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*Article*

# Medicinal Botanical Gardens as Living Laboratories for Knowledge of Medicinal Plants and School-Based Health Promotion: A Quasi-Experimental Study in Urban Mexican Children

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## Highlights

**What are the main findings?**

- A school medicinal botanical garden with a 15-session program was followed by a large increase in children's medicinal plant knowledge (knowledge score 4.14 to 11.39 out of 12; all 103 children improved).
- Small decreases were observed in BMI, body fat, cholesterol, triglycerides, and glucose; blood pressure and heart rate did not change.

**What are the implications of the main findings?**

- Medicinal botanical gardens appear to be a feasible educational resource for health promotion in urban schools.
- The single-group design prevents causal inference; controlled studies are needed.

## Abstract

**Background/Objectives**: Medicinal plants are central to traditional medicine and primary health care, yet few school programs use medicinal botanical gardens as learning spaces. We evaluated a school-based educational intervention centered on a medicinal botanical garden on medicinal plant knowledge and selected anthropometric, clinical, and biochemical indicators in urban primary school children. **Methods**: A quasi-experimental pretest–posttest study without a control group was conducted in an urban public school in Pachuca, Hidalgo, Mexico (January–June 2025). A garden with 15 medicinal species and a 15-session educational program (30 h) were implemented. A total of 103 children aged 7–12 years completed pre- and post-intervention assessments: a nine-item pictogram questionnaire (Cronbach's $\alpha = 0.83$ in a validation sample of 195 children; six knowledge items formed the knowledge score), anthropometry, vital signs, and capillary glucose, cholesterol, and triglycerides. Changes were analyzed with paired *t*-tests (Wilcoxon signed-rank as sensitivity analysis) and chi-square-based tests for categorical data. **Results**: The knowledge score (0–12) increased from $4.14 \pm 2.03$ to $11.39 \pm 0.90$ (mean difference 7.25, 95% CI 6.84–7.67; $p < 0.001$), and all children improved. Small but significant decreases were observed in weight (−0.33 kg), body fat (−0.25 percentage points), BMI (−0.43 kg/m$^2$), total cholesterol (−3.4 mg/dL), triglycerides (−5.6 mg/dL), and glucose (−7.0 mg/dL) (all $p < 0.05$),

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Academic Editor: Helena Guilhermina Da Silva Marques Nogueira

Received: 12 August 2026
Revised: 25 October 2026
Accepted: 3 November 2026
Published: 5 November 2026

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whereas heart rate, oxygen saturation, and blood pressure did not change. Most cholesterol and triglyceride values were at the lower limit of the device. **Conclusions**: A medicinal botanical garden combined with a structured educational program was associated with a large improvement in children's medicinal plant knowledge and small changes in some health indicators. Given the single-group design, causal effects cannot be established, and controlled studies are needed.

**Keywords:** botanical garden; education; nutrition; primary care; school

## 1. Introduction

Medicinal plants constitute an important component of traditional healthcare systems and biocultural heritage, while simultaneously representing an opportunity to promote health promotion and sustainable behaviors among younger generations. Consequently, in recent years, school-based interventions have increasingly incorporated experiential and nature-based learning approaches to improve health knowledge and healthy lifestyles during childhood. In this context, systematic evidence suggests that school garden programs positively influence nutrition-related knowledge, attitudes, and health practices, highlighting their potential as cost-effective educational strategies [1]. Likewise, garden-based learning has been associated with environmental awareness, health promotion, and community engagement [2]. In the context of public health, the concept of health promotion has come to the fore as a critical factor influencing both health equity and the abilities of individuals to manage their own health. Furthermore, recent evidence emphasizes that developing health promotion during childhood facilitates the acquisition of lifelong healthy behaviors and empowers children to make informed decisions regarding health and well-being [3]. Furthermore, playful and experiential educational interventions have demonstrated effectiveness in improving health promotion among children and adolescents [4]; thus, schools constitute an ideal setting for health promotion because they provide opportunities to integrate health education into everyday experiences and reach children regardless of socioeconomic background [5].

Botanical gardens, in particular, offer a unique educational environment that integrates biodiversity conservation, environmental education, and active learning [6]. Despite growing evidence supporting school garden interventions, most studies have focused on nutritional outcomes or environmental awareness, whereas little is known about the role of medicinal botanical gardens as culturally relevant tools for strengthening knowledge of medicinal plants and primary healthcare among urban schoolchildren. Furthermore, given the published evidence regarding the composition and antioxidant capacity of the plants [7] used in this study, as well as their implications for human health and obesity [8], a joint assessment was conducted to determine the intervention's effects on specific parameters such as BMI, blood pressure, weight, body fat percentage, oxygen saturation, and levels of triglycerides, cholesterol, and glucose [7–10]. However, the observed effects may also have been related to changes in the children's habits, such as choosing herbal infusions instead of soft drinks or high-sugar juices, or physical activity during the garden activities; these habits were not measured in this study, so this possibility is a hypothesis [11]. Therefore, this study aimed to evaluate the effect of a medicinal botanical garden integrated into a school-based experiential educational intervention on knowledge related to medicinal plants and selected anthropometric, clinical, and biochemical indicators among primary school children living in an urban area of central Mexico.

## 2. Materials and Methods

### *2.1. Methodological Design*

A quasi-experimental pretest–posttest study without a control group was conducted to evaluate the effectiveness of a medicinal botanical garden integrated into a school-based educational program aimed at promoting knowledge of medicinal plants and improving selected health indicators among primary school children. The study was conducted between January and June 2025 at an urban public primary school in Pachuca, Hidalgo, Mexico.

*Selection criteria*

The selection criteria for this study were based on the following inclusion criteria (children enrolled in the school, with parental informed consent and a signed assent form describing the study); exclusion criteria (children with plant allergies, physical limitations, or ongoing medical treatment); and elimination criteria (children who leave the school due to a change of address, miss three or more sessions of the educational intervention, or show poor cooperation).

### *2.2. Selection of the Study Population*

The study population consisted of 587 ($N$) schoolchildren enrolled at the school. Sample size was estimated using the formula for finite populations (Formula (1), assuming a 95% confidence level ($Z = 1.96$), a 5% margin of error ($e = 0.05$), and maximum variability ($p = 0.50$; $q = 0.50$), which yielded a required sample size of 233 participants.

$$n = \frac{N * Z^2 Z * p * q}{e^2 * (N - 1) + Z^2 * p * q} \quad (1)$$

$n$ = desired sample size;
$N$ = population size or universe;
$Z$ = statistical parameter that depends on the confidence level;
$e$ = maximum acceptable estimation error;
$p$ = probability of the estimated event occurring (success);
$q = (1 - p)$; probability of the event not occurring.
With the study values, the sample size was determined as follows:

$$n = (587 \times 3.8416 \times 0.25)/(0.0025 \times 586 + 3.8416 \times 0.25) = 563.76/2.4254 \approx 233.$$

A total of 233 schoolchildren were invited to participate through non-probability convenience sampling. Of these, 130 (55.8%) were not included in the final analysis: 72 (30.9%) declined to participate or did not have informed consent from their parents or legal guardians; 36 (15.5%) met the exclusion criteria (plant allergies, physical limitations, or ongoing medical treatment); and, of the 125 who started the intervention, 22 (9.4% of those invited) were eliminated due to a change of address, missing three or more sessions, or poor cooperation. The final sample consisted of 103 schoolchildren (44.2%) of both sexes, aged 7 to 12 years, who completed the baseline and post-intervention assessments. This sample was smaller than estimated and corresponds to an approximate error of 8.8% for the population of 587 schoolchildren (a reference value, given the convenience sampling).

Because the formula used estimates a proportion and the primary analysis is a paired pre–post comparison, a sensitivity analysis was also performed: with 103 paired observations, a two-sided $\alpha$ of 0.05 and 80% power, the study can detect standardized pre–post differences of $dz \geq 0.28$ (power > 98% for $dz \geq 0.40$).

### *2.3. Study Variables*

The independent variable was the educational intervention. The dependent variables were knowledge of medicinal plants and the anthropometric (weight, height, BMI, and body fat percentage), clinical (heart rate, oxygen saturation, systolic and diastolic blood pressure), and biochemical (glucose, total cholesterol, and triglycerides) indicators (Table 1).

**Table 1.** Study variables.

| Variable | Type | Unit Categories | Measurement Scale |
|---|---|---|---|
| Educational intervention | Independent | Medicinal botanical garden +15-session program | Nominal (pre/post) |
| Knowledge of medicinal plants | Dependent | Score 0–12<br>low, moderate, high | Continuous/ordinal |
| Weight | Dependent | kg | Continuous |
| Height | Dependent | cm | Continuous |
| Body Mass Index (BMI) | Dependent | $kg/m^2$<br>Underweight less than 18.5, obesity class III (morbid 40.0 or higher) | Continuous |
| Body fat | Dependent | % | Continuous |
| Heart rate | Dependent | beats/min<br>6 to 12 years (school-age): 60–100 bpm | Continuous |
| Oxygen saturation ($SpO_2$) | Dependent | % | Continuous |
| Systolic and diastolic blood pressure | Dependent | mmHg<br>normal < 90th percentile for age, sex, and height | Continuous |
| Total cholesterol | Dependent | mg/dL<br>desirable < 170,<br>borderline 170–199,<br>high ≥ 200 | Continuous |
| Triglycerides | Dependent | mg/dL<br>normal < 75,<br>borderline 75–99,<br>high ≥ 100 | Continuous |
| Glucose | Dependent | mg/dL<br>normal 70–99,<br>impaired 100–125,<br>high ≥ 126 | Continuous |

*Educational Intervention*

The botanical garden contained 15 species of medicinal plants that are frequently utilized in the region (Figure 1). Throughout the intervention period, students engaged in a variety of activities related to the garden's design, soil preparation, planting, cultivation, maintenance, harvesting, and observation. The program comprised 15 sessions, each spanning 120 min and held thrice weekly, amounting to 30 h of educational activities over a period of approximately five weeks. A multidisciplinary team of nutritionists, nurses, teachers, and researchers led these sessions, covering a range of topics. The sessions were structured to ensure a sequential progression, commencing with foundational principles of plant cultivation, an examination of plant components and their requirements, an explo-

ration of plant diversity, and a historical analysis of medicinal plant usage. Subsequently, the intervention encompassed the region's medicinal plants, the conceptualization and organization of a botanical garden, and its function as an educational instrument. Furthermore, the activities encompassed a comprehensive array of subjects, including the cultivation, harvesting, drying, and packaging of plants; the significance of medicinal plants in primary health care; the relationship between nutrition and physical activity; the preparation of healthy food; the consumption of water; the precautions associated with the use of medicinal plants; and the practice of aromatherapy. The culminating activities were designed to facilitate the integration and dissemination of the experiences and knowledge acquired during the intervention (Table 2).




**Figure 1.** Plant species implemented in the botanical garden.

The pedagogical approach was predicated on a hands-on learning model, incorporating direct observation, identification, cultivation, care, and interaction with plants in the botanical garden. The present study employed the method of guided observation to establish a linkage between direct experiences and a variety of concepts, including biological, environmental, traditional, and health-related ones. The integration of problem-based learning was achieved through the utilization of inquiries and practical scenarios concerning the applications, maintenance, health promotion, disease prevention, and safety measures associated with the utilization of medicinal plants. Games and audiovisual resources were used as complementary strategies to reinforce concepts and encourage participation. Conversely, it should be noted that no formal adaptations based on age or grade level were made, as the intervention was designed for the entire primary education population, which included children aged 7 to 12. Consequently, educational activities were presented using accessible language and participatory methods suited to the study population's overall age range, rather than employing age-differentiated curricula.

Interactive teaching strategies included problem-based learning, group discussions, guided observation, practical gardening activities, educational games, audiovisual resources, and the use of a digital interactive book developed specifically for the project.

**Table 2.** Thematic axes of the educational strategy linked to the botanical garden.

| Session | Main Topic | Pedagogical Approach | Main Activity |
|---|---|---|---|
| 1 | Plant cultivation and environmental benefits | Experiential learning | Introduction to the garden and plant cultivation |
| 2 | Plant parts and requirements for life | Guided observation | Direct observation and identification of plant structures |
| 3 | Types of plants and their uses | Problem-based learning + games | Classification and identification of plants and their uses |
| 4 | History of medicinal plants | Audiovisual resources + discussion | Historical introduction to medicinal plant use |
| 5 | Medicinal plants in the local region | Guided observation + experiential learning | Identification of local medicinal species |
| 6 | What is a botanical garden? | Problem-based learning + audiovisual resources | Components and development of a botanical garden |
| 7 | Botanical gardens as educational tools | Experiential learning + guided discussion | Educational and health-promoting functions of the garden |
| 8 | Plant protection and pests | Experiential learning + problem solving | Identification and prevention of plant pests |
| 9 | Medicinal plants and primary healthcare | Problem-based learning | Applications in health promotion and disease prevention |
| 10 | Nutrition and physical activity | Games + audiovisual resources | Healthy lifestyle activities |
| 11 | Precautions when consuming medicinal plants | Problem-based learning | Appropriate use and precautions |
| 12 | Plants and healthy food preparation | Experiential learning | Practical activities related to healthy foods |
| 13 | Aromatherapy and its uses | Audiovisual resources + guided observation | Aromatic plants and their traditional uses |
| 14 | Cultivation, harvesting, drying, and packaging | Experiential learning | Practical activities involving plant management |
| 15 | Integration and sharing of experiences | Experiential learning + reflection | Sharing experiences and consolidating learning |

*Knowledge Assessment*

Knowledge regarding medicinal plants was evaluated using a pictogram-based questionnaire specifically developed for children aged 7–12 years. The instrument assessed plant identification, traditional uses, safe consumption practices, environmental importance, and health-related applications (Supplementary Materials). Each of the nine items had three response options (coded 1 = best answer to 3 = worst answer. To distinguish knowledge from experience and perception, the items were classified into three dimensions (Table 3): knowledge (R1, R3, R6, R7, R8, and R9), experience (R2, prior consumption; R5, source of information), and perception (R4, perceived effectiveness). Only the six knowledge items were scored (2, 1, and 0 points for the best, intermediate, and worst answer, respectively), so the knowledge score ranged from 0 to 12 (Table 3). The experience and perception items were not included in the score and were analyzed separately, item by item. The level of knowledge before and after the intervention was classified into thirds of the score range, each level spanning four points: low (0–3), moderate (4–7), and high (8–12) (Table 4).

**Table 3.** Instrument composition for measuring knowledge about medicinal plants.

| Item | Aspect Evaluated | Dimension | Best Answer (Scored 2) | Score: Best/Intermediate/ Worst Answer |
|---|---|---|---|---|
| R1 | Concept of medicinal plants | Knowledge | Yes | 2/1/0 |
| R2 | Experience with consuming medicinal plants | Experience | - | — |
| R3 | Plants grown in the community | Knowledge | Yes, I know of some | 2/1/0 |
| R4 | Effectiveness of medicinal plants | Perception | - | — |
| R5 | Source of information on medicinal plants | Experience | - | — |
| R6 | When to use medicinal plants | Knowledge | Only when I'm sick | 2/1/0 |
| R7 | Where to acquire medicinal plants | Knowledge | Yes, I know | 2/1/0 |
| R8 | Importance of medicinal plants for the ecosystem | Knowledge | Yes | 2/1/0 |
| R9 | Parts of the plant that can be used | Knowledge | Totally agree | 2/1/0 |
| Total | Knowledge scale | 6 scored items (of 9) | | 0–12 points |

**Table 4.** Classification of knowledge level.

| Level of Knowledge | Score | Interpretation |
|---|---|---|
| Low | 0–3 | Low level of knowledge |
| Moderate | 4–7 | Intermediate knowledge |
| High | 8–12 | Adequate knowledge |
| Total | 0–12 | Global knowledge scale |

### *2.4. Content Validity (Pilot Test for the Knowledge Assessment Questionnaire)*

Instrument validation was conducted with an independent sample of 200 schoolchildren (46.1% male, 53.8% female), of whom 195 (97.5%) fully completed the questionnaire. Content validity was evaluated by an expert panel of 22 professionals (2 nutritionists, 1 physician, 2 botanists, 1 pharmacologist, 6 pedagogues, 2 nurses, and 8 primary school teachers). The panel evaluated ten criteria on a scale from 0 to 1 (Table 5). Qualitative feedback from experts identified specific items requiring modification regarding wording, logical sequence, and avoidance of response induction. Two criteria received mean scores below 0.80 (bias/response induction: $0.65 \pm 0.07$; contribution to research objective: $0.72 \pm 0.08$), prompting the rewording and refinement of those specific items. The overall mean score across all evaluated criteria was $0.84 \pm 0.07$, confirming adequate content validity after modifications. We established content validity through expert review and assessed internal consistency using Cronbach's alpha coefficient. Following refinement of the instrument, the final version consisted of nine items and demonstrated satisfactory reliability (Cronbach's $\alpha = 0.83$) (Table 6). The reliability coefficient ($\alpha = 0.83$) refers to the complete nine-item questionnaire in the validation sample. In the present study, only the six knowledge items were scored; the internal consistency of this six-item subscale was not estimated separately in the validation sample, as noted in the limitations.

**Table 5.** Results of the judges' panel evaluation.

| Indicator Evaluated by the Judges | Average Score ± SD |
|---|---|
| Clarity in writing | 0.90 ± 0.08 |
| Internal consistency | 0.89 ± 0.06 |
| Bias (induction of responses) | 0.65 ± 0.07 |
| Wording appropriate for the study population | 0.91 ± 0.08 |
| It contributes to the research objective | 0.72 ± 0.08 |
| It contributes to measuring the construct of the study | 0.89 ± 0.07 |
| Do you consider it necessary to remove or modify any item? | 0.81 ± 0.07 |
| The instructions clearly guide you on how to answer the questionnaire | 0.85 ± 0.06 |
| The sequence of items is logical | 0.91 ± 0.14 |
| The number of items is adequate for the study population | 0.83 ± 0.07 |

SD: Standar desviation.

**Table 6.** Refined Cronbach's α values and reliability coefficient.

| Item | Scale Measure if the Element Is Removed | Variance of the Scale if the Element Is Removed | Corrected Element-Total Correlation | Cronbach's Alpha if Element Is Removed |
|---|---|---|---|---|
| 1 | 15.74 | 12.75 | 0.528 | 0.702 |
| 2 | 15.51 | 12.33 | 0.530 | 0.700 |
| 3 | 15.24 | 13.53 | 0.418 | 0.738 |
| 4 | 15.77 | 12.58 | 0.559 | 0.797 |
| 5 | 15.57 | 12.99 | 0.480 | 0.725 |
| 6 | 15.78 | 13.25 | 0.307 | 0.711 |
| 7 | 15.58 | 13.19 | 0.230 | 0.724 |
| 8 | 15.86 | 13.79 | 0.143 | 0.746 |
| 9 | 16.21 | 14.14 | 0.150 | 0.733 |
| Cronbach's alpha | | | | 0.833 |

### *2.5. Intervention Process*

The methodology involved implementing a measurement instrument before and after the integration of the traditional botanical garden to evaluate changes associated with the educational strategy on students' knowledge of medicinal plants. Knowledge was assessed with the questionnaire described above, and anthropometric, clinical, and biochemical indicators were measured as described below. The pre- and post-test results were analyzed using descriptive statistics and comparative analyses (Figure 2).

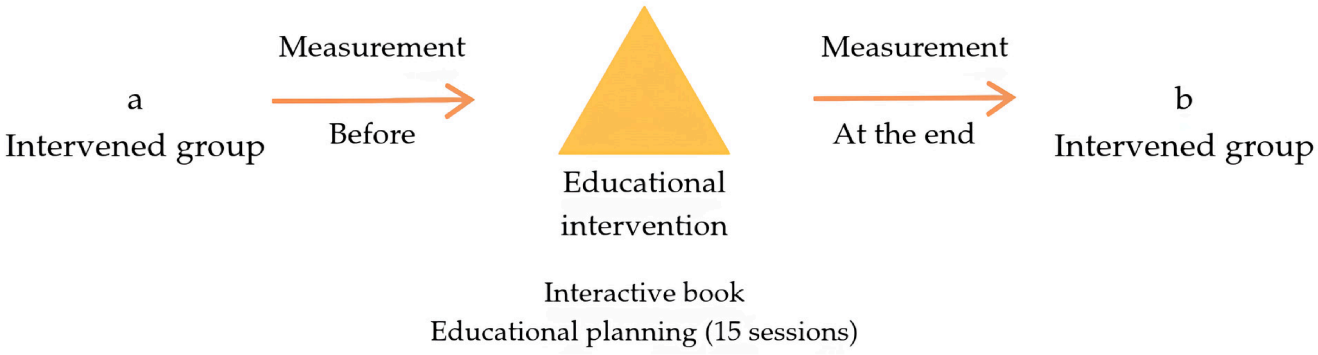



**Figure 2.** Educational intervention. Prepared by the author (2025).

All measurements were performed at baseline (pre-intervention) and repeated immediately after completion of the educational program (post-intervention).

Following completion of the intervention, a post-intervention assessment was conducted using the same anthropometric, biochemical, and educational measures applied at baseline. Comparisons between pre- and post-intervention assessments were performed to evaluate changes in participants' knowledge regarding medicinal plants and selected health indicators associated with participation in the educational program.

During the third stage, a baseline assessment and educational intervention were conducted with the participating schoolchildren. The baseline assessment included anthropometric measurements (weight, height, body fat percentage, and body mass index [BMI]), clinical measurements (heart rate [HR] and oxygen saturation [$SpO_2$]), blood pressure assessment (systolic and diastolic pressure), and biochemical evaluation (total cholesterol, triglycerides, and glucose). Samples were collected in the morning, between 8:00 and 9:00 h, before the children had eaten any food (fasting state), under the same conditions both at the beginning and after the intervention. For the analysis, the lower reporting limit of the device was taken as 170 mg/dL for cholesterol and 75 mg/dL for triglycerides; readings at or below these limits were recorded with these values.

These anthropometric measurements were obtained following standardized procedures. Body weight was measured using a calibrated digital scale, with participants wearing light clothing and no shoes. Height was measured with a portable stadiometer; BMI was calculated as weight (kg)/height$^2$ ($m^2$); and body fat percentage was estimated using a bioelectrical impedance analyzer (body fat monitor for children, Tanita BF-689,Tanita Corporation, Tokio, Japan).

Clinical and biochemical evaluation was performed by trained healthcare personnel using validated portable devices to measure resting heart rate (HR), oxygen saturation ($SpO_2$) (Pediatric oximeter ChoiceMMed, Panda Bear®, COD-CHC-MD300C5-P, Beijing Choice Electronic Technology Co., Ltd., Beijing, China), and blood pressure (systolic and diastolic pressure) after a 5 min rest period. The arterial pressure was evaluated according to the Clinical Practice Guidelines with an aneroid blood pressure monitor (MedStar®, MEDSTAR Co., Ltd., Uiwang, South Korea). Blood pressure was considered normal when both systolic and diastolic values were below the 90th percentile for age, sex, and height, according to the 2017 American Academy of Pediatrics guideline [12] (see also the American Heart Association scientific statement on pediatric primary hypertension [13]); resting heart rate was compared with the age-specific normal values of the American Heart Association Pediatric Advanced Life Support Provider Manual [14] (Section 2.6). The heart rate was evaluated at rest using a pulsometer (MedStar®). Capillary blood samples were collected following aseptic procedures, and glucose, total cholesterol, and triglyceride concentrations were determined using the system (Roche Diagnostics Diagnostics GmbH, Mannheim, Germany) according to the manufacturer's instructions.

### *2.6. Statistical Analysis*

Descriptive analyses were performed, with continuous variables expressed as mean ± SD and categorical variables as frequencies and percentages. Given the quasi-experimental pre–post design, differences were analyzed using paired-samples *t*-tests and reported as mean differences with 95% confidence intervals and Cohen's d (mean difference/SD of the differences); the Wilcoxon signed-rank test was used as a sensitivity analysis and for ordinal questionnaire items.

BMI was calculated as weight/height$^2$, and BMI-for-age z-scores were calculated using the WHO 2007 growth reference [15]; overweight/obesity was defined as a z-score > +1 SD. Blood pressure was classified using the 2017 American Academy of Pediatrics tables [12,13]

according to age, sex, and height percentile (CDC 2000 growth charts [16]) and was considered normal when both systolic and diastolic pressure were below the 90th percentile. Resting heart rate was also compared with the age-specific normal values of the American Heart Association Pediatric Advanced Life Support Provider Manual [14]. Glucose was considered normal between 70 and 99 mg/dL (Table 1). Because only age in completed years was available, an approximate age was used to calculate z-scores and percentiles (mid-year of the completed age at baseline, increased by the time elapsed between assessments at post-intervention).

Chi-square goodness-of-fit tests were used to describe the distributions of sex, age, and grade, and McNemar and McNemar–Bowker tests were used to compare paired categorical data before and after the intervention (overweight/obesity, blood pressure category, and knowledge level). A two-sided $p$-value $< 0.05$ was considered statistically significant. All analyses were performed using IBM SPSS Statistics, version 25 (IBM Corp., Armonk, NY, USA).

### *2.7. Ethical Considerations*

The study protocol was reviewed and approved by the corresponding Research and Ethics Committee (CEI-ICSa-2024/R241). All procedures were conducted in accordance with the ethical principles of the Declaration of Helsinki and applicable national regulations governing research involving human participants. Parents or legal guardians received detailed information regarding the study objectives, procedures, potential risks, and benefits before providing written informed consent. Likewise, age-appropriate information was provided to the children, and their assent was obtained before participation. Confidentiality and anonymity of all collected data were guaranteed throughout the study.

## 3. Results

### *3.1. Development of the Educational Intervention and Medicinal Botanical Garden*

A school-based educational intervention grounded in experiential learning was implemented with 103 primary school children aged 7–12 years. The intervention consisted of 15 sessions of 120 min each (30 h in total). It included activities related to plant biology, environmental conservation, healthy eating, hydration, physical activity, and the safe use of medicinal plants. Educational materials, including an interactive digital book and audiovisual resources, were developed to support the intervention.

Simultaneously, a medicinal botanical garden was established within the school grounds with the participation of teachers and students. Fifteen medicinal plant species commonly used in the region were cultivated and maintained throughout the study period.

### *3.2. Sociodemographic Characteristics of Participants*

A total of 103 primary school children (53 girls, 51.5%; 50 boys, 48.5%) aged 7–12 years (mean 9.87 ± 1.49 years) completed the study. The highest concentration of participants corresponded to children aged 10 and 11 years (representing 29.1% and 26.2%, respectively; descriptive $\chi^2 = 24.28$, $p < 0.001$), whereas the distribution of students across grades showed no statistically significant differences ($\chi^2 = 3.99$, $p = 0.26$).

The sociodemographic data (sex, age, and grade) of the participating population were balanced by sex, which allowed us to consider that the results were not biased by this factor. However, a statistically significant difference in the distribution of ages was identified, indicating a greater concentration of students in the fourth age group (participants 10 and 11 years old). This could influence the way in which the content of the educational intervention is assimilated, since these ages may have greater cognitive capacity.

### *3.3. Anthropometric, Clinical, and Biochemical Characteristics*

Following the intervention, statistically significant reductions were observed in body weight (−0.33 kg, $p = 0.006$), body fat percentage (−0.25 percentage points, $p = 0.028$), and body mass index (BMI; −0.43 kg/m$^2$, $p < 0.001$), while height increased as expected in a growing school-aged population (+0.97 cm, $p < 0.001$) (Table 7). When BMI was standardized for age and sex, the BMI-for-age z-score decreased from 0.99 ± 1.01 to 0.81 ± 0.93 ($p < 0.001$), and the proportion of children with overweight/obesity (z-score > +1 SD) decreased from 50.5% to 41.7% ($p = 0.004$). Resting heart rate, oxygen saturation ($SpO_2$), and blood pressure (systolic and diastolic) showed no statistically significant changes (all $p > 0.14$); the proportion of children with blood pressure below the 90th percentile for age, sex, and height was similar at baseline (69.9%) and after the intervention (67.0%) ($p = 0.749$).

**Table 7.** Pre–post changes in anthropometric, clinical, and biochemical parameters (paired-samples *t*-test, $n = 103$).

| Variable | Pre (Mean ± SD) | Post (Mean ± SD) | Mean Difference [95% CI] | t | *p* | dz |
|---|---|---|---|---|---|---|
| Weight (kg) | 37.95 ± 10.28 | 37.62 ± 9.79 | −0.33 [−0.55, −0.10] | −2.83 | 0.006 | −0.28 |
| Height (cm) | 137.60 ± 11.11 | 138.57 ± 11.13 | 0.97 [0.90, 1.03] | 28.68 | <0.001 | 2.83 |
| Body fat (%) | 24.29 ± 5.83 | 24.04 ± 5.58 | −0.25 [−0.48, −0.03] | −2.23 | 0.028 | −0.22 |
| Body Mass Index (BMI) (kg/m$^2$) | 19.70 ± 3.28 | 19.27 ± 2.92 | −0.43 [−0.56, −0.30] | −6.47 | <0.001 | −0.64 |
| BMI-for-age z-score | 0.99 ± 1.01 | 0.81 ± 0.93 | −0.18 [−0.23, −0.14] | −7.81 | <0.001 | −0.77 |
| Overweight/obesity, *n* (%) | 52 (50.5) | 43 (41.7) | — | — | 0.004 | — |
| Heart rate (bpm) | 98.31 ± 14.62 | 96.56 ± 13.44 | −1.75 [−5.83, 2.33] | −0.85 | 0.397 | −0.08 |
| Peripheral capillary oxygen saturation ($SpO_2$) (%) | 95.61 ± 3.09 | 95.45 ± 2.57 | −0.17 [−0.95, 0.62] | −0.42 | 0.676 | −0.04 |
| Systolic BP (mmHg) | 100.60 ± 12.00 | 100.48 ± 7.04 | −0.13 [−2.67, 2.42] | −0.10 | 0.922 | −0.01 |
| Diastolic BP (mmHg) | 67.08 ± 11.52 | 69.03 ± 10.05 | 1.95 [−0.70, 4.61] | 1.46 | 0.148 | 0.14 |
| Blood pressure (BP) < 90th percentile, *n* (%) | 72 (69.9) | 69 (67.0) | — | — | 0.749 | — |
| Total cholesterol (mg/dL) | 173.95 ± 10.60 | 170.51 ± 3.05 | −3.44 [−5.20, −1.67] | −3.86 | <0.001 | −0.38 |
| Triglycerides (mg/dL) | 81.63 ± 13.58 | 76.07 ± 6.30 | −5.56 [−8.54, −2.59] | −3.71 | <0.001 | −0.37 |
| Glucose (mg/dL) | 90.64 ± 9.38 | 83.68 ± 8.37 | −6.96 [−9.71, −4.22] | −5.03 | <0.001 | −0.50 |

Note: dz = mean difference/SD of the differences. BMI was calculated as weight/height$^2$. BMI-for-age z-scores were calculated with the WHO 2007 growth reference; overweight/obesity was defined as a z-score > +1 SD. Blood pressure was classified using the 2017 American Academy of Pediatrics clinical practice guideline tables [12], by age, sex, and height percentile. Overweight/obesity and BP < 90th percentile were compared with the McNemar test. Cholesterol and triglyceride values were at the lower reporting limit of the device in most children (96.1% and 97.1% post), so the Wilcoxon signed-rank test was used as a sensitivity analysis (cholesterol $p < 0.001$; triglycerides $p = 0.001$) Abbreviations: SD (Standard deviation), CI (Confidence Interval), *t* (Student's t) and *p* (*p*-value).

Biochemical analyses showed significant pre–post decreases in total cholesterol (−3.44 mg/dL, $p < 0.001$), triglycerides (−5.56 mg/dL, $p < 0.001$), and capillary glucose (−6.96 mg/dL, $p < 0.001$) (Table 7). However, statistical significance should not be equated with clinical relevance: mean glucose was within the normal range (70–99 mg/dL, Table 1) at both time points (90.64 and 83.68 mg/dL), and 85.4% of children were within this range at both assessments. The lipid results should be interpreted with caution, because most post-intervention cholesterol (96.1%) and triglyceride (97.1%) values were at the lower reporting limit of the device (Table 7).

### *3.4. Knowledge of Medicinal Plants Before and After the Intervention*

Before the intervention, 42 children (40.8%) were classified as having a low level of knowledge, 54 (52.4%) a moderate level, and 7 (6.8%) a high level (Table 9). After the intervention, all 103 participants (100%) were classified as having a high level of knowledge (McNemar–Bowker $\chi^2(2) = 96.0$, $p < 0.001$). The knowledge score (range 0–12) increased from 4.14 ± 2.03 to 11.39 ± 0.90 (mean difference = 7.25, 95% CI: 6.84 to 7.67; Wilcoxon $p < 0.001$; standardized effect size dz = 3.40), and all 103 participants improved. A sensitivity analysis restricted to the three items with an objectively correct answer (R6, R8, and R9; range 0–6) showed the same pattern (from 2.82 ± 1.13 to 5.73 ± 0.66; mean difference = 2.91, 95% CI: 2.67 to 3.16; Wilcoxon $p < 0.001$; d = 2.31). The experience and perception items (R2, R4, and R5) were not included in the score; the proportion of children giving the best answer increased from 5.8% to 84.5% (prior consumption), from 10.7% to 77.7% (perceived effectiveness), and from 21.4% to 94.2% (source of information) (Table 8).

**Table 8.** Items of the questionnaire (1 = best answer, 3 = worst answer; $n = 103$). Knowledge items (included in the score) are listed first; experience and perception items were not included in the score.

| Components ($n = 103$) | Before: Mean | SD | After: Mean | SD | $p$ | Best Answer, % (Before → After) |
|---|---|---|---|---|---|---|
| Do you know what medicinal plants are? | 2.41 | 0.68 | 1.00 | 0.00 | <0.001 | 10.7 → 100.0 |
| Do you know which plants are most grown in your community? | 2.69 | 0.61 | 1.23 | 0.42 | <0.001 | 7.8 → 76.7 |
| When should medicinal plants be consumed? | 2.62 | 0.51 | 1.17 | 0.51 | <0.001 | 1.0 → 88.3 |
| Do you know where medicinal plants can be purchased? | 2.58 | 0.60 | 1.11 | 0.31 | <0.001 | 5.8 → 89.3 |
| Do you think medicinal plants are important for the ecosystem? | 1.82 | 0.61 | 1.00 | 0.00 | <0.001 | 29.1 → 100.0 |
| The main parts of plants used to obtain their benefits are the flowers and the stem | 1.75 | 0.71 | 1.10 | 0.30 | <0.001 | 40.8 → 90.3 |
| Experience and perception items (not included in the score) Have you ever consumed medicinal plants? | 2.60 | 0.60 | 1.16 | 0.36 | <0.001 | 5.8 → 84.5 |
| How effective do you think medicinal plants are? | 2.20 | 0.62 | 1.22 | 0.42 | <0.001 | 10.7 → 77.7 |
| Who told you about medicinal plants? | 2.35 | 0.81 | 1.06 | 0.24 | <0.001 | 21.4 → 94.2 |

Statistical analysis: Data were analyzed using the Wilcoxon signed-rank test for paired ordinal data. The McNemar exact test was used to compare the proportion of correct answers before and after the intervention. A $p$-value < 0.05 was considered statistically significant.

### *3.5. Assessment of the Level of Knowledge of the Use of Medicinal Plants in Urban Schoolchildren*

The level of knowledge about the use of medicinal plants was assessed using a questionnaire developed during the second stage (before and after the educational intervention). Before the implementation of the medicinal botanical garden as a pedagogical strategy, students, regardless of age or grade level, had limited knowledge about the use of medicinal plants. However, after the educational intervention, a significant improvement in the level

of knowledge was observed, as shown (Table 9). This finding suggests that the botanical garden is an effective pedagogical resource for promoting health education.

**Table 9.** Level of knowledge before and after the intervention (thirds of the 0–12 knowledge score range).

| Level of Knowledge | Pre *n* | Pre % | Post *n* | Post % |
|---|---|---|---|---|
| Low | 42 | 40.8 | 0 | 0.0 |
| Moderate | 54 | 52.4 | 0 | 0.0 |
| High | 7 | 6.8 | 103 | 100.0 |

Note: McNemar–Bowker $\chi^2(2) = 96.0$, $p < 0.001$. The results would be significant regardless of the cutoff point, because no child got worse.

The decline in the mean values across the questions (Table 8) indicates better answers in both the knowledge items, which form the score, and the experience and perception items, which were analyzed separately. Likewise, the items that showed statistical significance corroborate that the educational intervention increased students' knowledge. Consequently, this particular questionnaire supports the idea that the medicinal botanical garden functioned as an effective educational tool for students' knowledge of medicinal plants.

## 4. Discussion

A principal finding of this study was the marked increase in knowledge of medicinal plants. All 103 participants achieved a high level of knowledge following the intervention, compared to widespread baseline unfamiliarity regarding medicinal plant uses and safety. This aligns with evidence demonstrating that garden-based experiential learning enhances botanical recognition, environmental awareness, and health concepts through active, hands-on engagement with living plants [17–21]. Rather than operating purely as ecological spaces, school gardens serve as living laboratories where children contextualize scientific and health concepts in everyday life [2,22].

An additional contribution is the development and psychometric evaluation of a structured pictogram-based questionnaire adapted for Mexican primary schoolchildren. Following refinement, the instrument demonstrated satisfactory internal consistency (Cronbach's $\alpha = 0.833$) and strong content validity as established by a multidisciplinary expert panel, offering a valuable tool for future health promotion assessments in school settings. Beyond the evident educational gains, a series of modest pre–post changes were observed in a range of selected anthropometric and metabolic parameters.

These included body mass index, total cholesterol, triglycerides, and capillary glucose. Changes in glucose and lipids are not interpreted as clinical benefits: mean glucose remained within the normal range at both assessments, and most lipid values were at the lower reporting limit of the device. It is imperative to acknowledge that these observed changes should not be attributed exclusively or directly to the botanical garden itself. Conversely, the intervention functioned as an integrative educational catalyst within a comprehensive health-promoting school environment. The experiential gardening activities involved light to moderate physical exertion (e.g., digging, planting, harvesting) and included structured guidance on nutrition, hydration, and lifestyle behaviors. In addition, engagement in the cultivation and harvesting of medicinal plants may have furnished an experiential opportunity for exploration of potential dietary substitutions, particularly the replacement of sugary beverages with unsweetened herbal infusions. This approach could potentially motivate children to consider healthier beverage options and improve their habits; indeed, previous studies have shown that individuals who regularly consume herbal infusions tend to have better overall dietary quality, characterized by a higher intake of plant-based foods and a lower intake of free sugars [7]. However, dietary habits and physical activity were

not measured in this study, so this explanation remains a hypothesis. Furthermore, the phytochemical profile and antioxidant capacity reported for common medicinal species may exert supportive cellular mechanisms against oxidative stress and metabolic dysregulation [23,24]. However, within the comprehensive school intervention, these botanical, educational, and behavioral factors may have collectively contributed to fostering a conducive health-promoting environment, superseding the notion of isolating these elements as mere clinical remedies.

Incorporating medicinal botanical gardens into health promotion extends traditional school garden models beyond food production by integrating ethnobotanical literacy, local biodiversity conservation, and culturally sensitive primary healthcare concepts [25–29]. This approach aligns with World Health Organization guidelines advocating the evidence-informed, safe integration of traditional medicine into public health education [30,31], providing children with structured tools for informed decision-making regarding personal health [2,32,33].

This study has several strengths, including the integration of educational, anthropometric, and biochemical evaluations within an interdisciplinary school-based framework, as well as the creation of reusable digital learning tools. However, several limitations must be noted. The single-group pre–post design without a control group prevents attributing observed health changes definitively to the program. Maturation, regression to the mean, and other changes in the school and family environment cannot be ruled out. Additionally, the study was conducted in a single urban public school, limiting generalizability, and the post-intervention assessment immediately followed the program, preventing evaluation of long-term knowledge retention or sustained behavioral changes. In addition, the final sample ($n$ =103) was smaller than the calculated sample size ($n$ = 233) because of non-participation, exclusions, and eliminations, which corresponds to an approximate margin of error of 8.8%; the study could detect effects of dz $\geq$ 0.28 with 80% power, so smaller effects may have gone undetected. Age was recorded in completed years, so z-scores and percentiles were calculated using an approximate age. Cholesterol and triglyceride values were at the lower reporting limit of the device in most children, and the same questionnaire items were used before and after the intervention, so part of the improvement may reflect familiarity with the questions. The knowledge items rely on self-report, and the six-item knowledge subscale, derived from a questionnaire validated as a nine-item instrument, was not evaluated separately for internal consistency in the validation sample. Future research utilizing randomized controlled or cluster-randomized trials with extended follow-up periods is warranted to evaluate the long-term impact and scalability of medicinal botanical gardens as supportive environments for pediatric health.

## 5. Conclusions

The implementation of a medicinal botanical garden integrated into a structured school-based educational program was associated with a substantial improvement in children's knowledge regarding medicinal plants, alongside observable pre–post changes in selected anthropometric and biochemical parameters following the intervention. Changes in glucose and lipids are not interpreted as clinical benefits. Moreover, the study developed and evaluated a nine-item pictogram questionnaire (content validity and internal consistency) whose six knowledge items assess medicinal plant knowledge among schoolchildren, and it generated educational materials for integration of traditional medicine into health education. Despite the quasi-experimental single-group design's inability to establish direct causal relationships, the findings indicate that medicinal botanical gardens can be integrated into primary school curricula as interdisciplinary educational resources, combining environmental education, health promotion, and the preservation of traditional knowledge.

The necessity for future controlled multicenter studies with extended follow-up periods is evident to confirm the effectiveness of this approach, to evaluate knowledge retention, and to test whether the knowledge gained translates into health-related practices, which was not measured in this study.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/children13111530/s1. Questionnaire S1: Pictogram-based questionnaire on knowledge of medicinal plants.

**Author Contributions:** Conceptualization, C.I.D.-R., J.A.-R., Z.O.-H. and E.R.-M.; Methodology, C.I.D.-R., J.A.-R., Z.O.-H. and E.R.-M.; Software, C.I.D.-R., J.A.-R., J.M.A.-G. and E.R.-M.; Validation, C.I.D.-R., J.A.-R., Z.O.-H. and E.R.-M.; Formal Analysis, C.I.D.-R., J.A.-R., R.M.B.-T. and E.R.-M.; Investigation, C.I.D.-R., Q.Y.Z.-R., J.A.-R. and E.R.-M.; Resources, C.I.D.-R., J.A.-R. and E.R.-M.; Writing—Original Draft, J.A.-R., and E.R.-M. Writing—Review & Editing, C.I.D.-R., J.A.-R., R.M.B.-T. and E.R.-M.; Visualization, C.I.D.-R., J.A.-R., J.M.A.-G. and E.R.-M.; Supervision, C.I.D.-R., J.A.-R., Z.O.-H. and E.R.-M. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by the Universidad Autónoma del Estado de Hidalgo, grant number PAO-UAEH 2025.

**Institutional Review Board Statement:** The study was approved by the Ethics and Research Committee of the Instituto de Ciencias de la Salud (ICSa) of the Universidad Autónoma del Estado de Hidalgo (UAEH), in Mexico (code CEI-ICSa-2024/R241) on 2 July 2024.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study, as well as from their parents.

**Data Availability Statement:** The data presented in this study are available upon request from the corresponding author. The data are not publicly available due to privacy and ethical reasons.

**Acknowledgments:** The authors gratefully acknowledge the support of the Master's scholarship in Public Health from the Secretaría de Ciencias, Humanidades, Tecnología e Innovación (SECIHTI), CVU 1190680.

**Conflicts of Interest:** The authors declare no conflicts of interest.

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