 (7.1)	-	Yes
	3.R.	6.50	0.21	7.00	1.00	19 (95.0)	-	1 (5.0)	
Laboratory materials	**2.R**.	5.93	1.44	7.00	2.25	12 (85.7)	1 (7.1)	1 (7.1)	No
	3.R.	6.00	0.24	7.00	2.00	19 (95.0)	-	1 (5.0)	
First-Aid Kit	**2.R**.	6.93	0.27	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.85	0.08	7.00	0.00	20 (100)	-	-	
Technological Tools (Computer and projection, etc...)	**2.R**.	5.43	1.99	6.50	3.25	9 (64.3)	2 (14.3)	3 (21.4)	No
	3.R.	5.25	0.36	5.00	2.75	15 (85.0)	2 (10.0)	3 (15.0)	
Clothing suitable for different weather conditions	**2.R**.	-	-	-	-	-	-	-	Yes
	3.R.	6.70	0.16	7.00	0.00	19 (95.0)	1 (5.0)	-	

Table 11 Importance of NaSOSLE for continuing professional development (questionnaire results).

,Item	Round	$\underline{x}$	Sd	Med	DBQ	Responses f (%)			
						Cons.	Neut.	No Cons.	Cons. based on criteria
Enriching teaching skills	**2.R**.	6.86	0.36	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.70	0.13	7.00	0.75	20 (100)	-	-	
Teachers gain knowledge and experience on what to do before, during and after out-of-school learning	**2.R**.	7.00	0.00	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.75	0.12	7.00	0.00	20 (100)	-	-	
Increased interest and curiosity in different disciplinary fields	**2.R**.	6.93	0.27	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.75	0.12	7.00	0.00	20 (100)	-	-	
Developing classroom management skills in out-of-school learning environment.	**2.R**.	6.93	0.27	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.75	0.12	7.00	0.00	20 (100)	-	-	
Supports teachers' individual development	**2.R**.	7.00	0.00	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.75	0.10	7.00	0.75	20 (100)	-	-	
Supports your interest and attitude towards your profession	**2.R**.	6.79	0.58	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.60	0.17	7.00	0.75	20 (100)	-	-	
Enable to the acquisition of practice-based knowledge and experience.	**2.R**.	7.00	0.00	7.00	0.00	14 (100)	-	-	Yes
	3.R.	6.75	0.12	7.00	0.00	20 (100)	-	-	

vital to acknowledge humanity's historical trajectory towards sustainability and explore actionable ideas to promote sustainable consumption behaviors. For example, programs such as the National Outdoor Leadership School (NOLS) report that immersive nature experiences can foster greater connections to, and intentions for, pro-environment behavior. This demonstrates the critical role of affective-prosocial processes in sustainability (Baird et al., 2022). In summary, structuring learning environments, particularly out-of-school learning environments, should consider the nature of learning and teaching. Such pedagogy often involves interdisciplinary and transdisciplinary learning content aligned with global sustainability goals, further strengthening its relevance and impact.

Continuous professional development is crucial in supporting teachers to effectively implement NaSOSLE. It is recommended that teacher education combine theory and practice-based learning experiences, integrating out-of-school activities. Teachers with effective leadership skills in the NaSOSLE programs should be equipped with skills in four main pillars of out-of-school education: extension, development, content, and teaching methodology. Training programs and workshops can play a vital role in developing teachers' pedagogical skills and enhancing their knowledge of nature- and science-based education. The significance of NaSOSLE for continuing professional development is further emphasized in research. Waite et al. (2015) studied the challenges of outdoor education professional development and identified place-related and mindset-related barriers as significant obstacles. However, the present study highlights positive aspects of professional development in outdoor learning, as shared by experts. These include enriching teaching skills, learning how to design before-during-after activities for outdoor learning, enhancing curiosity for other disciplines, improving classroom management skills in outdoor contexts, supporting professional identity and passion, and gaining practice-oriented teaching experiences. These findings reveal a promising potential for continuous professional development in NaSOSLE. For instance, professional development programs focusing on 'nature play' and 'fundamental movement skills' have been shown to significantly enhance teachers' self-efficacy in engaging children in physical activities in nature. Additionally, European educational policies support teacher training programs that emphasize the significance of interdisciplinary approaches in outdoor education. These programs foster key competencies and lifelong learning skills among learners, reflecting the evolving landscape of modern educational systems. Such programs also help educators familiarize themselves with nature-based play activities and improve their capacity to perform these activities, though their impact may vary depending on the socio-economic backgrounds of the learners (Bai et al., 2020). The "Teaching in Nature" method is another example, emphasizing team-based professional development. This approach supports teachers in designing and applying outdoor learning experiences by integrating natural heritage with the curriculum. It fosters educators' ability to implement high-quality outdoor education (Mannion et al., 2011). For the long-term success of nature education programs, continuous professional development must address the challenges and adapt to evolving educational demands (Jack et a.l, 2005).

Despite numerous objections, education technology has proven to be an essential component of outdoor learning, bridging the natural world with contemporary educational practices (van Kraalingen, 2021; Lai et al., 2013). By utilizing digital tools, students can fully appreciate the outdoors while accessing a wealth of information and interactive materials that enhance their educational experiences. Technology enables educators to create dynamic, engaging, and immersive outdoor learning environments, whether through smartphones and tablets for real-time data collection during field trips, augmented reality apps to identify flora and fauna, or online platforms for virtual field trips to distant locations (Stymne, 2020). As a result, education technology plays a pivotal role in creating meaningful outdoor learning opportunities, preparing children to engage with the natural world in tandem with the digital age. With the integration of artificial intelligence (AI) into non-formal learning contexts (Cooper and Tang, 2024; Ramsurrun et al., 2024), AI and education technology offer tremendous potential for lesson planning, authentic assessments, instructional material creation, and integrating audio and video tools into non-formal science learning environments. Programs like PRO(g)NATURA demonstrate the effectiveness of combining outdoor education with digital learning instruments, such as Scratch programming, to meet diverse instructional needs (de Almeida et al., 2019). This integration bridges theory with real-world applications, elevating the learning experience. For instance, mobile devices enable learners to apply in-class concepts to real-life scenarios, particularly in socio-environmental contexts (Mettis et al., 2022). Similarly, augmented reality and digital media provide immersive experiences that foster interdisciplinary and transdisciplinary learning (de Souza Berchez et al., 2019). Technology is also vital in special needs education, enhancing cognitive, affective, and motor learning domains within nature education settings (Coppola et al., 2021). In science learning, tools like GPS and data management systems enhance field experiences and prepare students for STEM career pathways (Nuss, 2018). During the COVID-19 pandemic, virtual fieldwork programs like #FieldworkLive demonstrated how nature-based learning could continue despite physical restrictions (Stagg et al., 2022). However, teachers must carefully balance technology use to avoid distractions and ensure its application supports nature-based learning objectives (Hills et al., 2024). Evidence-informed approaches, grounded in theories and emerging trends, are essential for effective technology integration (Hills and Thomas, 2021).

AI has the potential to further advance nature-based learning by providing personalized learning experiences, improving navigation, and strengthening connections with the environment. AI systems can track student progress and offer tailored activities that cater to individual needs, ensuring nature-based education remains engaging and efficient (Villegas-Ch et al., 2019). For example, studies like Kid Space utilize AI to design immersive learning opportunities, enhancing engagement while reducing screen time (Aslan et al., 2024). AI can also improve navigation in natural environments through vision-and-language tools, helping learners understand complex settings and enhancing their experiences (Sun et al., 2023). View-based approaches have demonstrated reliability in offering navigation support under varying conditions (Morita et al., 2005). Furthermore, AI tools can play a role in integrating indigenous cultures into education, promoting culturally responsive and environmentally aware learning experiences (North et al., 2024). By incorporating these innovations, educational technology and AI serve as critical enablers of nature-based learning, equipping students with the skills and awareness needed to thrive in a sustainable, technology-driven future.

Last but not least, the Delphi technique employed in this study is a critical methodological aspect of the research on outdoor learning, enabling the collection of insights and opinions from a panel of experts. This methodology allows for the aggregation of diverse perspectives on a specific topic, embodying the idea that "n heads are better than one," as stated by Dalkey (1962). This process provided a comprehensive and nuanced understanding of outdoor learning. The non-consensus items and rounds can be attributed to several factors. The experts or participants involved in this Delphi study came from diverse backgrounds and professional experiences. While this diversity enriched the panel by incorporating a broad spectrum of perspectives, it may have also led to differing interpretations of certain items. These differences may stem from personal beliefs or biases, such as self-serving bias, where participants' judgments are influenced by their own interests (Hussler et al., 2011). Such divergence can make it challenging to achieve consensus on specific topics. Furthermore, some items in the study addressed contentious or complex issues, where experts held strong and differing opinions. For instance, the concept of "a place where children spend time outside of school" did not reach a consensus. While outdoor education is generally recognized as an educational experience conducted outside of the school setting, variations in how experts interpreted this term revealed divergent perspectives that hindered unified agreement. As noted by Keeney et al. (2011), the Delphi technique relies on panels composed of individuals with heterogeneous expertise to capture a wide range of opinions (p. 8). However, this very heterogeneity can increase variability among responses, making consensus more difficult to achieve. Despite these challenges, the Delphi technique remains a valuable tool for gathering expert insights and exploring complex topics like outdoor learning.

Research recommendations. Based on the Delphi research results, the definition and features of NaSOSLE were expanded in accordance with the opinions of the experts. Experts identified forests, national parks, nature- and science-based camps, and museums of natural history as key examples of NaSOSLE spaces. In general, student-centered teaching methods—such as hands-on experiences, various discussion techniques, gamification, and collaborative learning—are recommended for the NaSOSLE teaching process. Moreover, the materials required in NaSOSLE include natural items encountered in outdoor settings, as well as tools like magnifiers, telescopes, microscopes, first-aid kits, and clothing suitable for different weather conditions.

Nature- and science-based out-of-school learning holds significant value for individuals. Nature-based learning should be experiential, allowing learners to actively engage with their environments, thereby developing scientific thinking skills, fostering curiosity, and enhancing mental health (Lane, 2024). However, the importance of repeated engagement and sustained involvement in outdoor settings to strengthen learners' connection to nature and promote sustainable behaviors remains underemphasized (Cosgriff, 2011). Studies should focus on devising different forms of NaSOSLE.

The recommended topics and contexts for nature- and science-based out-of-school learning include sustainability (sustainable development and life, etc.), global and local environmental problems, socio-scientific issues, scientific process skills, environmental education, recycling, social perspectives (interrelationship of environment, society, and technology, etc.), development of environmentally-friendly behavior (energy saving, use of renewable energy, protection of nature, respect for living things), first-aid and multi-perspectives thinking. These expert-recommended topics should be integrated into design and science courses in schools to enhance curriculum relevance and foster a deeper understanding of environmental and scientific concepts among students.

The importance of NaSOSLE for continuing professional development is related to enriching teaching skills, increased interest and curiosity in different trans and inter-disciplinary fields, developing classroom management skills in the out-of-school learning environment, supporting teachers' individual development, their interest and attitude towards your profession, enabling the acquisition of practice-based knowledge and experience, as well as, teachers' gaining knowledge and experience on what to do before, during and after out-of-school learning. Teachers with effective leadership roles attained from professional development programs can better contribute to NaSOSLE programs.

Educators should participate in team-based professional development programs that integrate practical, asynchronous, online, and collaborative learning methods to strengthen their nature-based teaching competencies (Mannion et al., 2011). In both pre-service and in-service contexts, such professional development should prioritize equipping teachers to effectively utilize outdoor learning environments, address diverse learner needs, and seamlessly incorporate nature-based education into curricula (Mann et al., 2022; Jordan and Chawla, 2019). To support these efforts, schools can integrate flexible curricula that blend outdoor and classroom instruction, enabling educators to draw upon local resources such as parks, museums, and nature reserves. Establishing partnerships with these community institutions is particularly beneficial, as it creates authentic, real-world learning experiences that go beyond conventional classroom boundaries. Within these settings, educators might employ hands-on activities, collaborative projects, and nature-based challenges to foster critical thinking, teamwork, and problem-solving. Incorporating structured discussions on environmental issues deepens students' understanding and connects academic content to broader ecological and societal contexts. Moreover, schools should provide teachers with hands-on training in outdoor teaching strategies, interdisciplinary methods, and reflective practices. Such support ensures that educators continuously refine their approaches to enhancing student engagement and learning outcomes. At the policy level, decision-makers can facilitate these initiatives by establishing dedicated outdoor classrooms equipped with scientific instruments, first-aid kits, and other essential tools. Both policymakers and schools can further strengthen students' connections to the natural world by emphasizing long-term outdoor projects and leadership opportunities that encourage sustained involvement. Finally, supporting research on effective nature-based education models is critical for informing and refining broader education policies (Jordan and Chawla, 2019), ensuring that future generations of learners are empowered to understand, appreciate, and preserve the environment. Also, by thoughtfully incorporating education technology, educators can enhance the learning experience without undermining the foundational values of nature-based education.

The success of nature-based education depends on adapting to the needs of diverse learners with varying socioeconomic backgrounds, emphasizing individual differences through comprehensive research and best practices. Researchers and curriculum developers should consider the definition, content, pedagogy, professional development, and methodological aspects when evaluating out-of-school learning environments.

Limitations. The study was conducted in three rounds with the participation of 14–20 experts. While conducting two or three rounds of Delphi iterations with varying panel participants sizes is typical (Manyara et al., 2024), certain studies suggest that additional rounds may be necessary to resolve highly complex or polarizing items, which can be referred to as non-consensus items. Veugelers et al. (2020) propose using multiple additional rounds as a potential strategy to address such challenges. Another issue often encountered in Delphi studies is self-serving bias, where experts favor their previously conceived ideas or those aligned with their interest groups (Veugelers et al., 2020). Despite possibility of these effects in any Delphi study, due to time constraints, the demanding nature of multiple rounds, and the voluntary basis of participation, this study could not extend beyond three rounds or include a larger panel of participants. Future research could address these limitations by focusing on non-consensus items in greater depth, potentially employing extended rounds with larger and more diverse participant groups, or exploring alternative methodologies to facilitate consensus. These strategies could enhance the robustness and comprehensiveness of findings in complex Delphi studies.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Author contributions

All authors, led by the principal investigator, contributed to the study's conception, design, methodology, material preparation, data analysis, writing, review, and editing. Each author reviewed and approved the final manuscript.

Competing interests

The authors declare no competing interests.

Ethical approval

The first ethical approval was obtained from the Ministry of National Education, Teacher Training and Development General Directorate (Approval No. E-20299769-605.99-30628090, dated 02.09.2021), which covered permission for data collection. A second approval was subsequently obtained from the Ibn Haldun University Board of the Scientific Research and Publication Ethics for Social and Human Sciences (Approval No. E-71395021-050.04-63721, dated 10.10.2025) to reconfirm compliance with ethical standards prior to publication. All processes and due regulations were followed in compliance with the Declarations of Helsinki (DoH) and local authorities.

Informed consent

Written informed consent was obtained from all participants prior to data collection on either a digital or a printed form, depending on the participants' proximity to researcher(s). Consent was obtained by the researchers during the data collection period conducted on September 2, 2021 (09.02.2021), and before any study-related procedures were initiated. Participants were fully informed about the purpose of the study, the non-interventional nature of the research, the voluntary nature of participation, and the intended use of the data for research and publication purposes. Participants were informed that their responses would remain confidential, that data would be anonymized and reported only in aggregate form, and that no personally identifiable information would be disclosed. They were also informed that they could decline to answer any question or withdraw from the study at any time without penalty or negative consequences. A copy of the written consent form is provided in the supplementary materials. Additional details regarding the consent procedure are available from the corresponding author upon reasonable request.

Additional information

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