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Growing Green with Screens: Integrating Technology to Enhance Sustainability Education in Early Childhood

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Abstract

Incorporating sustainability education in early childhood settings is essential to foster pro-environmental values from an early age. This study explores how integrating digital applications into school gardening can enhance sustainability education in preschool contexts. Grounded in Vygotsky's Sociocultural Theory, technology is conceptualised as a cultural tool that supports learning within the Zone of Proximal Development (ZPD). Using a mixed-methods approach, the study involved 30 preschool children (ages 5–6), with data gathered through children's lapbook portfolios (qualitative), parental surveys (quantitative), and teacher interviews (qualitative). Digital apps like iNaturalist and Plant Parent facilitated plant identification, documentation, and care routines. Findings reveal that digital integration enhances children's engagement, supports observational and scientific thinking, fosters environmental awareness and healthy habits, and promotes socio-emotional development. The VeggieNest Project, combining hands-on gardening with interactive digital tools, demonstrates how young children can meaningfully engage with sustainability through scaffolded, inquiry-based activities. The study proposes a replicable, developmentally appropriate model for digitally supported Early Childhood Education for Sustainability (ECEfS), addressing the challenge of embedding ecological literacy in early learning.

Keywords: Sustainability Education, Digital Tools, Preschool, Environmental Awareness, School Gardening

Introduction

In the 21st century, Early Childhood Education for Sustainability (ECEfS) has become central to fostering long-term environmental consciousness among young learners. It aims to foster environmental awareness, social responsibility, and sustainable behaviours from a young age (Güler Yıldız et al, 2021; Ardoin & Bowers, 2020; Ernst & Burcak, 2019). ECEfS is

increasingly recognised for its potential to shape future generations' attitudes towards sustainability, addressing global challenges such as climate change, biodiversity loss, and social inequalities (Watt & Frydenberg, 2024; Engdahl, 2021; Bascopé et al., 2019). Despite growing policy interest, teachers still face challenges in translating abstract and broad sustainability goals into meaningful learning experiences, particularly in Malaysia. The 2021 UNICEF-UKM Report, for instance, called for greater awareness and education on environmental issues for children, aligning with ECEfS's goals of empowering young learners through sustainable action.

As learning environments become increasingly digital, there is also a need to explore in what way nature-based activities can be enhanced with technology to promote sustainability in the years education. Recently, digital tools have emerged as promising mediators of learning, especially when combined with experiential methods. A study conducted in Germany by Stock et al. (2024) developed BeeLife Mobile Apps, a gamified app about one of the primary pollinators, wild bees, which have demonstrated the educational potential of mobile apps in nurturing environmental awareness among children. The pilot study involved 44 children aged 9 to 12, shown the app to be highly engaging, as most of the participants found it "*intuitive, engaging, and visually appealing",* and presented significant improvements in learning. This empirical study demonstrated how interactive digital tools can make environmental education more engaging and accessible, offering insights for adapting such tools for younger audiences in ECE settings.

Among nature-based activities, school gardening stands out and has long been recognised globally as a long-recognised approach to early childhood education, offering children direct, hands-on experiences with nature. These experiences foster observation, care, and responsibility while promoting holistic development across physical, cognitive, social, and emotional domains. Physically, tasks such as planting, weeding, and harvesting help improve motor skills and overall fitness (Dutta & Chandrasekharan, 2025; Holloway et al., 2023). Socially and emotionally, gardening encourages teamwork, communication, and conflict resolution as children work collaboratively to care for plants (Bergan et al., 2021; Keith, 2005; Koloszuki Maciel et al., 2022). Ohly et al. (2022) further highlight the role of gardening in strengthening interpersonal skills, emotional intelligence, and community belonging.

In addition, nature-based activities, particularly school gardening, significantly enhance engagement in science, technology, engineering, and mathematics (STEM). Through hands-on exploration of biodiversity and ecosystems, children make abstract scientific concepts more tangible (White et al., 2018) and subsequently cultivate critical thinking and inquiry, laying a strong foundation for STEM learning (Holloway et al., 2023; Turner et al, 2022). Mathematical concepts such as measurement and data collection are applied meaningfully as children track plant growth and plan garden layouts (Williams et al., 2023). For urban children with limited access to green spaces, school gardening provides essential opportunities to connect with the natural world (Deniz & Kalburan, 2024). Thus, school gardening is a multidisciplinary educational tool that supports children's holistic development while fostering environmental awareness and academic engagement.

Similar to the BeeLife, this study leverages mobile tools to scaffold learning, but within the early years' education. This study addresses a pressing educational gap by exploring how technology, specifically iNaturalist and Plant Parent apps, can be integrated into school gardening projects to enhance sustainability education in early childhood. Grounded in Vygotsky's Sociocultural Theory, the research positions technology as a cultural tool that mediates learning and cognitive development within the child's Zone of Proximal Development (ZPD). These tools serve not only to support children's identification and documentation of plant species but also to scaffold their inquiry-based learning through interactive and socially mediated experiences. In addition, the study aims to evaluate the extent to which such applications enhance children's environmental awareness, observational skills, and scientific curiosity.

A local study by Zulfikri and Masnan (2022) affirms technology-enhanced value in Malaysian preschool contexts, further supporting this approach, demonstrating that the use of technology in early childhood teaching and learning can enhance both teaching efficacy and children's engagement. This highlights the growing potential of technology as a pedagogical tool in Malaysia's early childhood context, particularly when integrated with nature-based approaches such as school gardening. These apps not only aid in plant identification and documentation but also scaffold children's scientific curiosity and inquiry through interactive, socially mediated experiences.

Despite growing interest in integrating technology-enhanced tools in education, limited research has been done on early years education, particularly in Malaysia. Therefore, by focusing on the integration of technology within nature-based activities, this study contributes a novel perspective to Early Childhood Education for Sustainability (ECEfS) in Malaysia. Unlike previous research, this study offers a new perspective by demonstrating how hands-on nature activities can be meaningfully extended through the use of technology, fostering a balance between ecological literacy and digital competence from an early age. This intersection opens new possibilities for future-ready curricula responsive to both ecological and digital imperatives.

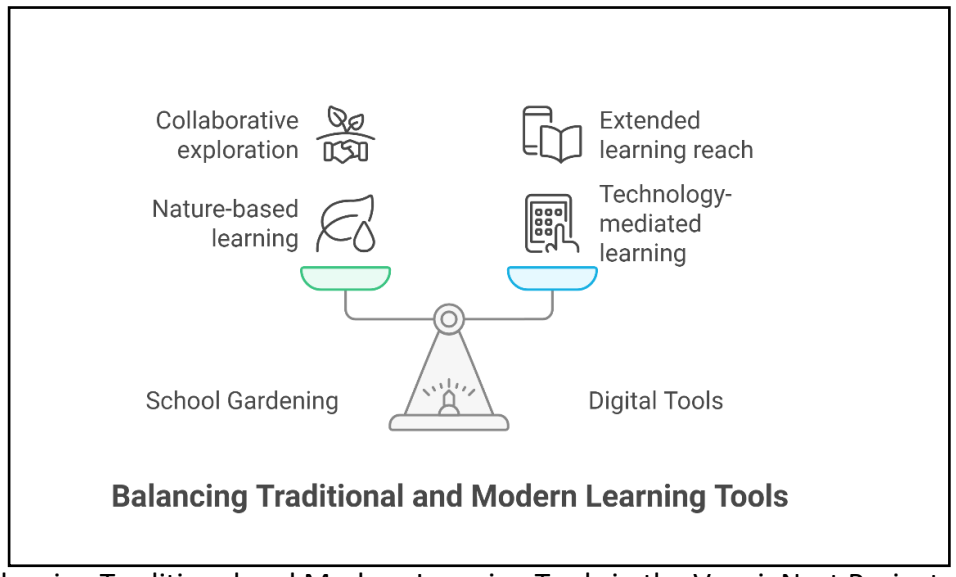

Figure 1: Balancing Traditional and Modern Learning Tools in the VeggieNest Project

Theoretical Framework

This study is grounded in Vygotsky's Sociocultural Theory, which emphasises the importance of social interaction and cultural tools into cognitive development which positing that cognitive development is shaped by social interaction and mediated through cultural tools. According to Vygotsky (1978), learning occurs through collaborative interactions with more knowledgeable others (MKO), such as peers, teachers, or educators within a specific cultural and social context. The theory highlights the critical role of guided participation and the use of tools, both physical and symbolic, in learning and skill acquisition. In this context, school gardening serves as a traditionally meaningful approach that fosters nature-based activities, collaboration, and environmental awareness. Digital tools, such as the iNaturalist and Plant Parent apps, act as mediational artefacts that extend children's learning experiences beyond the physical garden. These tools align with Vygotsky's concept of the Zone of Proximal Development (ZPD), where children are supported to achieve higher levels of understanding and competence through guided interaction with technology, their peers, and knowledgeable adults, their teachers and parents.

Methodology

The VeggiesNest Project spanned two months and combined hands-on gardening activities (from seed to harvest) with digital tools, specifically the *iNaturalist* and *Plant Parent* apps. Before participation, parental consent was obtained to ensure ethical compliance and safeguard the children's safety.

Figure 2: Preschoolers engaged in seed sowing for the VeggieNest Project

This empirical study employs a mixed-method research approach, combining children's lapbook portfolios, parental surveys and teacher interviews to evaluate the impact of the integration of technology (iNaturalist Apps and Plant Parent) in the VeggiesNest Project on 30 preschool children aged 5 to 6 years old. The iNaturalist App allowed children to take photos of plants, insects, and flowers to receive identification suggestions. For instance, children used the app to identify pollinators such as bees and butterflies or to discover which plants attract beneficial insects, fostering a deeper understanding of ecosystems and the

importence of sustainable gardening practices. Meanwhile, the Plant Parent app enables young learners to recognise plant species, set reminders for watering, fertilising, and taking care of the plants, track plant growth as the user can save the photos taken in the database, and better understand their garden environment. These tools were integrated into group activities, where children worked collaboratively to explore the garden, identify plants, and document their findings. Young children were actively planting, monitoring, and harvesting vegetables while simultaneously using the apps to track plant growth using Plant Parent Apps. With teachers' supervision and guidance, these apps supported hands-on learning and encouraged communication, teamwork, and shared discovery among the children.

Figure 3: Preschoolers are actively using the digital apps to support their learning

This integrated approach aimed to enhance both observational and technological skills while introducing sustainability and healthy lifestyle concepts engagingly and interactively. After the project was completed, an online survey was distributed to 30 parents, of which 27 responses were received, providing quantitative insights into their children's post-experiences with the program. The survey questions were divided into three sections: (1) involvement and enthusiasm in school gardening and growing their own food, (2) understanding the impact of gardening on the environment and sustainable and healthy living, (3) skills development and (4) interest in using technology for learning. Next, in triangulating the data, a semi-structured interview was conducted to explore their perception of integrating technology in the VeggieNest project, a school garden activity, also the challenges faced in integrating iNaturalist and Plant Parent Apps in the teaching and learning.

Data Analysis

The collected data were analysed using both qualitative and quantitative methods. Initially, the children's lapbooks were examined to assess learning outcomes, such as their understanding of plant growth cycles, sustainability concepts, and engagement in gardening activities. This analysis focused on the children's ability to observe, document, and reflect on their experiences. Next, parental responses were analysed to identify trends in children's attitudes toward gardening, their interest in healthy, sustainable living, their environmental awareness, and their reinforced interest in integrating technology into learning. Next, the interview transcripts were analysed using thematic analysis, a widely used method for identifying, analysing, and reporting patterns and themes within qualitative data. Following

the six-step approach proposed by Braun and Clarke (2006), the researchers began by familiarising themselves with the data through repeated readings. Initial codes were then generated inductively to capture meaningful segments of text. These codes were subsequently grouped into broader themes that reflected patterns across the dataset, particularly in relation to children's engagement, skill development, and environmental awareness through the VeggieNest project. The process allowed for an in-depth understanding of the teachers' perspectives and ensured that the findings remained grounded in the data. Atlas. ti software was used to support the coding and theme organisation process.

Findings and Discussion

The findings of this study are discussed separately into two sections: i) Children's Lapbook Analysis and ii) parental survey and teachers ' interview.

Children's Lapbook Analysis

In the lapbook, children were engaged in various portfolio activities that aligned with the national curriculum, learning objectives as below:

Table 1

Children's Lapbook Portfolio Activities Description

Section	Activities	Description
1	**How the Plant Grows**	The children illustrated and labelled diagrams of their plants, showing the stages from seed to harvest. They also wrote short descriptions of each stage, emphasising what they observed first-hand.
2	**What Plants Need to Live**	A section of the lapbook detailed the essentials for plant growth (sunlight, water, air, and soil). This was often reinforced during class discussions and hands-on activities, such as adjusting sunlight exposure for the plants.
3	**Plant's Life Timeline**	Children created visual timelines showing the journey of their plant, from planting the seed to harvesting. They added stickers or coloured icons to represent milestones like the first sprout or flowering.
4	**What We Can Eat from Plants**	This section encouraged exploration of the edible parts of plants. For example, some children learned that carrots are roots, while lettuce is a leaf, which sparked excitement about discovering similar foods at home.
5	**Plant Circle Time**	During circle time, the children shared their observations, challenges, and successes with their peers. They also engaged in storytelling, imagining the "life story" of their plants. This activity nurtured creativity and deepened their connection to the project.

Figure 4: A4-sized lapbook portfolio divided into five activity sections, designed to be child-friendly and easy to handle.

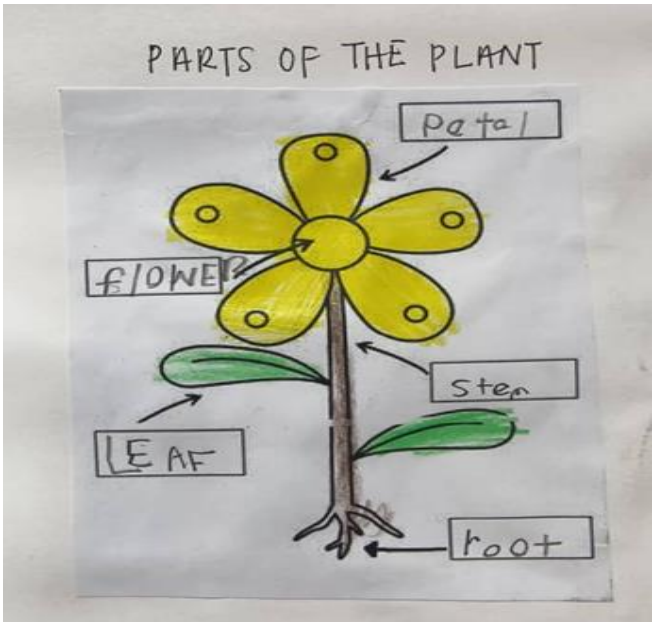

Figure 5: A child's diagram of plant parts, demonstrating early scientific understanding through labelled components and symbolic representation.

Figure 6: This activity helps children learn about the parts of the plant consumed, matching them with actual edible plants.

Figure 7: Children documenting the growth of a bean seed. This hands-on activity fosters observational skills and scientific thinking.

Figure 8: During circle time, the children shared their documented observations, challenges, and successes with their peers.

The analysis of children's lapbook activities reveals meaningful insights into their scientific understanding and developmental progress. This suggests that the lapbook activities served as an effective tool for consolidating learning and expressing conceptual understanding. From a sociocultural perspective, this aligns with Vygotsky's Zone of Proximal Development (ZPD), highlighting how teacher guidance and hands-on activities scaffold the child's ability to represent knowledge meaningfully.

In addition, it has provided valuable insights into children's understanding and engagement with the VeggieNest project. The majority of children demonstrated a clear grasp of the plant growth cycle, with most accurately depicting the stages of seed sowing, growth, and harvesting. The creativity displayed in the lapbooks highlighted the children's engagement with the project, with several incorporating original drawings, labels, and descriptions. One recurring theme was a strong sense of connection to nature, with many children sharing personal reflections on how they enjoyed the tactile experiences of gardening, such as touching the soil, observing the plants grow, and seeing insects in the garden. This suggests that the hands-on nature of the gardening activities effectively fostered sensory and emotional engagement with the natural world.

Moreover, the integration of technology was evident in several lapbooks where children had used the iNaturalist app to document plant species. However, this was mostly limited to identification tasks rather than deeper reflections on the ecological importance of the plants or how they contribute to environmental health. This finding suggests that while digital tools engaged children in the process, there was potential for further integration of critical reflection on environmental sustainability, which could enhance their learning experience.

In summary, the lapbook analysis revealed that the children were highly engaged with the gardening activities, and many showed a basic understanding of plant growth. However, there is room to deepen their understanding of sustainability and its broader environmental impacts. Future lessons could focus on explicitly linking gardening activities with sustainable actions and encouraging more reflective thinking about environmental conservation.

Parental Survey and Teacher's Interview

Based on the parental survey and teacher interview analysis, four (4) themes have emerged: ***i) engagement and motivation, ii) Observational and Scientific Thinking, iii) Environmental Sustainability and Healthy Lifestyle*** and ***iv) Social and Emotional Development.***

Engagement and Motivation

From this empirical study, it is indicated that the integration of technology and nature-based activities in the VeggieNest project revealed key insights into both children's engagement and skill development, as captured by the teacher interviews. One of the most significant findings was the increased enthusiasm and excitement that children demonstrated toward gardening activities. As one Teacher 1 noted, *"... children who were initially hesitant about gardening became more enthusiastic through the apps. One child, who struggled with traditional activities, excelled in using iNaturalist to identify and categorise plants, proudly presenting his findings during circle time".* This aligns closely with the parental survey, where 69% of parents reported seeing their children excited about gardening. This suggests that the hands-on nature of gardening activities, integrated with the Apps as learning mediators, was highly motivating for their children.

In addition, Teacher 2 further explained that "*The children were fascinated by the iNaturalist app's ability to recognise plants and provide detailed information. For example, when a child discovered their 'bean plant' was part of the legume family, it sparked discussions about related plants like peanuts and lentils among them!*. This finding is aligned with a recent scoping review by Trina et al (2024) notes that gardens become natural "workspaces" where young children *"raise questions about the natural world, take hands-on action, and seek answers through observation, exploration, and data collection.* It collectively underscores the influential role of hands-on, tech-enhanced gardening experiences in fostering young children's active engagement and positive attitudes toward nature-based activities. The synergy between digital tools like iNaturalist and tangible gardening activities not only sustained children's interest but also nurtured curiosity and a deeper connection to the world around them.

Observational and Scientific Thinking

In addition, the teachers observed notable improvements in children's observational and inquiry-based skills, which are essential components of early scientific thinking. For example, Teacher 2 described, "*They were constantly asking questions, comparing plants, and even drawing different stages of growth in their lapbooks."* This indicates that the children were actively engaged in processes such as comparing, documenting, and reflecting. The integration of gardening tasks with tools like lapbooks and digital apps has stimulated curiosity and promoted deeper engagement with natural phenomena. Teacher 1 also noted, *"I saw one child sketch the initial sprout and compare it to the next stage when leaves appeared, proudly noting the plant's progress. (Refer to Figure 4)".*

These observations are mirrored in the survey data, where 53.8% of parents reported noticing improvements in their children's observational abilities. The overlap between teachers' and parents' perspectives suggests that the VeggieNest project not only engaged children in hands-on gardening tasks but also fostered cognitive development, particularly in attention to detail and critical thinking. This behaviour reflects early forms of scientific observation, analytical thinking, and documentation in early childhood education. The findings align with existing literature, which highlights how school gardening can stimulate shared "scientific discourse" and cultivate higher-order thinking skills such as observation, analysis, and reasoning (Núñez et al., 2021; White et al., 2018). In short, school gardening promotes children's ability to observe, hypothesise, and communicate their understanding of natural processes.

Another key theme identified through the teacher interviews was the positive impact of integrating technology with the school gardening project. By combining digital tools in learning, the project bridged the gap between modern technology and nature-based learning, showing children how both can coexist. For example, the teachers observed that the use of digital tools, such as plant identification apps, enhanced children's understanding of the environment. As one teacher explained, *"When they used the app to identify different plants, it was as though they were 'learning with technology' rather than just using it as a tool" (Teacher 1).* Regarding the Plant Parent app, Teacher 1 shared examples: "*…one child excitedly said, 'My bean plant has a big root now, and I think it's looking for more water"* and "*The children began to describe their plants using scientific terms they had learned, such as "roots," "stems," and "leaves", through their interactions with the app."* In addition, according to the teacher, the gamified elements of Plant Parent, such as earning badges for consistent care, motivated children to stay engaged and attentive to their plants' needs. This perception aligns with the survey results, where 50% of parents reported an increased interest in technology among their children. Notably, when integrated with nature-based activities, technology does not merely function as an external tool but serves as a scaffold for learning and inquiry, supporting Vygotsky's concept of the Zone of Proximal Development (ZPD) in early years education.

Environmental Awareness and Dietary Habits

Next, from the environmental consciousness perspective, the teacher also indicates the growing awareness of the interconnectedness between the children's gardening experiences and broader ecological concepts. One teacher mentioned*, "I noticed the children starting to talk about how our plants help the environment and why we need to take care of them. They started making connections between their plants and how plants help clean the air or provide food"*. This indicates that the gardening project was not only about growing food; it also encouraged children to reflect on environmental sustainability and the role of nature in supporting healthy living, as emphasised in Dutta & Chandrasekharan (2025). Furthermore, Teacher 1 highlighted that *"We also compost plant waste activity to introduce the concept of recycling and the importance of minimising waste to protect the environment, and the children have practised it."* This observed behavioural shift aligns with the project's broader aim of promoting healthy and sustainable living from an early age (Dutta & Chandrasekharan, 2025), reinforcing the value of school gardening as a tool for fostering both personal and environmental well-being. The finding echoes the Early Childhood Education for Sustainability (ECEfS) stands, which emphasises connecting children with nature in ways that

foster a sense of responsibility toward ecological conservation and sustainability (UNICEF, 2021).

In addition, the teachers observed that children were more willing to taste vegetables when they had grown them themselves, as she mentioned, *"For example, during one observation, a child exclaimed, 'This is my carrot! I want to eat it right away!"* showed that they have developed the personal connection and pride, making them more open to trying the vegetables they grew. Parental feedback supported this observation, with 73.1% reporting increased enthusiasm for eating vegetables. These behavioural changes suggest that direct involvement in planting and harvesting fosters a stronger connection to food and healthier eating habits (Robinson-O'Brien et al., 2009). This change suggests a positive shift in children's dietary preferences, likely influenced by their direct involvement in planting, nurturing, and harvesting vegetables. Research indicates that experiential learning, such as gardening, can enhance children's willingness to try new foods, particularly vegetables (Chat et al, 2022). The hands-on experience fosters a sense of ownership and curiosity, making children more open to tasting what they've grown.

Social and Emotional Development

The collaborative nature of gardening activities promoted teamwork, communication, and shared responsibility. Teachers observed a shift from solitary work to coordinated group roles. As Teacher 2 noted, *"At first, the children worked individually or in pairs during the planting seeds activity. However, as the project progressed, we noticed a significant shift toward teamwork. For example, during watering routines, children began assigning roles among themselves. One child would hold the watering can while another ensured the correct amount of water was given to each plant."* Further supported by Teacher 1, *"One particularly striking moment occurred during a group activity where the children designed a poster about what plants need to live. They not only brainstormed ideas together but also negotiated which illustrations to include, demonstrating collective decision-making and shared responsibility."* This development echoes the parental survey findings, in which 70.4% of parents reported enhanced communication and collaboration skills in their children. The integration of social-emotional learning through group gardening activities thus contributes to the holistic development of the children, reinforcing the multidimensional benefits of nature-based learning as highlighted by Bergan et al. (2021). This is also consistent with Vygotsky's (1978) sociocultural theory, which emphasises the role of social interaction and collaborative learning within the Zone of Proximal Development (ZPD) in fostering cognitive and emotional growth.

Challenges

Despite the benefits, educators also identified the need for careful integration of digital tools. One recurring concern was that excessive screen interaction might detract from direct, sensory engagement with nature. As Teacher 1 cautioned, *"There's a fine line between using technology to enhance the learning experience and allowing it to distract from the natural world."* This insight underscores a potential tension that educators may encounter when integrating digital tools into nature-based learning. It also raises a critical consideration: while fostering digital literacy is important, it must not come at the expense of children's direct, sensory engagement with the natural environment. In this context, there is a clear need to strengthen teachers' pedagogical training in the purposeful integration of technology,

ensuring that digital tools are used to support and scaffold, not overshadowing experiential, hands-on learning.

Limitations and Future Research Recommendations

Despite the valuable insights generated by the VeggieNest project, several methodological limitations should be acknowledged to contextualise the findings and guide future scholarly inquiry. Firstly, the study was conducted with a relatively small and geographically limited sample, comprising a specific demographic group within Malaysia. This small sample size constrains the generalizability of the results and highlights the need for replication across more diverse socio-cultural and educational contexts. Future studies should therefore aim to involve larger, demographically varied cohorts, enabling comparative analysis and broader applicability of the findings.

Conclusion

The findings from the children's lapbook, parental surveys and teacher interviews indicate that the VeggieNest project successfully engaged children in nature-based learning while also enhancing key skills, such as observation, collaboration, and environmental awareness. Furthermore, the project's emphasis on growing food and interacting with nature seemed to foster a sense of responsibility toward the environment, which is a critical component of environmental sustainability education. However, the critical integration of technology needs to be carefully managed to ensure it enhances, rather than distracts from, the core learning objectives of the project. In addition, the VeggieNest project serves as a promising model for incorporating sustainability into early childhood education while promoting holistic development and fostering digital literacy in balance with ecological awareness. Ultimately, these empirical findings can inform teachers and policymakers in integrating digital tools meaningfully and effectively to enhance sustainability education in early years education.

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Conflict of Interest Statement

The authors declare no conflict of interest.

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