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How Does Nature-Based Education Contribute to Green and Low-Carbon Development?

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ABSTRACT

This study explores the integration of nature-based education (NBE) into educational frameworks aimed at green and low-carbon development. Although interest in NBE is increasing, research on its alignment with the country's climate goals, especially in relation to curriculum development and pedagogical strategies, remains limited. To address this gap, a comprehensive literature review was conducted, drawing on studies from databases such as Web of Science, Scopus, and CNKI. Keywords including "nature-based education," "experiential learning," "place-based education," "biophilic design," and "ecological civilization" were used to ensure broad coverage of relevant research. The selected studies were categorized and analyzed to evaluate the applications, findings, and challenges of NBE across various theoretical frameworks. The efficacy of nature schools in enhancing sustainability education and carbon literacy was also assessed. These schools employ place-based, immersive, and multidisciplinary methods to engage students in practical experiences that deepen their understanding of carbon cycles and sustainable behaviors. The findings demonstrate that NBE curricula significantly improve environmental awareness and foster student participation in carbon reduction initiatives, thereby contributing to national climate goals. However, barriers such as inadequate teacher training, limited financial resources, and inflexible curricula hinder broader implementation. This review underscores the vital role of education in meeting green and low-carbon development objectives and calls for policy reforms to support the development of future sustainability elites.

1 | Introduction

Under the green and low-carbon development framework, various countries around the world have implemented effective low-carbon initiatives, which reflect the world's ambitious vision for environmental preservation and sustainable development (Zhao 2022). Green and low-carbon development is grounded in the principles of reverence for nature and harmonious coexistence, emphasizing the integrated advancement of society, economy, and the environment. Achieving this vision necessitates innovations in both policy and technical domains, as well as profound transformations in societal attitudes and behavioral patterns-areas where education is regarded as a pivotal influence (Shutaleva 2023).

Summary

This study explores how nature-based education (NBE) can contribute to green and low-carbon sustainable development. NBE refers to learning through direct engagement with nature, with the goal of cultivating learners' environmental awareness and sustainability skills. Nature schools typically adopt immersive, regional, and experiential learning methods to impart knowledge about climate change, carbon cycling, and sustainable development. This study finds that NBE enhances students' understanding of sustainability and motivates them to participate in carbon reduction actions. However, challenges remain, including insufficient teacher training, limited funds, and rigid curriculum settings. This study calls for policy reforms to help nature schools more effectively integrate NBE into curriculum design and practical strategies, ultimately empowering learners to contribute to sustainable development.

- **Practitioner Points**
  - Integrate interdisciplinary teaching, local ecological knowledge, and virtual reality (VR) technology to deepen students' understanding of climate change.
  - Encourage experiential learning through ecological project-based learning (PBL), outdoor activities, and community service to promote sustainable behaviors.
  - Promote low-carbon campus initiatives, including the use of renewable energy, carbon footprint monitoring, and green certification programs, to improve sustainable management.
  - Raise public awareness of climate change and advocate for low-carbon lifestyles to drive collective sustainable action.

The education system not only serves to disseminate knowledge but also as a key platform for instilling social and environmental values and fostering sustainable development literacy. This will assist the next generation in comprehending and addressing the issues posed by climate change and carbon emissions (Cordero et al. 2020). Nature schools represent an innovative educational model that incorporates the concept of ecological civilization into educational practice through immersive and experiential learning techniques (York 2014). By integrating local natural resources and cultural heritage, nature schools provide students with direct experiences of natural processes while imparting foundational concepts such as the carbon cycle, energy conservation, and ecological preservation (Littledyke 2008; Gann et al. 2019).

This instructional approach raises students' environmental awareness while simultaneously motivating them to adopt low-carbon practices in their daily lives, shaping them into proactive advocates of ecological civilization. Consequently, nature schools occupy a unique position at the convergence of green and low-carbon development, advancing progress toward a sustainable future (Baumber et al. 2019; Kiehle 2021; Shi 2024).

In recent years, nature-based education (NBE), environmental education, and sustainability education have emerged as vital frameworks for cultivating ecological awareness and advancing sustainable practices. Although these notions have similar purposes, they vary widely in emphasis. Environmental education focuses on enhancing awareness and understanding of environmental issues, usually within formal or classroom-based settings. Sustainability education takes a broader approach by incorporating economic, social, and environmental dimensions, prompting students to contemplate comprehensive systemic solutions for sustainable development. In contrast, NBE, a distinct subcategory within these broader fields, centers on experiential learning through direct interaction with natural ecosystems. It prioritizes the development of a strong emotional connection with nature, the cultivation of ecological consciousness, and the promotion of environmental stewardship by facilitating direct engagement with the natural world.

NBE is especially effective at bridging theoretical knowledge with practical application (Salovaara et al. 2021). Through hands-on experiences in nature, students cultivate a deep connection to their surroundings, an essential foundation for long-term environmental stewardship and active participation in carbon reduction initiatives. The concept of the “nature school” in China offers a distinctive framework that aligns closely with the country's ecological civilization programs and low-carbon objectives (Xie 2022). What distinguishes the nature-school framework is its comprehensive integration into national policies related to ecological civilization construction and low-carbon development objectives. This alignment is evident not only in curriculum content but also in the wider policy and sociocultural landscape. Nature schools are uniquely integrated into the nation's ecological civilization policy and align with the National Green Development Goals.

Unlike many nature education models in the West, which tend to prioritize individual development and cognitive skills, nature schools in China place greater emphasis on collective engagement and social responsibility. These schools encourage students to participate in community-based environmental protection initiatives, thereby fostering a shared commitment to environmental action within local communities. This distinctive blend of education and social responsibility has positioned China's nature schools as important contributors to the nation's carbon peaking and carbon neutrality targets.

By adopting NBE principles, these schools promote environmental awareness while fostering critical thinking and problem-solving skills needed to address sustainability challenges and implement effective carbon reduction strategies (Ramchunder and Ziegler 2021). Research demonstrates that NBE substantially enhances students' comprehension of ecological interconnectedness and the carbon cycle, equipping them with the knowledge and values necessary to make educated decisions regarding their environmental impact (Sisk-Hilton 2023).

Nature schools frequently integrate practical activities, such as carbon footprint assessments, tree planting, and renewable energy projects, enabling pupils to interact directly with sustainability principles (Suarlin 2023). For example, students might monitor their school's carbon emissions and propose actionable reduction measures—an approach that reinforces academic knowledge and fosters a sense of responsibility and agency. These experiences empower students to champion environmental change within their communities. Moreover,

incorporating local ecological and cultural contexts into curriculums increases the relevance of sustainability education. By linking lessons to tangible, real-world environmental challenges within their own communities, students develop an appreciation for sustainable behaviors and a stronger comprehension of their responsibility in combating climate change. This localized approach corresponds with place-based education principles, which have been shown to increase student involvement and cultivate a sense of connection with the local environment (Soucy et al. 2024).

This study conducts a thorough review of existing research on NBE and sustainable curriculum development, offering insights into how educational institutions can support the green and low-carbon development. A systematic review methodology was employed to classify and analyze the selected literature by thematic focus, examining the application, findings, and challenges of NBE across various theoretical frameworks. The research explores the intersection of low-carbon objectives with NBE, focusing on key areas such as curriculum development, pedagogical methods, and the implementation of experiential education initiatives.

Literature retrieval for this study was primarily conducted through Web of Science, Scopus, and CNKI to ensure comprehensive coverage of relevant domestic and international research. Key terms, including "nature-based education," "experiential learning," "place-based education," "biophilic design," and "ecological civilization," were used to access research related to nature education, experiential pedagogy, localized education, biophilic design, and ecological civilization. Articles were selected based on the following exclusion criteria: (1) non-peer-reviewed articles, (2) studies unrelated to education or ecological civilization, and (3) literature lacking empirical data or systematic analysis.

The review highlights the need for interdisciplinary methodologies that combine environmental science, ethics, and indigenous cultural knowledge. Such comprehensive strategies are crucial for addressing the multifaceted challenges of climate change and for preparing students to become environmentally responsible leaders (Li et al. 2023; Duan and Zhao 2021). The following sections will examine the application of NBE in Chinese schools, its effectiveness in promoting sustainability education and carbon literacy, and the barriers impeding its broader implementation. Key issues, including teacher training, financial constraints, and curricular rigidity, will also be examined. The review concludes with policy recommendations aimed at strengthening the role of NBE in advancing green and low-carbon development.

2 | Nature-Based Education and Low-Carbon Goals

2.1 | Theoretical Foundations of Nature-Based Education

NBE has emerged as a pivotal approach for cultivating environmental literacy, emotional well-being, and ecological responsibility. Central to NBE is experiential learning, which emphasizes meaningful interactions with natural ecosystems. This pedagogical approach draws heavily from Dewey (1938) theory of experiential learning, which posits that knowledge is formed through direct participation in activities that evoke sensory and emotional responses. Dewey's concept of "learning by doing" aligns closely with the core principles of NBE, encouraging students to engage with nature through practical activities such as gardening, nature walks, and ecological projects. These hands-on experiences facilitate reflection and analysis of the natural world, promoting both cognitive and emotional learning outcomes. Dillon and Herman (2023) highlight that immersive experiences in nature not only enhance students' understanding of ecological systems but also nurture emotional connections to the environment. Such connections contribute to a more profound sense of ecological responsibility and influence both cognitive and affective learning outcomes.

Place-based education (PBE), which is closely tied to experiential learning, contextualizes ecological teaching within local environmental and cultural settings. Hamilton and Marckini-Polk (2023) found that integrating ecological education into the local community and utilizing regional resources cultivates a strong sense of environmental stewardship. PBE situates learning in students' immediate surroundings, increasing engagement and fostering a deeper connection to their local environment. By addressing region-specific ecological challenges and cultural histories, PBE enables students to better understand and solve local environmental issues.

Davis's (2023) research further underscores the emotional influence of NBE, particularly in fostering lasting environmental ethics. Davis argues that positive early experiences in nature are crucial for developing a lifelong bond with the environment, which in turn inspires individuals to support sustainability and conservation efforts throughout their lives. This emotional connection fostered by NBE is vital for promoting proactive ecological stewardship, as it links personal values with environmental action.

The philosophy of biophilic design complements both experiential and place-based approaches by emphasizing the psychological and cognitive benefits of natural environments. DeLauer et al. (2022) assert that incorporating biophilic elements—such as natural materials, daylight, and views of nature—into educational settings can enhance mental health and cognitive functioning. Dale et al. (2020) provide empirical evidence showing that exposure to natural environments improves attention, reduces stress, and boosts creativity, thereby enhancing academic performance and overall well-being. These findings suggest that biophilic design not only improves learning outcomes but also contributes to students' emotional and physical well-being.

In China, NBE strongly correlates with the concept of "Ecological Civilization," a national plan aimed at reconciling economic development with environmental conservation. This paradigm encourages the incorporation of environmental responsibility into education, supporting behaviors that cultivate harmony between humans and nature. Zhang and Teng (2023) emphasize that nature schools in China exemplify these principles by offering experiential learning opportunities rooted in the values of ecological civilization. Some institutions provide tangible examples of sustainable practices, enabling students to participate in community-oriented conservation initiatives that promote biodiversity and strengthen a sense of agency and community affiliation (Lee and Lee 2021).

The interconnected frameworks of experiential learning, place-based education, biophilic design, and ecological civilization together form the foundation of NBE (Wei-Ting and Paichi Pat 2022). Through a combination of educational methodologies, NBE fosters environmental awareness alongside the cultivation of abilities and motivations required to tackle urgent ecological issues. Ultimately, NBE equips students to become responsible, informed citizens committed to building a sustainable future.

2.2 | Low-Carbon Goals and Educational Implications

Green and low-carbon development goals represent both a monumental challenge and a significant opportunity. These ambitious targets necessitate transformative changes across various sectors, including energy, transportation, and industrial production. One of the most critical contributions to achieving these goals will come from the education sector (Qi et al. 2024). The integration of carbon literacy into educational curricula is essential for preparing students to lead the transition to a low-carbon economy and equipping them with the knowledge and skills necessary to confront environmental challenges. Some researcher emphasizes green and low-carbon development as a national priority, explicitly calling for enhanced environmental education at all levels of schooling (Hepburn et al. 2021). It recognizes education as a powerful tool for promoting sustainability and fostering a culture of environmental stewardship among future leaders. The plan highlights the need to cultivate awareness and practical skills that can drive the shift to more sustainable lifestyles and carbon-reduction strategies.

Since 2020, schools across China have introduced carbon education programs specifically designed to enhance students' understanding of carbon cycles, renewable energy, and sustainable practices (Chen et al. 2022). These programs often incorporate hands-on learning components, allowing students to explore concepts such as carbon footprints, greenhouse gas emissions, and the importance of biodiversity in mitigating climate change. Tian et al. (2023) found that nature-based carbon education programs significantly improved students' understanding of carbon neutrality and led to increased pro-environmental behaviors both in school and at home. This shift in understanding is crucial, as it empowers students to make informed decisions and take initiative in their communities regarding sustainability efforts. Research by Ullerup (2022) further supports the effectiveness of nature-based education, reporting that students in nature schools demonstrated greater engagement and comprehension of sustainability concepts compared to their peers in traditional classrooms. These nature-based programs foster academic knowledge and also build emotional connections to nature, thereby reinforcing the principles of ecological stewardship and responsibility. Engaging with nature in educational contexts has also been shown to promote critical thinking, problem-solving skills, and collaboration—skills that are indispensable for navigating the complexities of carbon management and sustainability.

The current educational framework builds upon earlier initiatives that laid the groundwork for contemporary practices. For instance, the "Green Schools" initiative launched in the early 2000s aimed to promote environmental education, significantly influencing current curricular reforms and practices (Huang and Lee 2020). This initiative served as a catalyst for integrating environmental issues into the educational system, establishing a foundation for programs that address carbon literacy and sustainability. Moreover, a brief recommended substantial investments in sustainability education and the establishment of school-based platforms for carbon reduction learning (Hoque et al. 2022). Such platforms could serve as incubators for innovative practices and provide students with opportunities to engage in real-world carbon reduction projects, fostering a sense of agency and responsibility. Recent studies emphasize the necessity of interdisciplinary approaches to carbon education, integrating subjects such as science, geography, and social studies to create a holistic understanding of the issues at hand (Eilam 2022; Molthan-Hill et al. 2022; Granados-Sánchez 2022). For instance, Reddy (2021) highlighted the importance of developing curricula that connect carbon education with local environmental issues, allowing students to see the relevance of their learning in the context of their communities.

In summary, the integration of carbon literacy into educational curricula is paramount for equipping students with the competencies necessary to participate actively in the transition to a low-carbon future. As the world advances toward green and low-carbon development, education will play a central role in shaping the values, knowledge, and skills of future generations, enabling them to drive sustainable change in their communities and beyond.

3 | Curriculum Design, Pedagogical Approaches, and Practical Programs

3.1 | Curriculum Development for Sustainable Talent Advancement

Designing a curriculum that advances green and low-carbon development necessitates an interdisciplinary approach aligned with UNESCO's Education for Sustainable Development (ESD) framework, which emphasizes climate awareness, energy conservation, and carbon reduction (UNESCO 2014). Nature schools effectively incorporate ESD concepts by linking academic knowledge with practical activities relevant to students' local environments, thus cultivating a strong sense of responsibility toward sustainability (Li et al. 2023). Activities such as tree planting and renewable energy workshops connect theoretical learning with practical application, involving students in carbon sequestration and energy-saving initiatives that yield tangible environmental outcomes and promote environmental responsibility. Studies demonstrate that hands-on experiences, including carbon footprint assessments and energy conservation projects, significantly enhance students' sustainability competencies (Jimlan 2021; Gaffney and O'Neil 2019). These activities help students internalize environmental concepts and empower them to apply their knowledge beyond the classroom. Moreover, interdisciplinary curricula that integrate environmental science, economics, and ethics promote a holistic understanding of sustainability challenges. This comprehensive approach equips

students with essential critical thinking and problem-solving skills needed to address complex environmental issues (Hogan and O'Flaherty 2022; Denham et al. 2021).

A key feature of curriculum design is the integration of indigenous ecological knowledge. Community-oriented initiatives that address local environmental issues—such as clean-up campaigns or biodiversity assessments—enhance students' comprehension of their ecosystems and nurture a sense of communal accountability (Hamidullah 2024). Grounded in local contexts, these projects help students appreciate the relevance of sustainability principles in their daily lives and prepare them to actively contribute to local conservation efforts.

3.2 | Educational Methodologies in Nature-Based Schools

Nature-based schools utilize educational methodologies that prioritize experiential, place-based, and collaborative learning. Experiential learning, grounded in Kolb's theory (Kolb and Kolb 2009), is essential to nature-based education, engaging students in hands-on activities such as carbon tracking and emissions analysis. These practices help students develop data analysis and strategic planning competencies. Studies indicate that experiential initiatives enhance environmental advocacy and foster a deeper personal commitment to sustainability (Menon and Suresh 2020; Stefanakis 2022).

Place-based education reinforces these outcomes by integrating local ecological and cultural elements into the curriculum. Students collaborate with neighborhood organizations to address issues such as pollution mitigation and habitat restoration (Zhang et al. 2022). This method contextualizes education within students' neighborhoods while fostering agency and accountability, enabling students to champion local environmental concerns. Collaborative initiatives—such as the construction of energy-efficient edifices or the creation of educational gardens—promote teamwork and environmental stewardship (Karaca 2020). These projects promote collaboration among students, leveraging their abilities and perspectives to improve learning outcomes and equip them for real-world sustainability initiatives.

Presenting project outcomes to community stakeholders enhances students' communication skills and underscores the real-world relevance of their work (Martín-Hernández et al. 2021; Penuel et al. 2020). Technology is essential, allowing students to monitor carbon footprints, participate in virtual simulations, and connect with international peers to exchange sustainability knowledge. This digital integration broadens students' perspectives and increases engagement, while techniques such as gamification and interactive applications promote sustainable behaviors through real-time feedback and reinforcing positive actions (Ullah and Anwar 2020).

3.3 | Practical Educational Initiatives in Nature Schools

Since 2020, practical education programs in nature schools have proliferated, exemplified by the Carbon-Neutral Campus Initiative, which engages students in energy audits, community-led tree planting, and conservation activities (Chen et al. 2022). Through these initiatives, students acquire fundamental competencies in data collection, analysis, and project management. Energy audits, for example, allow students to propose actionable solutions—such as the installation of energy-efficient lighting—thereby connecting classroom learning with tangible environmental impact.

Research on community-based conservation initiatives underscores the efficacy of student-led habitat restoration efforts, including wetland rehabilitation and the removal of invasive species (Raisya and Djuwita 2018; Mathie and Wals 2022). These projects promote ecological stewardship and facilitate collaborations with local governments and NGOs, underscoring the significance of collective action in environmental conservation.

However, several challenges hinder the implementation of these programs, including limited funding, inadequate teacher training, and inflexible curricula (Shutaleva et al. 2020). Overcoming these obstacles necessitates policy reforms that promote professional development in experiential learning, increased financial investment in environmental projects, and greater curriculum flexibility. By leveraging community resources and integrating digital technologies—such as smartphone applications for carbon tracking and virtual reality simulations—Chinese nature schools can improve student engagement and promote comprehensive, data-informed environmental learning experiences.

The thorough design and implementation of these practical educational programs at nature schools represent a vital step toward achieving green and low-carbon development, equipping students with the skills and mindset to spearhead future sustainability initiatives.

4 | Discussion

NBE has emerged as an effective approach to foster environmental awareness and encourage active participation in carbon reduction efforts, thus aligning closely with national climate objectives. This section explores the potential of NBE, identifies barriers to its implementation, and discusses strategies for overcoming them.

NBE promotes environmental responsibility by fostering emotional connections with nature and deepening students' understanding of their role in carbon reduction (Davis and Elliott 2023). Activities such as exploring local ecosystems or participating in renewable energy projects—like constructing small solar panels or wind turbines—allow students to directly observe and influence their environment. These experiences build key skills essential for sustainability leadership, including problem-solving and critical thinking, and help prepare students to meet complex climate-related challenges (Atler 2024).

However, the successful implementation of NBE requires addressing several specific barriers with targeted solutions. One significant barrier is the insufficient teacher training in

environmental science and experiential learning. A practical and well-supported solution is to establish comprehensive professional development programs that equip educators with both content knowledge and pedagogical skills in experiential and place-based education. Partnerships with environmental organizations can further support these efforts by offering hands-on training opportunities and mentorship, thereby increasing teacher confidence in delivering NBE content effectively (Nouri et al. 2021).

A second challenge is the rigidity of traditional curricula, which often limits the flexibility needed for place-based and interdisciplinary education. As suggested by several studies (Rickinson 2001; Brouwers 2024; Mpuangnan and Ntombela 2024), policymakers should support curriculum reforms that allow greater flexibility for local adaptation. For instance, integrating region-specific projects on biodiversity conservation or community carbon reduction efforts can make education more relevant and actionable. Involving community stakeholders in curriculum development ensures that local environmental priorities are reflected in educational practices.

A third challenge is resource scarcity, particularly in rural or underserved areas. To overcome this, schools can pursue partnerships with NGOs, apply for government grants, or seek corporate sponsorships to fund outdoor facilities and specialized equipment (Seguin et al. 2005; Sleegers 2019; Reiling et al. 2021). Moreover, leveraging technological tools such as virtual reality and interactive online platforms can help compensate for physical limitations. For example, virtual field trips give students the opportunity to experience diverse ecosystems and renewable energy systems, increasing access to NBE learning experiences regardless of location (Moorman et al. 2021; Jerowsky 2024).

Finally, community engagement is crucial for the success of NBE. It provides students with real-world learning opportunities while fostering a collective sense of environmental responsibility (Kelly and Given 2024). Schools can build strong connections with local communities by organizing volunteer projects, hosting public environmental workshops, and involving students in neighborhood conservation efforts. These initiatives offer real-world learning experiences and help create a shared commitment to carbon neutrality.

5 | Conclusion

The integration of green and low-carbon development into the education system offers an opportunity to cultivate a generation equipped with the necessary skills, knowledge, and motivation to drive sustainable change. NBE represents a promising approach that aligns with the principles of ecological civilization and offers practical strategies to improve students' environmental awareness. Through experiential and place-based learning, NBE provides students with foundational knowledge of carbon cycles, renewable energy, and conservation practices while fostering a strong emotional connection to nature. This connection is essential for promoting long-term environmental stewardship and supporting sustainable climate goals.

Strategic investment in teacher training is essential for equipping educators to effectively deliver interdisciplinary environmental content. Training should emphasize practical, immersive approaches and strengthen educators' understanding of ecological systems and carbon management. Policymakers should also develop flexible curricula that allow schools to integrate local environmental issues and customize learning experiences to fit regional contexts. Localized learning opportunities enhance the relevance and impact of climate education for students, fostering a sense of responsibility for their immediate environment.

Alongside teacher training and curriculum reform, addressing resource disparities that restrict access to outdoor learning environments and specialized materials is essential. Collaborations with environmental organizations, governmental support, and advances in technology—such as virtual reality—can help to bridge these gaps, making NBE more accessible to schools, including those in remote or under-resourced regions. Technology can enhance NBE by providing virtual experiences of ecosystems and renewable energy initiatives, enhancing students' educational experiences.

Involving local communities in collaborative environmental projects further strengthens the effectiveness of NBE (Al-Balushi et al. 2014). Community involvement enhances students' comprehension of sustainability and cultivates a culture of shared responsibility—crucial for attaining low-carbon goals at the societal level. Community-based NBE projects can enhance the significance of students' education and raise wider environmental awareness across society.

This study emphasizes the transformative potential of NBE in furthering sustainable climate objectives and highlights the essential role of educational reform in achieving sustainable development. Future research should examine the long-term effects of NBE on students' environmental attitudes and behaviors and investigate scalable models that can be adapted for various educational contexts. Furthermore, investigations into the incorporation of emerging technologies into NBE may yield significant insights for improving accessibility and engagement in related curricula. Addressing these areas will position the education system as a powerful driver for climate action—preparing a new generation to lead in a carbon-neutral future. NBE enables students to acquire ecological literacy and empowers them to serve as agents of change, thereby contributing to sustainability vision and inspiring global initiatives toward a more resilient and environmentally conscious world.

Author Contributions

Linyu Xu: writing – review and editing, writing – original draft, funding acquisition, visualization, validation, conceptualization, supervision, project administration. **Yuqi Dai:** conceptualization, validation, writing – original draft, writing – review and editing, visualization.

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Ethics Statement

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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