

Reimagining learning environments for children with Autism Spectrum Disorder: The role of nature in regulation, participation, and development: A narrative review

Georgia Katsiaflaka ¹, Pantelis Pergantis ^{2,3,*}, Konstantinos Georgiou ⁴, and Andreas Petropoulos ^{5,6,*}

¹ Department of Education, School of Humanities and Social Sciences, University of Nicosia, 1700 Nicosia, Cyprus

² Net Media Lab and Mind and Brain R&D, Institute of Informatics and Telecommunications, National Centre of Scientific Research 'Demokritos', 153 41 Agia Paraskevi, Greece.

³ Department of Information and Communication Systems Engineering, University of the Aegean, Greece.

⁴ Occupational Therapy Department, School of Health Sciences, University of Western Macedonia, 502 00 Ptolemaida, Greece.

⁵ School of Medicine, National and Kapodistrian University of Athens, "Aghia Sophia" Children's Hospital, 11527 Athens, Greece.

⁶ Department of Physiotherapy, University of Thessaly, 35132 Lamia, Greece.

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Abstract

Background: Children with Autism Spectrum Disorder (ASD) often experience challenges related to sensory processing, emotional regulation, social participation, and engagement within traditional educational environments. Increasing attention has been given to nature-based educational and therapeutic approaches as supportive contexts that may promote regulation, participation, and learning through multisensory, flexible, and meaningful experiences.

Objective: This narrative review explores the role of nature-based activities in supporting the educational, developmental, and well-being needs of children with ASD, with particular emphasis on sensory regulation, social interaction, anxiety reduction, physical activity, executive functioning, and inclusive participation.

Methods: A narrative synthesis of relevant literature was conducted, focusing on studies and theoretical contributions examining nature exposure, outdoor play, gardening, hiking, structured nature-based programs, and related educational or therapeutic interventions for autistic children. The review also considers barriers to implementation, including limited access to natural environments, insufficient professional training, and variability in children's individual sensory and developmental profiles.

Results: The literature suggests that nature-based activities may provide meaningful opportunities for sensory modulation, emotional calmness, social engagement, and active participation. Natural environments appear to offer rich but often less overwhelming sensory input, while activities such as gardening, outdoor exploration, and structured play may support cooperation, communication, attention, autonomy, and motor engagement. However, the evidence base remains heterogeneous, with variation in intervention design, outcome measures, and methodological quality.

Conclusions: Nature should not be viewed merely as an alternative setting for education or therapy, but as a dynamic, occupation-rich environment that can support children with ASD in regulation, participation, and learning. Future research should prioritize longitudinal designs, clearer intervention protocols, individualized approaches, and stronger collaboration between educators, occupational therapists, families, and multidisciplinary teams. Integrating nature-based practices into inclusive educational frameworks may represent a promising direction for supporting the holistic development and well-being of children with ASD.

* Corresponding authors: Pantelis Pergantis and Andreas Petropoulos

Keywords: Autism Spectrum Disorder; Autistic Children; Nature-Based Education; Outdoor Learning; Sensory Regulation; Social Participation; Emotional Regulation; Inclusive Education; Occupational Therapy; Nature-Based Interventions.

1. Introduction

Nature is defined as the sum of natural phenomena and elements, including living organisms, the natural landscape, and the physical forces that interact in our world [1]. This inherent composition of nature not only offers aesthetic value but also acts as a catalyst for mental and physical well-being, as recognized by numerous studies. Research conducted in recent years reveals that contact with the natural environment can have significant beneficial effects on mental well-being and cognitive development, especially in vulnerable populations such as children with autism [2].

Autism is a common neurodevelopmental disorder characterized by qualitative and quantitative deficits in social interaction and communication, as well as repetitive behaviors, persistent interests, and difficulties in sensory processing [3-9]. Children with autism often struggle to adapt to the demands of traditional educational environments and to develop essential social interaction skills [10-13]. These challenges highlight the need for alternative educational approaches tailored to the unique needs of these children. Integrating nature into educational interventions represents a promising strategy that can contribute to improving the quality of life and educational experience of children with autism [14].

Recent studies emphasize nature's role in reducing anxiety, enhancing concentration, and improving sensory processing [15, 16]. Natural settings provide multisensory experiences and motor activities that can alleviate sensory overload in children with autism [17]. For children with autism, who often experience sensory difficulties, nature can serve as an environment that enhances their well-being and development [18].

Nature has the potential to enhance the social skills of individuals with ASD through activities that require cooperation and communication. For example, programs incorporating gardening, exploration of natural environments, and structured play in nature have been proven particularly effective in improving social interaction. These activities provide a less structured yet equally functional setting where children can learn to collaborate and communicate without the pressure often associated with typical school environments [19-21].

The integration of nature into educational interventions is not without challenges. Limited access to natural spaces, lack of appropriate training for educators, and insufficient infrastructure are obstacles that must be overcome [22, 23]. However, incorporating nature into educational settings presents a unique opportunity to align the cognitive, social, and physical needs of children with autism with the beneficial effects of the natural environment.

This study examines the impact of nature on the education of children with autism, aiming to highlight its benefits, challenges, and directions for future research. Through a literature review and the presentation of examples, it will explore how nature can serve as a fundamental tool in supporting the development and well-being of children with autism.

2. Material and methods

This study was a narrative review with a structured literature synthesis. Its goal was to explore how nature-based educational and therapeutic activities can support regulation, participation, learning, and well-being in autistic children. A narrative review was suitable because the existing literature on nature-based approaches for autistic children varies widely in terms of intervention types, settings, participant characteristics, outcome measures, and methods.

Instead of only looking at how effective the interventions were, this review aimed to provide a broader overview of literature. It highlighted key mechanisms, reported outcomes, implementation barriers, and implications for educational and therapeutic practices.

2.1. Search Strategy and Sources

A structured literature search was conducted across major academic databases, including PubMed, Scopus, Web of Science, PsycINFO, and ERIC, with Google Scholar used as a complementary source to identify relevant empirical studies, reviews, and theoretical papers examining nature-based educational and therapeutic approaches for children with ASD. The search concentrated on literature covering outdoor learning, nature exposure, gardening, outdoor play, hiking, forest activities, sensory experiences in natural settings, and nature-based interventions for children on the autism

spectrum. We used various combinations of the following keywords: autism, autistic children, autism spectrum disorder, nature-based interventions, outdoor learning, nature exposure, green space, gardening, outdoor play, sensory regulation, social participation, inclusive education, occupational therapy, and well-being. In addition, a snowballing method was applied by screening the reference lists of relevant studies and theoretical papers to identify further literature examining nature-based educational and therapeutic approaches.

2.2. Eligibility Criteria

We included studies and scholarly sources that addressed at least one of the following areas: nature-based activities involving autistic children; educational or therapeutic use of natural environments; sensory, emotional, social, cognitive, or participation-related outcomes; outdoor learning or play in inclusive or special education contexts; or barriers and facilitators related to using nature-based practices. We excluded sources that did not focus on children or developmental populations, did not address autism or neurodevelopmental needs, were unrelated to nature-based or outdoor contexts, or focused only on general environmental education without relevance to regulation, participation, learning, or therapeutic practices.

2.3. Data Extraction and Organization

We extracted relevant information and organized it into the following categories: type of nature-based activity, target population, setting, reported outcomes, proposed mechanisms of action, and implementation challenges. We grouped nature-based activities into broad categories such as gardening, outdoor play, hiking and exploration, structured educational programs, and therapeutic activities in natural settings. The outcomes of interest included sensory regulation, emotional regulation, anxiety reduction, social interaction, communication, physical activity, executive functioning, concentration, autonomy, and participation in educational or daily life activities.

2.4. Data Synthesis

We used a narrative synthesis approach to integrate findings across the literature. This synthesis focused on identifying recurring patterns, theoretical links, and practical implications rather than providing a quantitative estimate of intervention effectiveness. We paid particular attention to how natural environments can serve as multisensory, flexible, and occupation-rich contexts that encourage autistic children's engagement and participation. We organized the findings thematically around the following areas: sensory processing and regulation; social interaction and participation; emotional well-being and anxiety reduction; physical activity and motor engagement; cognitive and executive functioning; and barriers to implementation in educational and therapeutic settings.

2.5. Methodological Considerations

Given the variety of evidence available, this review does not claim to establish definitive intervention effectiveness. The included literature differs in quality, sample size, intervention duration, outcome measurement, and contextual characteristics. Therefore, we present conclusions cautiously, aiming to highlight promising directions, practical implications, and areas that need further investigation. Future studies should use clearer intervention protocols, longitudinal designs, standardized outcome measures, and more detailed descriptions of participant characteristics and environmental contexts. These methodological improvements would strengthen the evidence base and support the development of more individualized and context-sensitive nature-based practices for autistic children.

3. Theoretical Background

3.1. The Importance of Nature for Psychology and Development

Nature profoundly impacts human psychology and development, offering a wide range of benefits that impact mental health and well-being [24]. Recent research suggests that exposure to natural environments can have significant positive effects on psychological well-being, enhancing the sense of connection with nature and promoting psychological restoration [24, 25]. Nature functions as an ecosystem service provider, offering psychological benefits such as stress reduction and mood improvement, as demonstrated through field experiments in urban areas [24].

Furthermore, the quality and type of natural environment influence psychological well-being. According to [25], certain natural settings provide greater psychological restoration and a stronger sense of connection to nature compared to others. This connection to nature can be enhanced through activities such as forest hiking or participation in nature therapy programs, which have been proven effective in supporting mental health, particularly among children and adolescents with psychological disorders [26].

The concept of biophilia-the innate human tendency to connect with nature-is essential to understanding these benefits. Biophilia extends beyond material and physical support to include aesthetic, spiritual, and cognitive needs. This need for connection with nature may have evolutionary roots, influencing both behavior and psychology [27].

Nature-based therapy, including forest therapy, has been shown to provide significant mental health benefits, reinforcing a sense of place and psychological well-being among participants [26]. Individuals engaging in such therapies report improved mood and reduced symptoms of depression and anxiety, highlighting the therapeutic significance of nature [28].

Modern psychology acknowledges the necessity of a holistic approach that incorporates nature as part of therapeutic and psychological support. The integration of biophilic principles into space design and therapeutic programs can enhance mental well-being and promote health [27]. However, these principles are often applied in a limited and fragmented manner, indicating the need for a more systematic approach [30].

Nature, therefore, is not merely a backdrop for human activity but a vital element that influences our psychology and development. Understanding our relationship with nature can help us develop more effective strategies for promoting mental health and well-being [24-26]. Recognizing this relationship can lead to new psychological and mental health approaches, encouraging the integration of nature into therapeutic processes and everyday life [29].

Further research is essential to better understand how different types of natural environments influence psychology and how this knowledge can be used to promote mental health [25, 26]. Nature provides a powerful tool for psychological restoration and development, and its integration into therapeutic processes can have long-term benefits for society as a whole [31].

The connection with nature may be particularly important in times of crisis, such as climate change, when individuals may experience heightened anxiety and concern [32]. Understanding our relationship with nature can help us develop more sustainable and healthier lifestyles, strengthening our psychological resilience and ability to cope with modern challenges [33].

Overall, nature and psychology are interconnected, and acknowledging this relationship can lead to new approaches in mental health and well-being. The integration of nature into therapeutic processes and the promotion of a connection with the natural environment can provide significant benefits for mental health and human development [34].

3.2. The Fundamental Needs of Individuals with Autism

The quality of life of individuals with autism depends on a range of factors related to education, psychology, and social interactions. The needs of these individuals are multidimensional, requiring comprehensive interventions to improve their living conditions. Research highlights the importance of education and awareness among healthcare professionals regarding the unique requirements of individuals with autism to ensure the provision of adequate support services [35]. Access to quality healthcare is critical, as individuals with autism often face challenges in communication and understanding their needs, negatively affecting their quality of life [36]. Furthermore, Ghahari et al. demonstrate that support in education and therapy can enhance the overall mental and emotional well-being of individuals with autism by providing strategies that promote relationships and social skills [37].

Educational support is critical, as students with autism often face challenges in education, particularly related to social interaction and learning; therefore, educators require proper training and support to implement strategies that enhance the education of students with autism [38]. The necessity of individualized interventions is also critical, as strategies that work for one student may not be effective for another [39].

Social support is equally important, as individuals with autism often experience social isolation and difficulties in forming relationships. Social acceptance and positive peer interactions can improve self-esteem and social inclusion [39,40]. The need for educators and parents to understand the challenges faced by individuals with autism is crucial in fostering a supportive environment [41].

Psychological support helps mitigate high levels of anxiety and depression that often accompany autism. Understanding the relationship between autism and trauma is important for developing effective therapeutic approaches [42]. The need for appropriate diagnostic procedures that take psychological aspects into account is also crucial, as autism spectrum disorders can be complex and require specialized interventions [41].

The daily lives of individuals with autism are also affected by their ability to perform basic daily activities. Those with severe forms of autism often require assistance in carrying out daily tasks such as personal hygiene and self-care [43]. Support in these areas is essential for enhancing their autonomy and quality of life.

The need for research and the development of assessment tools to identify the needs of individuals with autism is also significant. The development and testing of tools can contribute to a better understanding of the needs and preferences of individuals with autism [44]. The evaluation of these tools can aid in the creation of individualized support plans that address the specific needs of individuals with autism.

Understanding the environmental and genetic factors that interact and relate to autism is also crucial for developing intervention strategies [45-47]. Research reveals that genetic variations may influence the functionality of individuals with autism, emphasizing the need for personalized approaches that consider both genetic and environmental influences [48].

Additionally, the need for public awareness and education about autism is fundamental. Increasing knowledge and understanding of autism can help reduce stigma and promote the acceptance of individuals with autism in society [40]. Encouraging positive interactions and educating peers can contribute to the social inclusion of these individuals.

Therefore, the fundamental needs of individuals with autism are multidimensional and require a comprehensive approach that includes educational, social, and psychological support. Understanding these needs is crucial for developing effective interventions and support strategies that will improve the quality of life of individuals with autism [35, 49]. Collaboration between educators, parents, and healthcare professionals is essential to achieving these goals and promoting the well-being of individuals with autism.

3.3. Scientific Evidence on the Positive Impact of Nature on Mental and Physical Health

The positive impact of nature on mental and physical health has been widely recognized by the scientific community, with numerous studies confirming that exposure to natural environments can provide significant health benefits such as stress reduction, improved mental health, increased physical activity and reduced risks of chronic diseases [50-52]. Nature's benefits also include enhanced social interaction and personal rejuvenation [53].

Researchers found that vegetation can have a protective effect on health by promoting physical activity and reducing exposure to pollutants. These findings suggest that policies promoting the expansion of greenery in urban and rural areas can contribute to public health improvements [52]

Connection with nature can also have positive effects on mental well-being. According to recent reviews, contact with nature can mitigate negative environmental effects such as pollution and noise while also helping to reduce stress and increase physical activity [54, 55]

A systematic review and meta-analysis by [53] confirmed that exposure to green spaces offers opportunities for physical activity, social cohesion, and stress reduction. Their study suggests that contact with nature can provide immunoregulatory benefits and reduce inflammation, reinforcing the need for policies that promote access to natural environments [56].

Moreover, research by White et al. indicates that spending at least 120 minutes per week in nature is associated with good health and well-being [57]. The researchers found that simply being in nature, even in a sedentary manner, can provide psychophysiological benefits, suggesting that the positive effects of nature are not limited to physical activity but also encompass other aspects of well-being [58]. Residing in green areas during childhood is associated with a lower risk of psychiatric disorders from adolescence to adulthood. This fact underscores the importance of exposure to nature during development and the need for policies encouraging access to natural environments for children and adolescents [59].

The impact of nature on mental health has become even more apparent during the COVID-19 pandemic, which underscored the importance of natural spaces in mitigating anxiety and depression [60, 61]. Additionally, a study by Shanahan and his colleagues indicates that regular visits to green spaces can prevent cases of depression and hypertension. This emphasizes the importance of integrating natural spaces into urban areas to enhance public health [62].

Overall, scientific evidence suggests that exposure to nature has multiple benefits for mental and physical health. Promoting access to natural environments can help reduce mental disorders, increase physical activity, and improve overall well-being. Policies that encourage the development and maintenance of green spaces are crucial for advancing public health and well-being [63, 64].

4. Autism And Education

4.1. Educational Challenges for Individuals with Autism

The education of individuals with autism is hindered by several challenges that arise from the specific needs and characteristics of the autism spectrum. One of the main challenges is the lack of sufficient knowledge and training among teachers regarding autism [65]. Research has shown that teachers often do not possess the necessary knowledge to identify and support students with autism [66, 67]. This lack of training can lead to inadequate support and to educational programs that do not meet students' needs. It is crucial for teachers to receive proper training in order to design and implement strategies that will facilitate learning for students with autism [68, 69].

Students with autism often face social and emotional challenges that affect their ability to participate in the educational process [70-72]. Difficulties in social interaction and the development of emotional self-awareness are common among these individuals and may lead to social isolation and affect students' mental health [73]. The need for support in developing social skills is urgent, as students with autism often do not have the same social learning opportunities as their peers [74].

An individualized approach in education for students with autism is also essential because they have unique needs and abilities, and tailored teaching strategies must be adapted accordingly (Cannon et al., 2021). The implementation of individualized educational, STEM, and emerging technologies like AI and ICT programs can help strengthen students' skills and promote their participation in the learning process. Cooperation between teachers, parents, and health professionals is critical to the development of such programs [75-79].

The lack of resources and support in schools can be an obstacle to the education of individuals with autism. Lack of sufficient resources in order to provide the necessary support for students with autism can affect the quality of the education that they receive [69]. The need for adequate funding and support from government authorities is urgent to ensure that all students have access to quality education.

Social prejudices and stereotypes about autism may also affect the education of individuals with autism. Teachers and classmates may hold misconceptions about autism, which can lead to discrimination and exclusion [80]. Raising awareness and educating the school community about autism is crucial to promoting a supportive and inclusive environment [81].

It becomes clear that the educational challenges for individuals with autism are numerous and diverse. The lack of knowledge and training among teachers, the social and emotional difficulties of students, the need for individualized approaches, the shortage of resources, and social prejudice are some of the main challenges that require attention. The development of strategies to address these challenges is essential for promoting the education and well-being of individuals with autism [82, 83].

4.2. The Role of Sensory Experiences in the Education of Individuals with Autism

Sensory disorders refer to difficulties in processing sensory information coming from the environment or the body itself [84]. They are common among individuals with autism and may include hypersensitivity or hyposensitivity to various stimuli [85]. Sensory experiences play a crucial role in the education of children with autism, as the sensory challenges can directly impact their ability to participate in and perform within the educational environment, affecting their concentration, social interaction, and the overall learning process [86].

The study by [85] suggests that interventions focusing on sensory integration can reduce emotional and behavioral problems in children with autism. Improving the processing and regulation of sensory stimuli may lead to better behavior and increased participation in educational activities. Teachers can benefit from understanding their students' sensory needs in order to create a more supportive learning environment.

Sensory disorders also appear to be linked to specific behaviors in children with autism, such as rocking or spinning, which function as self-regulation mechanisms or reactions to difficulties in processing sensory information [86].

Incorporating sensory activities into the educational process can improve the performance of students with autism and intellectual disabilities by helping them manage their sensory challenges and enhancing their learning experience [87]. Understanding these needs allows educators to adapt their teaching approaches and create a more supportive educational environment.

Paying attention to sensory experiences during both education and therapy can improve concentration and reduce anxiety in individuals with autism, making sensory processing a key element in educational strategies [88]. Furthermore, training teachers about sensory processes and environmental adaptations can enhance student engagement and contribute to the creation of supportive conditions that facilitate learning and reduce sensory overload [83].

Understanding sensory experiences is also important for the development of assessment tools that help identify the needs of students with autism. The study by [89] refers to the development of new measurements for sensory behaviors in children with autism, which can provide valuable insights into their preferences and needs.

Overall, sensory experiences play a decisive role in the education of individuals with autism. Understanding and managing sensory challenges can lead to improved learning experiences and greater participation in the educational process. Educators, parents, and health professionals must collaborate to develop strategies that support the sensory needs of students with autism, thereby promoting their well-being and success in education.

5. Nature Contact in Education

5.1. Types of Nature-Based Activities

Nature-based activities, such as gardening, hiking, and play in natural environments, can enhance autistic children's cognitive, social, and emotional development, while also providing opportunities for learning and exploration [90-92].

Recent study states that participation of children in educational and activities in nature, such as gardening, contributes to their cognitive and social development. Interaction with the natural environment enhances their social confidence, ability to cooperate and communicate, as well as memory and understanding of natural processes [93]. Similarly, hiking in natural settings has been found to offer important benefits for children's physical and mental well-being. Mayr and colleagues demonstrate that contact with nature can reduce blood pressure and stress, strengthen the immune system, and improve overall mental mood [94]. These benefits make such activities particularly useful for children with autism, as they help regulate their emotional world and reduce the stress resulting from daily sensory processing challenges.

In addition to physical and cognitive effects, nature can also play a crucial role in the development of children's social skills. According to the study by [30], play in natural environments creates opportunities for interaction and cooperation, especially for children with autism, who often struggle with social interaction. The presence of a safe and supportive environment can facilitate their participation in symbolic play activities, enhancing their communication skills and social adjustment [30]. At the same time, a study of [95] proposes a categorization of nature-related educational activities aimed at developing better teaching strategies. This systematization may contribute to the more effective integration of nature into the educational process, offering tailored teaching practices that meet the needs of diverse learners [95].

In another study, Cooper et al. reveals that the positive effect of nature extends to the mental health and self-image of children with autism. They emphasize that participation in nature-based activities can enhance self-esteem and the social identity of individuals with autism. Through the positive experiences they gain, they can develop greater self-confidence, reduce their anxiety, and improve their ability to interact with others. Nature, therefore, is not only a means of physical activity but also a valuable tool for the overall development and well-being of children, especially those who face challenges in the social and emotional domain [96].

Contact with nature through activities such as gardening, hiking, and play in natural environments provides a rich source of educational and developmental opportunities for children, including those with autism. Integrating these activities into the educational process can contribute to the development of social skills, the enhancement of mental and physical health, and the overall well-being of children with autism (Table 1).

Table 1 Nature-based activities and their potential contribution to autistic children's regulation, participation, and learning

Nature-based activity	Main characteristics	Potential developmental/educational benefits	Practical considerations
Gardening activities	Planting, watering, caring for plants, touching soil, observing growth and natural cycles	May support sensory regulation, attention, sequencing, responsibility, autonomy, and hands-on learning	Activities should be structured, predictable, and adapted to each child's sensory profile
Outdoor free play	Play in gardens, parks, schoolyards, forests, or other natural spaces	May encourage exploration, motor activity, creativity, emotional regulation, and peer interaction	Requires safe boundaries, adult supervision, and flexible support
Structured outdoor play	Guided games, cooperative activities, group exploration, and social play in natural settings	May promote social communication, cooperation, turn-taking, shared attention, and participation	Clear rules, visual supports, and gradual exposure may improve engagement
Hiking and nature exploration	Walking trails, observing plants/animals, exploring natural landscapes	May support physical activity, endurance, curiosity, emotional calmness, and connection with nature	Routes should be accessible, safe, and matched to children's motor and sensory needs
Nature-based therapeutic programs	Therapeutic sessions delivered in outdoor or nature-rich environments	May support sensory modulation, anxiety reduction, emotional well-being, and functional participation	Requires trained professionals and individualized intervention planning
School-based nature integration	Use of gardens, outdoor classrooms, natural materials, and curriculum-linked activities	May enhance inclusive learning, concentration, environmental awareness, and participation in school routines	Implementation depends on school resources, educator training, and access to natural spaces

5.2. The Impact of Nature on the Education of Children with Autism

Natural environments can offer a wide range of benefits at physical, mental, social, and cognitive levels. Contemporary research highlights the role of nature in improving sensory integration, social interaction, reducing anxiety, and promoting physical activity [97-98].

Children with autism often face challenges in sensory integration, that is, in their ability to process and respond to multiple sensory stimuli. The study by [28] emphasizes the importance of nature in improving this process. The researchers examined the role of nature-based therapy, which included family activities such as gardening and outdoor play. The results showed improvement in the management of sensory stimuli, including sound, light, textures, and movement [97]. Natural environments offer diverse yet predictable sensory stimuli that facilitate children's adaptation and familiarization [99].

Social interaction is often a challenge for children with autism due to their difficulty in developing social skills and interacting with others. The study by [100] analysed the effects of an outdoor adventure program that included activities such as hiking, organized play, and exploration of natural settings. The results showed that children who participated in the program significantly developed their cooperation, communication, and social interaction skills. Nature was found to be less stressful and more supportive, creating the right conditions for developing these abilities [101].

Nature can also be a powerful ally in reducing anxiety, which is a common feature among children with autism. The study by [102] focused on the benefits of exposure to natural environments, showing that participation in activities such as gardening or nature exploration helps reduce anxiety and improve concentration. Similarly, [103] reported that early exposure to nature is associated with lower levels of anxiety in preschool-aged children, including those with special

needs such as autism. Natural settings seem to have a calming effect, offering a space where children can relax and feel safe.

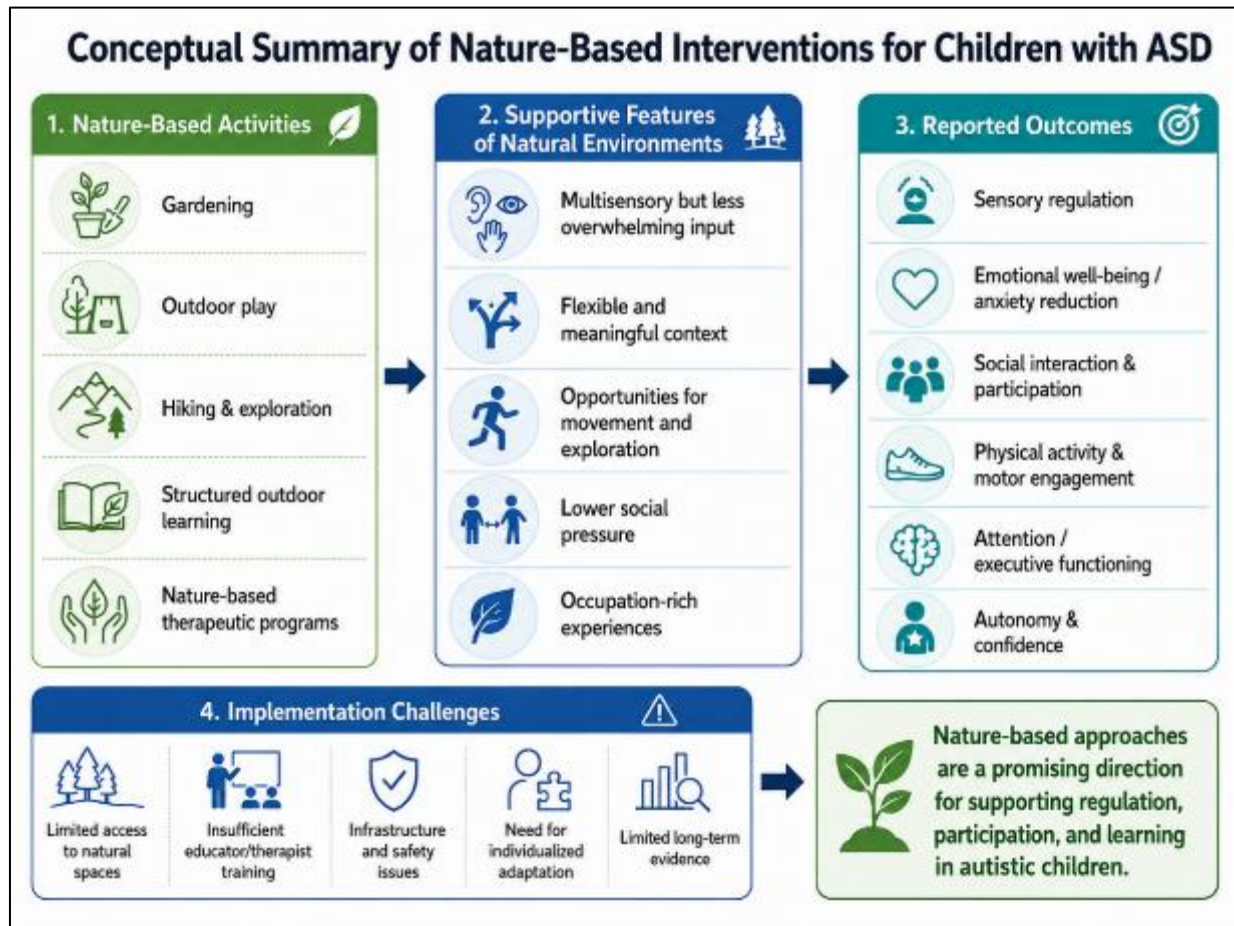


Figure 1 Conceptual summary of nature-based interventions for children with ASD

Physical activity is an important tool for promoting the health and well-being of children with autism. According to [10], nature-based interventions encourage physical activity and reduce sedentary behavior. [104] and [105] emphasize that natural environments provide stimuli that motivate children to move, explore, and participate in activities that improve mobility and physical wellness. Furthermore, the study [105] demonstrated that physical activity improves sleep quality and executive functions in children with autism. Improved sleep quality can have positive effects on their concentration, memory, and overall behavior.

Despite the recognized benefits, integrating nature into the education of children with autism faces significant challenges [101]. [102] noted that limited access to natural spaces, the lack of appropriate educational resources, and time constraints in school schedules are major obstacles. Additionally, [106] pointed out that preschools and schools often lack the necessary infrastructure for outdoor activities.

Nature offers a unique opportunity to support the education of children with autism. Natural environments contribute to improved sensory integration, social interaction, emotional calmness, and physical activity. Although challenges exist, such as lack of access and limited resources integrating nature into educational programs can provide significant benefits to children with autism. Further research and the development of strategies to overcome these barriers are essential to maximizing the positive effects [107] (Figure 1).

The figure illustrates how nature-based activities, such as gardening, outdoor play, hiking and exploration, structured outdoor learning, and nature-based therapeutic programs, may support regulation, participation, and learning through multisensory, flexible, movement-rich, and occupation-based environmental features. It also summarizes reported outcomes and key implementation challenges identified in the reviewed literature.

6. Discussion

The literature and data reviewed demonstrate that nature-based interventions can substantially improve various skills in children with autism. Natural environments, through their rich variety of sensory stimuli and opportunities for activities that promote learning, have proven to be particularly effective. The skills that are enhanced include sensory integration, social skills, concentration, and executive functions [108].

Children with autism often face difficulties in processing sensory stimuli, such as sensitivity to sounds, textures, colors, or movements. Nature provides a rich yet naturally balanced environment, full of sensory input that helps improve this ability. Sounds like rustling leaves or birdsong, contact with soil during gardening, or even the movement of water in a pond are gentle and pleasant sensory experiences [109]. Ramshini et al. showed in their study that nature-based therapy can significantly reduce sensory difficulties in children with autism [28]. Through these interventions, children demonstrated increased adaptability and improved ability to process sensory information. These improvements enhance their daily functioning and facilitate participation in activities both inside and outside the school environment [105].

Nature provides an ideal setting for developing social skills, offering opportunities for participation in organized activities that require collaboration and communication. In programs such as those examined by Zachor and his colleagues, children with autism took part in group activities in nature, such as hiking, games, and exploration. These activities helped the children develop cooperation skills and improve their ability to communicate effectively with peers [100].

Furthermore, the less structured nature of outdoor environments reduces the pressure and anxiety that children may experience in typical social situations. This less stressful context helps them focus on building relationships and gain confidence in their social abilities. The results of these interventions are especially important, as social interaction is one of the main challenges for children with autism [110].

Nature contact has also been linked to improvements in concentration and executive functions, such as planning, working memory, and decision-making. Participating in activities such as hiking or gardening requires children to focus on specific tasks and develop problem-solving skills. Gardening, for example, requires children to organize their work, follow steps to care for plants, and evaluate progress [111]. These types of activities, combined with the calming effect of nature, contribute to improved concentration and the development of cognitive skills that are essential in both educational and everyday life [112]. [111] Also revealed that nature-based activities improve cognitive skills and are also associated with enhanced sleep quality, which is a key factor for cognitive and emotional well-being.

Beyond skill development, nature also has a significant impact on the behavior of children with autism. Natural environments offer opportunities for mental calmness, physical fitness, and the development of autonomy, creating the appropriate conditions for the holistic development of children [112].

Natural settings are recognized as spaces for psychological restoration for children with autism. Exposure to nature provides a calm and predictable environment that reduces stress levels and helps with emotional regulation. According to the study by Li et al, children who regularly participate in nature-based activities such as gardening or hiking show reduced anxiety and increased emotional calmness [102]. Nature has a soothing effect on the nervous system, allowing children to feel safe and relaxed. This emotional regulation facilitates their participation in educational activities and improves their overall well-being [113].

Engaging in activities such as hiking or free play in nature significantly enhances physical endurance and improves the motor skills of children with autism. Gray et al., emphasize the importance of physical activity for physical health and motor development [104]. Outdoor physical activities not only improve physical fitness but also encourage children to develop skills such as coordination, balance, and flexibility [114].

Nature offers unique opportunities for the development of autonomy in children with autism. Through participation in activities that require personal responsibility and initiative, children gain confidence and enhance their independence. For example, caring for plants in a gardening program or navigating through natural trails allows them to make decisions and face challenges on their own. These experiences, as highlighted by relevant research, improve children's sense of self-efficacy and support their overall functioning [115] (Table 2).

Table 2 Proposed mechanisms linking nature-based activities with outcomes in children with ASD

Proposed mechanism	Description	Potential outcome
Multisensory but naturally graded input	Natural environments provide varied sensory stimuli such as sounds, textures, movement, light, and smells, often in a less artificial and more predictable way than indoor settings.	Sensory regulation, reduced sensory overload, improved engagement
Reduced social pressure	Outdoor and nature-based settings may be less rigid and less socially demanding than traditional classroom environments.	Increased social participation, peer interaction, communication
Opportunities for movement and exploration	Activities such as hiking, outdoor play, gardening, and exploration naturally encourage active movement and physical engagement.	Physical activity, motor engagement, endurance, body awareness
Meaningful occupation-based participation	Gardening, caring for plants, outdoor learning tasks, and nature exploration provide purposeful activities with visible outcomes.	Autonomy, responsibility, motivation, participation
Emotional restoration and calming effects	Contact with natural environments may support emotional calmness and reduce stress or anxiety.	Emotional regulation, anxiety reduction, improved well-being
Executive function demands in real contexts	Nature-based activities often require planning, sequencing, problem-solving, attention, and flexible responses.	Attention, working memory, planning, cognitive flexibility
Individualized environmental adaptation	Natural activities can be adapted according to the child's sensory profile, interests, motor abilities, and participation needs.	Personalized engagement, inclusion, functional participation

Despite the clear importance of nature in the education of children with autism, there are certain limitations and challenges that must be addressed for the broader implementation of such interventions. Many schools and therapeutic centers lack the necessary infrastructure to conduct outdoor activities. According to Li et al., the absence of nearby natural spaces or suitable facilities can limit the frequency and effectiveness of these interventions [102]. Moreover, in urban areas, restricted access to safe and clean natural locations is a significant challenge [116].

Another limiting factor is the lack of appropriate training for educators and therapists. Predy et al., notes that many professionals do not possess the necessary knowledge or skills to organize and manage nature-based activities. This lack of training may hinder the implementation of such approaches, despite their proven benefits [106]

The outcomes of nature-based interventions vary significantly depending on the individual needs and characteristics of each child, as well as the conditions under which the interventions are applied. This highlights the need for personalized approaches that take into account the unique specificities of each child with autism. Many of the studies conducted thus far examine the short-term effects of nature, leaving questions about the long-term impact of such interventions. There is a pressing need for longitudinal research to better understand how regular nature contact affects the overall development and learning of children [117].

Despite these limitations, nature proves to be a powerful tool for the education and skill development of children with autism. Addressing the challenges related to access, training, and program adaptation can lead to a more effective integration of nature within educational settings. By investing in long-term strategies, we can ensure the optimal utilization of the beneficial effects of nature in the lives of these children.

7. Conclusion

Nature contact has emerged as a highly effective way to support the education and skill development of children with autism. The studies reviewed in this paper demonstrate the positive impact of nature on sensory, cognitive, social, and

emotional levels. Despite the existing challenges in integrating nature into education, its benefits are clear and supported by scientific evidence [10].

The literature review highlighted nature as an excellent tool for enhancing skills and the overall well-being of children with autism. One of the most important findings is nature's contribution to sensory integration. Natural environments provide diverse sensory stimuli that help children better process and regulate sensory information, thereby reducing sensory difficulties [28].

At the same time, natural environments offer a less stressful [118] and more predictable setting that promotes social interaction [30]. Group activities in nature, such as hiking and outdoor games, have been shown to foster cooperation, communication, and social skills in children with autism. In addition, nature-based activities such as gardening enhance executive functions, concentration, and working memory, contributing to cognitive development [105]. Finally, contact with nature has a soothing effect, reducing anxiety and promoting the emotional well-being of children [10]. This improvement in emotional regulation facilitates their participation in daily and educational activities, enhancing their overall quality of life [113].

The integration of nature into educational settings is a promising practice that can be implemented through targeted interventions [32]. One key recommendation is the creation of natural spaces within schools and therapy centers. The construction of gardens, trails, and outdoor play areas can provide children with autism with direct access to natural environments, reducing the need for external travel [107].

Moreover, teachers and therapists can organize regular outdoor activities such as trips to parks, forests, or beaches. These activities can combine recreation with learning, strengthening children's connection to nature. In parallel, incorporating activities like gardening into the curriculum can help children learn through hands-on experiences, developing both cognitive and social skills [92].

Training for educators and therapists is also a critical component for the successful implementation of these proposals [38]. It is essential that they acquire knowledge and skills related to using nature as an educational and therapeutic tool. Training programs could help professionals design and deliver nature-based activities with greater confidence and effectiveness. Lastly, it is important that the activities are personalized to meet the unique needs of each child. Adapting the program based on the child's abilities, interests, and preferences can maximize the benefits of the interventions [42].

Despite the positive outcomes already recorded, research on the relationship between nature and the education of children with autism remains in its early stages. There are many directions that should be explored for a better understanding and application of this relationship. First, long-term studies are needed to evaluate the lasting effects of nature exposure [104]. Most existing research focuses on short-term outcomes, leaving questions about the sustainability of the observed improvements.

In addition, it would be useful to conduct comparative studies examining different types of interventions. For example, comparing gardening to hiking or free play may reveal which activity is more effective for specific goals. Furthermore, the personalization of interventions requires further investigation. Future research could explore how individual characteristics such as age, functioning level, and sensory profiles affect children's responses to nature-based activities [84].

Assessing the cost-effectiveness of these interventions is another critical direction. It is important to determine the implementation costs and evaluate cost-benefit relationships to support their wider adoption. Finally, examining cultural and geographic factors could provide valuable insights into implementing nature-based interventions in different social and cultural contexts [55]. Perceptions of nature, accessibility, and local conditions may all influence the effectiveness of these programs.

Overall, nature represents a promising field for supporting children with autism, offering unique opportunities for learning, skill development, and improved quality of life [19]. With proper training for professionals, the creation of natural spaces, and ongoing research, we can ensure the optimal use of nature's benefits in education. Investing in such interventions can be a vital step toward building a more supportive and inclusive educational system for children with autism.

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