Journal of Applied Life Sciences International

Volume 27, Issue 5, Page 22-39, 2024; Article no.JALSI.121978
ISSN: 2394-1103

The Role of Garden Based Nutrition Education in Enhancing Healthy Eating Habits and Cognition among Preschoolers

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jalsi/2024/v27i5657

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/121978

Systematic Review Article

Received: 21/06/2024
Accepted: 27/08/2024
Published: 05/09/2024

ABSTRACT

Aims: 1)To assess the effectiveness of garden-based nutrition education in promoting healthy dietary habits and nutritional knowledge among preschool-aged children; 2) to evaluate the methodologies employed in studying the impact of garden-based nutrition education on cognitive development and academic performance in preschoolers; 3) to analyse the results of research studies investigating the use of garden-based nutrition education in improving nutritional status, cognitive function, and learning outcomes among preschool-aged children; and 4) to discuss the implications of findings related to the use of garden-based nutrition education for early childhood education, parental involvement, and public health policy.

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Cite as: *N, Shiji, and Beela G K. 2024. "The Role of Garden Based Nutrition Education in Enhancing Healthy Eating Habits and Cognition Among Preschoolers". Journal of Applied Life Sciences International 27 (5):22-39. https://doi.org/10.9734/jalsi/2024/v27i5657.*

Methods: We conducted a systematic literature review using electronic databases such as PubMed, PsycINFO, and Google Scholar to identify relevant peer-reviewed articles, reviews, and meta-analyses published between 2010 and 2022. Studies examining the impact of garden-based nutrition education on food habits and cognitive development among preschool-aged children were included in the review. Data extraction was performed to compile information on study objectives, methodologies, key findings, and implications.

Results: The review identified a growing body of literature highlighting the positive impact of garden-based nutrition education on cognition among preschool-aged children. Studies have demonstrated that garden-based nutrition education interventions lead to improvements in dietary intake, nutritional knowledge, and dietary behaviour among preschoolers and their families. Moreover, engagement in garden-based activities has been associated with enhanced cognitive function, academic readiness, and socio-emotional development among preschool-aged children.

Conclusion: In conclusion, garden-based nutrition education offers a promising approach to enhancing cognition among preschool-aged children by promoting healthy dietary habits and supporting cognitive development. This review highlights the importance of further research and innovation in the development and implementation of garden-based nutrition education programs tailored to the unique needs of preschoolers and their families. By integrating garden-based activities into early childhood education curricula and community-based interventions, stakeholders can work towards ensuring that all preschoolers have the opportunity to reach their full cognitive potential and thrive in their early years.

Keywords: Garden-based nutrition education; nutrition gardening; garden-based learning; food-based education; horticultural therapy preschoolers; cognition; early childhood; academic readiness; nutritional knowledge and dietary behaviour.

1. INTRODUCTION

The preschool years are when children go through the most momentous developmental changes and acquire vital skills that provide school zeal. Cognitive growth throughout the preschool years is often a good indicator of future success in life [1]. Specifically, children's later academic success is significantly influenced by how quickly they establish working memory and attention control [2]. Preschool is a time where children's healthy growth is ensured and their cognitive, emotional, social, motor, and language development are supported [3]. Since the recognition that the initial 1000 days of life are crucial for cognitive development, dietary regulations enacted by policymakers have supported the brain development of young children [4]. Similarly, adequate nutrition intake remains vital for cognitive development during the subsequent 1000 days of life [5]. Despite the importance of cognitive and behavioural development in preschoolers during this period, they often receive limited attention in public policy [2].

The early years offer a significant opportunity to promote health as they lay the foundation for lifelong habits, including healthy ones, influencing overall lifelong health [6]. Innovative methods such as educational and experiential learning approaches have proven crucial in promoting health during early childhood. School gardens have been associated with improved health outcomes for children, prompting many schools to incorporate them into their educational programs. Garden-based nutrition education effectively boosts children's knowledge of gardening and promotes higher vegetable intake by involving them in planting, growing, harvesting, and preparing vegetables. These initiatives often involve producing fresh produce, educating about food origins and systems, and providing hands-on learning opportunities with fruits and vegetables [7]. Garden-based nutrition education programs are implemented in a wide variety of ways such as school-based, during normal school hours, afterschool hours, during an afterschool program but still on school grounds, and community based, in a community garden either on weekends or during school hours [8]. School garden lessons offer abundant opportunities for direct experiences, including cultivating plants and encountering animals such as soil organisms like earthworms, spiders, and woodlice.

Garden-based interventions have shown improvements in nutrition-related factors such as fruit and vegetable consumption, weight status, child nutritional status, and food security [9]. Moreover, nutrition education helps children understand the benefits of eating more vegetables, especially when they participate in

planting, growing, and harvesting vegetables themselves. This hands-on experience has been found to reduce children's aversion to vegetables, enhance their taste preferences, and increase their understanding of various types of foods, thereby boosting vegetable intake [10]. Positive experiences and sensory engagement, such as seeing, touching, and handling vegetables directly, enhance children's familiarity with food, potentially reducing food neophobia and encouraging them to try new foods.

Garden-based activities grant various health benefits, though their impact on cognitive development in children is not extensively researched. Exposure to natural environments is considered bottom-line for brain development, with green spaces providing children unique opportunities for engagement, risk-taking, discovery, creativity, mastery, and emotional well-being, all of which are believed to positively influence cognitive development. In addition to this, proximity to green spaces has been linked to increased physical activity levels, which in turn are associated with enhanced cognitive development.

Throughout preschool years, children experience significant cognitive growth, underscoring the importance of establishing healthy dietary habits and promoting optimal nutrition. Garden-based nutrition education offers a hands-on, experiential learning approach that involves children in growing, harvesting, and preparing fruits and vegetables, fostering a deeper understanding of food and potentially supporting cognitive development. Gardening can enhance cognitive functions by stimulating functional connectivity in the brain, activating positive emotions, and promoting mindfulness [11]. A 20-session horticultural therapy program, incorporating common gardening activities, significantly improved cognitive function in older adults with dementia [12]. There is a bacterium in a soil called *Mycobacterium vaccae* that has anti-inflammatory and immunoregulatory properties that could protect against stress and anxiety [13]. Gardening helps improve and/or preserve cognitive functions [11]. It may also stimulate serotonin production which regulates mood, anxiety, and happiness. There is growing research on the positive effect of gardening on mental health [14]. Gardening helps reduce stress, anxiety, and depression. It also helps overcome the effects of the coronavirus pandemic [15]. Moreover, garden-based interventions have been employed as therapeutic approaches for various illnesses and conditions, including autism spectrum disorder [16]. Additionally, apart from promoting outdoor physical activity [17], these pragmatic treatments have shown potential in improving academic performance [18].

This review seeks to explore the potential role of garden-based nutrition education in enhancing cognition among preschoolers, highlighting its effectiveness as a holistic intervention for promoting cognitive development and academic readiness during early childhood. The present study aimed to: 1) assess the effectiveness of garden-based nutrition education in promoting healthy dietary habits and nutritional knowledge among preschool-aged children; 2) evaluate the methodologies employed in studying the impact of garden-based nutrition education on cognitive development and academic performance in preschoolers; 3) analyse the results of research studies investigating the use of garden-based nutrition education in improving nutritional status, cognitive function, and learning outcomes among preschool-aged children; and 4) discuss the implications of findings related to the use of garden-based nutrition education for early childhood education, parental involvement, and public health policy.

2. MATERIALS AND METHODS

A systematic literature search was conducted using electronic databases such as PubMed, PsycINFO and Google Scholar. The search terms used for the literature search were "garden-based nutrition education," "preschoolers," "cognition," "early childhood," “nutrition gardening,” “garden-based learning,” “food-based education,” “horticultural therapy,” and "academic readiness" to identify relevant peer-reviewed articles, reviews, and meta-analyses published between 2010 and 2022. Time frame was chosen with the aim of obtaining the most recent and relevant research developments in garden-based nutrition education intervention and, it will help in understanding how GBNE has culminated in addressing nutritional and cognitive changes. Studies examining the impact of garden-based nutrition education on cognitive development among preschool-aged children were included in the review. Grey literature was not included. Approximately 170 studies were generated from the literature search. After removing duplicates and those that did not meet the inclusion criteria, we analysed 19 articles. Analysis of these articles provided few assessments of direct or

indirect impact of garden-based nutrition education on cognitive development among preschool-aged children. Data extraction was performed to compile information on study objectives, methodologies, key findings, and implications.

2.1 Inclusion and Exclusion Criteria

We included studies that met the following inclusion and exclusion criteria.

2.1.1 Inclusion criteria

2.1.1.1 Population

Preschool children and school-going children (both boys and girls) attending nursery, kindergarten, primary, secondary, high school education, and special schools were included. Children under the age of 3 would also be included as long as they were classified as 'students' or still attending nurseries or kindergartens.

2.1.1.2 Intervention

We included systematic reviews that focused on or included garden-based interventions. Garden-based interventions are inherently complex to define due to variation in type and setting. Therefore, we included any intervention that engaged children in active learning about nutrition, food systems, agriculture, or environmental health through connections with outdoor fruit or vegetable gardens, farms, raised garden beds, greenhouses, container gardens, microfarms, or other alternative gardening methods.

2.1.1.3 Context

The review included garden-based interventions implemented worldwide across various settings, such as homes, early care and education programs (e.g., preschool or child care), community centers or community gardens, afterschool programs, and summer camps. These interventions ranged from those solely focused on gardening to multi-component programs incorporating gardening alongside other activities. The inclusion criteria aimed to capture diverse approaches in using gardens to promote learning and health among children.

2.1.1.4 Outcomes

The review included systematic reviews that evaluated child-level health outcomes such as nutrition-related behaviors (e.g., consumption, attitudes, preferences, dietary quality), nutritional status, anthropometric measures (e.g., BMI), physical activity, and cognition-related outcomes (e.g., academic performance, developmental milestones). Reviews were excluded if they did not report on any of these child health outcomes relevant to the population of interest. Additionally, adverse or unintended consequences noted in the reviews were taken into consideration.

2.1.1.5 Study design

The review included randomized controlled trials, non-randomized controlled trials, and pre-post intervention studies. These studies examined changes in outcome measures from post-intervention compared to baseline, involving individuals or clusters (such as classes or schools) that were randomly assigned to trial arms. With practical considerations like whack of resources for translating and reviewing non-English sources, only studies written in English were considered. There were no restrictions on authorship, sample size, funding sources, intervention duration, or the country where the intervention occurred. This inclusive approach aimed to gather a broad range of evidence on interventions related to the review's focus.

2.1.2 Exclusion criteria

The review excluded unprinted, grey literature, and ongoing studies with only preliminary findings. Due to the chance for more inaccuracies, bias, or incomplete information grey literature were excluded. Additionally, studies that focused solely on describing school-based gardening programs without examining their effects on nutritional and health status, behavior, and cognition were also excluded. The inclusion criteria aimed to prioritize studies that provided comprehensive evaluations of the impacts of school-based gardening on various health and cognitive outcomes.

2.2 Study Selection

The review involved segregation and selecting studies for inclusion, conducted by one reviewer with miscue from another. Initially, titles and abstracts were segregated to assess acceptability based on predefined inclusion and exclusion criteria. During the segregation process, any disagreements between reviewers were consigned through a structured approach to ensure precise and translucent study selection. Initially, two independent reviewers evaluated

each study based on predefined inclusion and exclusion criteria. In cases where discrepancies arose in the assessment, the reviewers discussed their differing perspectives to reach a consensus. This discussion involved revisiting the study's relevance to the research question and ensuring that both reviewers had a shared understanding of the criteria. In the subsequent phase, full-text articles meeting the initial criteria were obtained and further screened using the same criteria to determine final inclusion in the review. This structured approach ensured rigorous selection of relevant studies for comprehensive analysis.

3. RESULTS

Tables 1 and 2 provide an overview of research conducted on various types of nutrition education programs cantered around gardens, highlighting their effectiveness. Specifically, 13 studies assess how school gardens contribute to encouraging healthy eating habits and enhancing nutritional knowledge among children of school age (Table 1). These programs encompass activities conducted within school hours, after school, farm-to-school initiatives, programs incorporating cooking, and those targeted at children but based in community gardens. A shared feature across all these programs is their agricultural aspect, engaging children in hands-on activities with fruits and vegetables. In programs where schools cultivate edible crops, students gain knowledge in science and nutrition while actively participating in the harvesting of vegetables. Some garden-based interventions included cooking sessions also. In "farm-to-school" programs, schools procure produce directly from local farmers or farmers' markets, with the farmers delivering the produce to the school. Subsequently, children visit the farms to learn about the cultivation process and the origins of the food. These programs serve various purposes, including using outdoor green spaces to educate children about nutrition and science, as well as providing spaces for them to play.

This review covers interventions that consisted of specially designed garden-based curricula [17, 18,19,20,21,22,23,24,25]. These interventions encompassed a variety of approaches, including nutrition education combined with garden activities [17,22,24]; gardening, nutrition education, and local food sourcing [19]; and nutritional education alongside cooking activities using harvested produce [18,19,20,21,23]. One community garden-based program featured regular gardening sessions, cooking and nutrition workshops, and social events for parents and children [25,26]. Two studies compared the effectiveness of nutrition education lessons with and without gardening components [17,22].

Most of the interventions occurred during school hours and varied in duration from short-term to long-term, spanning up to 4 years: one month [17]; 4-18 months [27]; 4 months [28]; ranging from 6 weeks to 4 years [18]; 12 weeks [20]; lasting one school year [21]; one month to one year [29]; 10 weeks [22]; 8-10 months [25]; and 4 terms [24], spanning Summer Term 2010 to Summer Term and Autumn Term 2011 to Autumn Term).

Considerable variability displayed in sample sizes, ranging from 25 to 3135 participants. Participants were aged between 2 and 15 years, with the majority falling within the 6 to 12-year-old range.

Studies have demonstrated substantial advancements in several facets of nutrition knowledge [17,18,20,22,23], enhanced openness to trying new foods [17,22], improved attitudes and preferences towards fruits and vegetables compared to snacks [17,18,20], exploration of new vegetables and choosing fruits and vegetables over chips or candy [17, 24,23], and increased ability among intervention groups to identify vegetables [17,30]. Significant findings were observed in the daily consumption of fruits and vegetables ($p < 0.05$) [28,18,20,23]. One study indicated that children's familiarity with new foods grew, thereby enhancing their willingness to try unfamiliar foods [19], while another study reported a notable reduction in food neophobia [20].

Some studies produced mixed results or did not find significant outcomes. Increasing the availability of fruits and vegetables was associated with higher consumption [25]. For example, Davis and coworkers (2021) observed an increase in vegetable intake but did not find any effects on fruit intake, consumption of sugar-sweetened beverages, obesity measures, or blood pressure [21]. Ohly and coworkers (2016) systematic review of 16 qualitative studies revealed diverse health outcomes [27]. Significant increases in fruit and vegetable intake were reported in two studies, while four out of six studies showed statistically significant changes in nutrient intake and other dietary outcomes. Eight

Table 1. Interventions involving school gardens with dietary outcome measures

Study	Participants	Duration	Research findings	Design
(Berezowitz et al. [18])	Studies: 7 studies in total. Participants: 2316 participants overall. Age/Grade: Age ranges from 7.3 to 11.1 years, or grades first through seventh. Schools: Conducted across 25 schools. Groups: 5 studies included both control and intervention groups.	1 month	Significanly higher Nutrition Knowledge, Willingness to Taste Vegetables, attitudes toward vegetables and fruit/vegetable snacks, preferences for trying new vegetables, able to identify vegetables and more willing to taste fruits and vegetables, increased intake of fruits and vegetables	Quasi-experimental with non-random group assignment, including cross-sectional and longitudinal components, and lacking a control group.
(Ohly et al. [28])	Age:3-13yr	4-18 months	i)significant increases in fruit and vegetable intake post-intervention (Two out of thirteen studies), ii)significant changes in nutrient intake and other dietary outcomes (Four out of six studies), iii) increased preference for fruits and vegetables among participants (Eight out of thirteen studies), iv)improved knowledge and attitudes towards food(Seven out of ten studies)	21 quantitative studies; 16 qualitative studies; 3 mixed methods studies
(Somerville et al. [29])	6-to-12-year old children	4-month	Significant results were found in fruit and vegetable servings consumed daily ($p<0.05$)	Pre and post-test validated survey assessed
(Chan et al, [19])	726 students from 341 schools and 8 nurseries	from 6weeks to 4 years	benefcial efects on children's nutritional knowledge, their attitudes and acceptability towards fruits and vegetables and children's dietary practices including the actual F&V consumption and dietary diversity	Randomised, non-randomised controlled and pre-post intervention studies
(McCloskey et al. [20])	children		-build children's familiarity with new foods and increase their likelihood of trying new foods	Descriptive Study(250 surveys)
(Benkowitz et al. [31])	119 children (between six and twelve years old)		Improved ability to identify vegetables; likelihood of vegetables	
(Kim and Park [21])	202 elementary school students (average age: 11.6 ± 1.5 years)	12 weeks	, dietary self-efficacy, outcome expectancies, gardening knowledge, nutrition knowledge, vegetable preference, and vegetable consumption were	pre-post-test experimental design was employed

Study	Participants	Duration	Research findings	Design
			significantly increased, and food neophobia was significantly decreased	
(Davis et al. [30])	kindergarten through 8th grade students	One month to one year	Out of the eleven programmes that examined dietary intake, six found that the programme resulted in increased vegetable intake, whereas four showed no effect. Seven of the eight studies that measured preference found that the programmes resulted in increased preference for vegetables. Gardening programmes also resulted in improved attitudes towards, willingness to taste, identification of and self-efficacy to prepare/cook fruit and vegetables.	Quasi-experimental design; Non-randomized
(Davis et al. [22])	3135 children; average age 9.2 years	one school year long (9 months)	resulted in increased vegetable intake; no effects on fruit intake, sugar sweetened beverages, any of the obesity measures or blood pressure	control group comparative study
(Morgan et al. [23])	127 students in Grades 5 and 6 (11–12 years old; 54 % boys)	10-week	significant between-group differences were found for NE&G and NE students for overall willingness to taste vegetables ($P < 0.001$) and overall taste ratings of vegetables ($P < 0.001$)	Quasi-experimental intervention with control and experimental group study
(Castro et al. [26])	95 children aged 2–15 years	8-10 month	increase the availability of fruits and vegetables; increase in the consumption of fruits and vegetables	pre- and post-program
(Christian et al. [25])	641 children, mean age of 8.1 years	4 terms (Summer Term 2010 to Summer Term andAutumn Term 2011 to Autumn Term)	gardening intervention is implemented at a high level within the school it may improve children's daily fruit and vegetable intake by a portion	cluster randomised controlled trial
(Laird [24])	children		improve knowledge about fruits and vegetables, perceptions of fruits and vegetables, and influence consumption patterns	quasi-experimental design

Table 2. Interventions Involving School Gardens with Measures of Academic Outcomes

Study	Participants	Duration	Outcomes	Design
(Berezowitz et al. [18])	No of participants -5928; Age /grade:7.8-8yrs,3 to 5th grade	1 month	-Intervention students scored significantly higher science achievement test scores than control students; -Intervention students' scores higher at post-test, versus no difference in control students; -Significant improvement in FCAT math scores; -Statistically significant improvements in academic test scores	post-test only, quasi-experimental and control group, nonrandom intervention
(Paño et al., [32])	Students (age not reported)	Not mentioned	improvement in academic performance	Qualitative analysis
(Vella-Brodrick and Gilowska, [33])	School Children (ages 5, 12 and 18)	short-term nature exposures (from a few to 60 min) and long-term exposures(from 2 months to 2 years)	enhanced cognitive functioning-selective attention, sustained attention and working memory	Experimental and quasi-experimental studies with comparison groups
(Eugenio-Gozalbo et al. [34])	44 children: 4-year-old; 40 9-year-old; 50 13-year-old students)	One academic year	significantly developed students' science knowledge	cause-effect study
(Weeland et al., [36])	school children (aged 4-12 years and/or the sample or subsample mean age was under 12 years); 21,443 children	Not specified	stimulating children's self-regulation Two studies reported a significant negative effect.	Meta-analysis (quasi-)experimental studies
(Dadvand et al. [35])	N= 2,593 schoolchildren in the second to fourth grades (7–10 y) of 36 primary schools	12 month	Enhanced working memory and superior working memory and greater 12-mo reduction in inattentiveness.	computerized cognitive tests for each outcome

out of thirteen studies reported significant intervention effects, indicating increased preference for fruits and vegetables, with seven out of ten studies showing overall significant intervention effects. Among eleven programs assessing dietary intake, six reported increased vegetable intakes, while four found no effect. Of the eight studies measuring preference, seven found an increased preference for vegetables. Gardening programs also enhanced attitudes toward, willingness to taste, identification of, and self-efficacy in preparing/cooking fruits and vegetables [29].

Six studies examined the cognitive outcomes of garden-based interventions in schools (Table 2). Four of these studies employed a hands-on school gardening curriculum alongside traditional classroom instruction [17,31,32,33], while two focused on exposure to green environments [34,35]. The sample sizes ranged from 33 to 21,443 participants, aged between 4 and 18 years. Intervention durations varied from weekly sessions lasting 30 minutes to programs spanning 2 academic years. Academic outcomes included science, math, and reading achievement test scores in one study, with computerized cognitive tests assessing working memory outcomes [34]. Agricultural learning was evaluated through students' graphical representations of a garden before and after participating in the garden-based learning program. The impact of garden-based education (GBE) on cognitive learning domains revealed five emerging themes. Two studies documented significant improvements in cognitive domains such as enhanced working memory and reduced inattentiveness. Additionally, two studies highlighted advancements in academic performance and knowledge of traditional agriculture.

4. DISCUSSION

The studies reviewed here enabled an exploration of how school gardens improve cognition and cognitive functioning across different attentional domains, alongside examining their impact on dietary outcomes in children. This article investigated the potential effects of various school-based garden interventions on both academic and health-related outcomes among students. Nineteen studies on school garden interventions assessed cognitive and dietary outcomes in children.

4.1 Effectiveness of Garden-based Nutrition Education in Promoting Healthy Dietary Habits and Nutritional Knowledge among Preschool-Aged Children

This review of 13 studies shows that school garden programs successfully enhance healthy eating habits and nutritional knowledge, and foster positive attitudes and behaviors towards vegetables among students. However, certain studies found no substantial improvements in dietary practices like consuming fruits and vegetables or achieving dietary variety. The majority of studies highlight perceived nutritional advantages for children engaged in school gardening, such as increased knowledge and awareness, improved attitudes toward food, including a greater willingness to try new foods, and the development of healthier eating habits.

The findings showed that school garden initiatives had a positive impact on dietary habits, particularly increasing the consumption of fruits and vegetables, as well as influencing cognitive performance. Specifically, garden programs boosted vegetable consumption in most of the studies examining this aspect, and either enhanced or demonstrated no change in cognitive functioning compared to students not participating in gardening activities (Tables 1 and 2).

Healthy eating habits improved as children substantially increased their fruit and vegetable intake following participation in garden-based nutrition education (Table 1). Across the world, children's consumption of fruits and vegetables has been noted to fall below recommended levels. This review underscores that garden-based nutrition education effectively boosted children's inclination to eat fruits and vegetables.

Participating in growing and preparing food from their own garden directly increased children's reported willingness to try new foods. Notably, while children's acceptance and attitudes toward vegetables improved, this change was not observed for fruits. Previous research suggests that actively engaging in food production and preparation can positively influence preferences for foods that are typically challenging to change. Garden-based nutrition education (GBNE) provides children with hands-on learning

experiences that consistently expose them to vegetables in a positive manner. By participating directly in activities like planting, harvesting, and cooking, children gain familiarity with vegetables and are more likely to develop a positive attitude and taste preference for these foods. This might also explain why interventions focusing predominantly on vegetables had minimal effects on improving children's attitudes toward fruits, as they had fewer opportunities to interact with fruits and thereby enhance their acceptability.

Another positive dietary outcome observed in children after engaging in GBNE is an increased preference for food. Seven studies documented statistically significant intervention effects, showing a heightened liking for fruits and vegetables [17,27,20,29,24]. Enhancing preferences for fruits and vegetables is a critical first step in promoting increased consumption of these foods. The increased willingness and preference for vegetables extends not only to those cultivated in school gardens but also to vegetables in general, suggesting that the intervention had a broader impact on preferences. While we recognize that food preferences mark an initial stage toward behavioral change, they do not in themselves indicate complete behavioral transformation.

Garden-based education has the potential to improve children's openness to trying new foods and decrease food neophobia. Food neophobia describes the reluctance to eat and experiment with unfamiliar foods, which can hinder children's preference for and consumption of fruits and vegetables, thereby influencing unhealthy eating behaviors [18] Moreover, gardening activities such as cooking sessions, where children are encouraged to freely taste and share self-prepared meals during kitchen classes without pressure to eat, foster a supportive social setting for children to explore new foods and potentially reduce their food neophobic tendencies.

School garden programs have shown significant benefits in improving children’s comprehension of food, nutrition, gardening, and science. Acquiring knowledge is fundamental for bringing about behavioral change. Besides enhancing students' skills in gardening, school gardening activities have enriched their understanding of declarative knowledge (what constitutes a healthy diet), procedural knowledge (how to achieve a healthy diet), and conditional knowledge (when and why to choose a healthy diet). This is because school gardens allow students to actively participate in food and nutrition education beyond the traditional classroom setting. As a result, children are more likely to make informed decisions about their dietary choices. Research has demonstrated that school gardening effectively enhances schoolchildren’s understanding of nutrition and their preferences for fruits and vegetables [36].

Due to conflicting findings in the studies, the impact of interventions aimed at increasing fruit and vegetable (F&V) dietary intake remains uncertain. Understanding of F&V is recognized as one of the most critical factors influencing their consumption. Social cognitive theory supports the idea that enhancing knowledge about food and nutrition through learning horticultural skills could enhance individuals' ability to adopt F&V intake behaviors. Knowledge, attitudes, taste preferences, and acceptability are commonly cited as strong predictors of future F&V consumption. However, our review suggests that improvements in these factors through garden-based programs may not be sufficient to significantly increase actual F&V consumption. The limited impact of interventions on dietary habits identified in this review indicates that GBNE may not adequately address other influential factors affecting children's F&V intake. These factors include the availability of F&V at home and school, parental food behaviors and feeding practices, perceived control over dietary choices, self-confidence in making dietary changes and peer influences.

4.2 Improving Cognitive Function, Academic Performance and Learning Outcomes among Preschool-aged Children

According to this review, only a limited number of garden-based nutrition interventions have evaluated how gardening activities influence cognitive functioning and academic performance. Specifically, six of these interventions suggested that such programs improve cognitive functioning and academic achievement, particularly showing strong evidence in science test scores. However, improvements in math and language arts scores were less pronounced. Moreover, two interventions were noted to have positive effects on children's working memory and attention.

The ways in which school nutrition interventions impact academic performance are still not fully

understood. While healthier school meals can potentially improve nutrient intake and nutritional status over the long term, which may have a positive effect on cognition, academic achievement is influenced by socioeconomic factors alongside nutritional considerations. Some researchers propose that improvements in academic outcomes could stem from better attendance leading to increased instructional time. It may be beneficial to assess pro-academic behaviours like task engagement, classroom conduct, creativity, and learning attitudes to better gauge students' potential for academic success.

School garden programs typically aim to improve children's dietary choices by enhancing their knowledge of and attitudes toward fruits and vegetables (FV), often based on social cognitive theory. However, their direct impact on academic performance is not clearly established. Research in the field of protein-energy malnutrition suggests that improving students' nutritional status can boost academic achievement, although this effect is less pronounced in students who already receive adequate protein and energy. Gardens also help students develop observational skills and offer opportunities to integrate interdisciplinary content in a real-world setting. Indeed, experiential learning opportunities like school gardens have been shown to enhance student engagement.

The established correlations between obesity and academic performance indicate that children with better health tend to achieve higher academic success. Initiatives such as nutrition education, school meal improvements, and the introduction of school gardens also aim to prevent obesity by fostering healthier eating habits through increased awareness, better food choices within school environments, and promoting lifelong dietary improvements.

Cognitive learning forms the basis for advanced thinking skills, allowing students to recall information, engage in logical reasoning, solve complex problems, think critically, acquire knowledge, evaluate, and make informed decisions. According to Paño and colleagues [32], garden-based education (GBE) influences the cognitive aspects of learning through five key themes: 1) experiential learning, 2) meaningful learning, 3) explicit and implicit learning, 4) discovery learning, and 5) application of learning to new contexts [31].

These themes illustrate how garden-based education [37] facilitates the cognitive aspect of learning. Experiential learning occurs when students participate in multisensory, cooperative, and collaborative activities. They find their lessons tangible as they explore the garden, where they understand the significance of engagement through planting and consuming their harvest. Additionally, the garden enriches their learning journey by allowing them to assume roles as problem solvers and community contributors while nurturing plants.

The immersive nature of school gardens makes them a potent tool for discovery learning, fostering deep engagement among students. Their natural curiosity acts as a catalyst for analytical and creative involvement in their studies. This approach impacts the cognitive development of students by nurturing their curiosity and sense of wonder, qualities highlighted as essential by Cross and Kahn (2018) and Davis and Brann (2017) in integrating curriculum connections and enriching learning opportunities [38,39]. Mohamed and Othman (2018) corroborate these findings, emphasizing the diverse learning potentials offered by school gardens as they function as organic laboratories for honing cognitive skills and deepening understanding of the natural world [40].

Gardens offer rich opportunities for children to engage in mathematical thinking, including activities like counting seeds and measuring the leaves, fruits, and flowers of seedlings. This outdoor setting provides a deeper learning experience than the classroom, allowing children to actively participate in this educational approach. Enhancements in cognitive outcomes in science were noted across different settings that were not exclusively tied to gardening tasks. Engaging in garden-related activities enabled children to showcase their grasp of scientific concepts like taxonomy, scientific methods such as designing experiments, scientific knowledge covering habitats and life cycles, and using appropriate scientific terminology.

School gardens animate the curriculum by providing students with hands-on, real-world learning experiences. This approach promotes experiential learning, facilitates the exploration of novel ideas, and cultivates skills such as responsibility, teamwork, accountability, and environmental stewardship [41]. Synthesized research underscores the positive impact of garden-based education on cognitive

development. Regular engagement with outdoor environments supports the development of creativity, observational skills, imagination, and collaboration, while also improving language acquisition, attention span, reducing stress levels, and encouraging greater physical activity.

Gardens and activities centred around garden-based nutrition provide opportunities for exposure to green environments and contribute to enhancing the greenery in their surroundings. Research indicates that both the school and overall greenness index of surrounding areas are associated with improved progress in working memory indicators over a 12-month period, superior working memory, and reduced inattentiveness [34]. Additionally, living close to green spaces has been found to increase physical activity levels, which correlates with improved cognitive function among children. Furthermore, parental psychological stress and depression have been linked to adverse effects on children's cognitive development, whereas exposure to green spaces has shown evidence of reducing stress and alleviating depression in adults.

Gardening is not only enjoyable and entertaining but also constitutes a significant component of a physically active lifestyle, contributing significantly to overall physical activity levels. Engaging in gardening provides children with a range of activities that vary in physical intensity, from gentle tasks like transplanting and harvesting to moderate activities such as weeding and mulching, and more vigorous tasks like digging and raking [42]. Nonetheless, there has been limited research conducted in this specific area.

Garden-based education also supports social and emotional development in children. Research on garden programs indicates they have a positive, indirect impact on children's social skills. Exposure to nature enriches children's emotional experiences and improves their emotional intelligence, which involves recognizing and understanding emotions, distinguishing between different feelings, accurately labelling emotions, and using emotional information to guide behavior. Developing emotional skills during early childhood is essential for overall human development. Engaging directly with nature through activities like planting enhances emotional well-being and provides enjoyable and meaningful experiences. Gardening activities, involving interaction with living plants, foster a sense of responsibility. Additionally, collaborating with peers offers opportunities to learn cooperation and patience. Engaging in gardening with friends, colleagues, or family members provides a chance to develop essential life skills such as teamwork, cooperation, goal attainment, self-assurance, self-expression, and respecting others' decisions [43].

Participation in garden work helped children develop confidence in various ways. Some learned to overcome their aversion to touching worms or beetles and to enjoy getting their hands dirty. Others gained an appreciation for patience as they awaited the growth of crops, while some simply enjoyed the experience of being outdoors and witnessing the natural process of growth. For some children, the garden served as a tool for building resilience to face life's challenges, not only in times of crop failures but also when they needed to replant beds. Improved self-confidence and self-esteem were also observed as outcomes of contributing—both through practical work and the perceived value of their contributions—to the school and wider community via the garden.

The conclusions drawn from this review emphasize that garden-based nutrition education holds significant promise as a holistic approach to enhancing cognitive development and preparing preschool-aged children for academic success. Despite ongoing advancements in research within this area, several hurdles remain, including the need to ensure that garden-based nutrition education programs are accessible, sustainable, and scalable. Additionally, future research should prioritize uncovering the mechanisms that link garden-based activities to cognitive development. It should also explore the enduring impact of these interventions on cognitive outcomes as children progress into later stages of childhood and adolescence.

Gardening programs had positive effects on children's inclination towards consuming fruits and vegetables. Additionally, most studies indicated that gardens were effective educational resources. Research also suggested that garden programs indirectly benefited children's social development. However, overall, these studies lacked scientific rigor, and the inclusion criteria for this article yielded only a small number of studies. While it is encouraging that the studies did not contradict each other, the limited number of studies reduces the robustness of this article.

4.3 Methodologies Employed in Studying the Impact of Garden-based Nutrition Education on Cognitive Development and Academic Performance in Pre-Schoolers

The interventions reviewed here exhibited methodological diversity. However, as noted in previous reviews, these garden interventions frequently included incomplete methodological descriptions, the use of convenience samples, and often lacked a control group or involved small cohorts. In this review, studies examining the effects of garden-based nutrition education on cognitive development and academic performance in preschoolers employ a range of effective methodologies. These include experimental and quasi-experimental studies with comparison groups that employed standardized cognitive measures (e.g., participants randomly assigned to groups, pre- and post-assessments, comparison groups, or controlled trials) [32], which track changes in cognitive skills and academic abilities before and after participation in garden activities through standardized tests, observations, and developmental milestones. Eugenio-Gozalbo et al. [34] employed a cause-effect study with pre- and post-stages of intervention, analyzing paired graphic representations of a garden that students drew both before and after their participation in a garden-based learning program [33]. Weeland et al. [36] conducted a meta-analysis based on correlational studies and quantitative data analysis, including quasi-experimental studies [35]. Berezowitz et al. [18] utilized a quasi-experimental design with control and experimental groups, using a nonrandom intervention and post-test only, enabling direct comparison of outcomes to attribute any differences to the garden intervention [17]. Paño et al. [32] adopted qualitative analysis methods such as interviews and focus groups to delve into children's experiences and perceptions of garden activities, identifying five themes related to learning and academic outcomes [31]. Many studies also utilize mixed-methods approaches, combining quantitative data with qualitative analysis to offer a comprehensive understanding of how garden-based education influences preschoolers' cognitive and academic development [30, 35,32]. Together, these methodologies contribute robust evidence supporting the integration of gardens into early childhood education to promote holistic learning outcomes.

4.4 Implications of Findings Related to the Use of Garden-Based Nutrition Education for Early Childhood Education, Parental Involvement, and Public Health Policy

4.4.1 Implications for early childhood education

Age plays a pivotal role in determining how effective Garden-Based Nutrition Education (GBNE) is in remodeling children's food choices and dietary habits. This review suggests that interventions like SGBP, when introduced early, tend to result in more positive results by enhancing children’s perspective of nutrition, eagerness to consume fruits and vegetables, and actual intake of vegetables. Since children’s food preferences and eating habits are established early and often persist into adulthood, early childhood represents a crucial time to nurture healthy eating behaviors [44]. Younger children are more malleable in their food inclinations and more likely to embrace foods that are readily available in their surroundings, which helps explain why SGBP interventions have been particularly fortunate when aimed at this age group.

Garden-based nutrition education in early childhood education offers subtle benefits through firsthand learning experiences. Gardens provide a riveting surroundings where young children can precisely engage with supposition of nutrition, plant growth, and the natural world, tending experiential learning that augment cognitive development. These exercises not only teach children about the origins of food and the gravity of consuming fruits and vegetables but also inculcate long-lasting healthy eating habits. Garden-based activities assimilate seamlessly across multiple subjects such as science (exploring plant biology and ecosystems), math (measuring growth and counting harvest), and language arts (documenting observations and storytelling), enriching the early childhood curriculum with interdisciplinary connections that reinforce learning in diverse domains.

Garden-based nutrition education in early childhood education not only enhances cognitive development and promotes healthy habits but also plays a crucial role in social, emotional, and community aspects. Involving in garden activities

cultivate important social skills like cooperation, communication, and teamwork among young children. It provides an adjuvant environment for emotional expression and stress relief, contributing significantly to their overall socio-emotional development.

4.4.2 Implications for parental involvement

Results of garden-based nutrition education highlight compelling connections for parental involvement. Research consistently shows that involving parents in garden activities not only enhances children's learning experiences but also strengthens familial bonds and improve a shared commitment to healthy behaviors. Parents who involved in garden-based education programs tend to exhibit increased knowledge about nutrition and gardening practices, which they can then booster at home. This quandary not only footing children in making healthier food choices but also encourages family engagement in physical activity and outdoor learning. Furthermore, garden programs often serve as a platform for parents to interact with educators and community members, fostering a collaborative environment where they can exchange ideas and support each other's efforts in promoting healthy lifestyles.

This review affirms that when parents participate in garden-based activities, it can significantly improve children's attitudes towards and willingness to eat fruits and vegetables (F&V). According to social learning theory, children learn and mimic behaviors observed in others, particularly their parents [45]. Since children spend substantial time with their parents, their food choices, eating habits, and attitudes toward food are deeply influenced by them. Actively involving parents in GBNE is more likely to cultivate a preference for F&V and promote healthier eating habits among children [46]. Overall, the findings underscore the crucial role of parental involvement in garden-based nutrition education, emphasizing its potential to create lasting impacts on children's health and well-being through shared learning and active participation.

4.4.3 Implications for policymakers

Findings of this review hold significant importance for policymakers aiming to implement practical and targeted interventions, such as expanding garden-based activities in schools. Increased engagement in gardening among school children could lead to improved cognitive development and mental acuity that can benefit them throughout their lives. Gardening promotes better nutrition and physical activity among participants and can serve as a tool to raise awareness among policymakers and communities about obesity prevention strategies.

Addressing micronutrient malnutrition in children is crucial, and regular consumption of a diverse range of vegetables can help prevent deficiencies. Garden-based activities not only contribute to improving nutritional outcomes but also offer a new approach for public health policies. Nutrition education plays a vital role in comprehensive health programs by empowering children with knowledge and skills to make healthy food choices.

Garden-based nutrition education offers policymakers multiple outlets for positive impact. By assimilating garden activities into educational curricula, policymakers can foster healthy eating habits and physical activity among children, aligning with public health goals to combat childhood obesity and enhance overall well-being. Gardens also enrich education by providing hands-on learning opportunities that span science, math, and environmental studies, creating a comprehensive educational experience. These programs promote community engagement by involving parents and local residents, which strengthens community ties and shared responsibility for children's health and education. Teaching children about gardening and nutrition additionally instils values of environmental sustainability and stewardship, supporting broader goals of sustainable development and environmental awareness. Policymakers can further support these efforts by allocating resources for garden infrastructure, teacher training, and curriculum development, advocating for policies that integrate gardening into school wellness programs, and fostering collaboration with local agriculture initiatives. Ultimately, investing in garden-based nutrition education holds potential for long-term health benefits, reducing healthcare costs associated with diet-related illnesses in the future.

Communities also getting benefits from garden-based programmes like boosting connection with environment, mutual community bond, improving mental health, moral development, offering therapeutic benefits and access for availability of fruits and vegetables.

To ensure long-term sustainability, programs should integrate local community support, including engaging parents and community members in garden activities and nutrition education. Establishing strong partnerships with schools, local businesses, and non-profit organizations can provide additional resources and ongoing support. Monitoring and evaluating program outcomes regularly will help in making data-driven adjustments and demonstrating the program's value to stakeholders. Additionally, promoting the benefits of GBNE through success stories and evidence-based results can aid in garnering continued support and interest.

5. CONFLICTING FINDINGS

Disparities identified in this study included outcome measures of the programmes. Some studies have shown positive results in fruit and vegetable intake while others are found no effect or minimum effect in the same. Differences in duration and sessions included in interventions, parental involvement all are may the contributing factors of these variations. These findings highlight the importance of standardization of garden- based intervention programme designs.

6. FUTURE RESEARCH DIRECTIONS

Future research directions should primely consider the garden -based programme design and evaluation standardization including activities, duration, parental involvement, trained instructors, and time of interventions whether in school time or after school hours.

7. SCOPE AND LIMITATIONS

One of the major limitations observed in the current review is the time frame of studies published and variability in study designs, sample size, evaluation of outcome and duration of study which are included for review. Even though there are variations in studies, the results were positive in many studies. Future research with more standardized methodologies and larger sample sizes could provide more comprehensive insights into the long-term benefits of garden-based nutrition education.

8. CONCLUSION

In conclusion, garden-based nutrition education shows potential in improving cognitive development among preschool-aged children through encouraging healthy eating habits. The impact of this education on outcomes is notably affected by social and environmental factors, with more significant benefits observed when introduced at a younger age, like preschool or primary school. Additionally, positive results in children's understanding of nutrition and dietary habits observed in studies with shorter intervention periods, smaller participant groups, or lower child-to-staff ratios may be due to increased focus and more precise measurement techniques. However, the diversity in study designs and methodologies has compromised the analysis of these outcomes. Involving parents has the potential to improve children's attitudes, behaviors, and willingness to eat fruits and vegetables. This review emphasizes the ongoing need for research and innovation in designing and implementing garden-based nutrition education programs tailored to the specific needs of preschoolers and their families. By integrating garden activities into early childhood education curricula and community interventions, stakeholders can ensure that all preschoolers have the opportunity to develop their cognitive abilities fully and thrive during their early developmental years.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

We hereby declare that generative AI technologies such as Large Language Models (ChatGPT) have been used during some minor editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1. Open AI
2. ChatGPT
3. GPT-4o

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/121978