



Effectiveness of eToyBox Online Learning Platform Versus Print-Based Learning Materials: A Three-Arm Cluster Randomized Controlled Trial in Improving Malaysian Preschool Teachers' Capacity to Promote Healthy Eating and Physical Activity Behaviours

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Abstract

ToyBox Study Malaysia (TSM) is an evidence-based programme aimed at preventing childhood obesity by promoting healthy behaviours among preschool children, including water consumption, healthy snacking, increased physical activity, and reduced sedentary time. Adapted from ToyBox Study Europe, TSM was first implemented in Malaysian preschools in 2018 and later converted into an online learning system, eToyBox. This study evaluated the effectiveness of eToyBox compared to print-based learning in enhancing preschool teachers' knowledge, attitudes, and self-efficacy in teaching these behaviours. This cluster-randomized controlled study involved 138 preschool teachers assigned to control group (CG), intervention group I (IG-I), or intervention group II (IG-II). IG-I ($n=46$) completed 13-week asynchronous eToyBox programme, while IG-II ($n=47$) implemented printed ToyBox modules over the same period. CG received no intervention but completed the same assessments. Outcomes were measured using ToyBox Teacher's Questionnaire at baseline (T0), post-intervention (T1), and 3-month follow-up (T2), and analysed using Friedman test and repeated measures ANOVA. Compared to CG, IG-I teachers showed significant improvements in knowledge, attitudes, and self-efficacy after eToyBox programme ($p<0.001$), while IG-II showed significant gains only in attitudes ($p=0.028$) and self-efficacy ($p=0.002$). Direct comparison between both IGs revealed that there was no statistically significant difference for knowledge and self-efficacy, IG-I significantly outperformed IG-II in enhancing teachers' attitudes ($p=0.027$). These findings support digital health promotion interventions as a scalable strategy to empower educators in childhood obesity prevention.

Keywords Childhood obesity · Nutrition education · Online learning · Obesity intervention · Preschool teachers

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Introduction

Childhood obesity has emerged as a pressing global public health issue in recent decades. According to the World Health Organization, the number of children under the age of five affected by obesity worldwide has risen markedly, increasing from 33 million (5.3%) to 37 million (5.6%) over the past two decades (World Health Organization, 2024). Nearly half (48%) of these 37 million children live in the Asian region, followed by Africa, which accounts for more than a quarter (28%) of the global burden. In Southeast Asia specifically, the prevalence of obesity among children under five has increased by half a million cases over the past decade, rising from 3.6 million in 2012 to 4.1 million in 2022. Malaysia ranks second only to Brunei in childhood obesity prevalence, with 12.7% of children aged 5 to 19 years classified as having obesity. Alarming, over half of affected children (7.1%) are under the age of five years (UNICEF, 2019).

Childhood obesity is a multifaceted condition shaped by complex interplays among individual factors, socioeconomic circumstances, and community context. Rather than stemming solely from individual dietary patterns and physical inactivity, these behaviours are heavily influenced by broader environmental, genetic, and psychosocial determinants (Kansra et al., 2021). Introducing health promotion interventions early during the school years is therefore important, since schools are considered ideal venues for implementing such programmes due to their structured environment (Barnes et al., 2021), the significant amount of time children spend in school, and the opportunities they provide to offer healthy food options through school meal programmes (Clarke et al., 2013). Furthermore, nutrition education programmes have shown effectiveness in reducing children's body mass index (BMI) (Chatterjee & Nirgude, 2024), while the inclusion of experiential environmental sustainability components, such as gardening, food tasting, and cooking activities, has been associated with increased fruit and vegetable consumption (Karpouzis et al., 2025). Teachers represent a critical delivery agent for school-based nutrition education, and teacher-led nutrition education has been shown effectively to enhance students' nutrition knowledge and dietary behaviours (Cotton et al., 2020; Snelling et al., 2016).

However, teachers' capacity to teach healthy behaviours is influenced by several factors, including their foundational knowledge (Jones & Zidenberg-Cherr, 2015), confidence in teaching about healthy lifestyles, and their perceptions of the importance of nutrition education (Hall et al., 2016). A significant challenge faced by teachers is their lack of knowledge and confidence in delivering nutrition education in the classroom (Aydin et al., 2022; Esdaile et al., 2024).

This issue often stems from insufficient institutional support (Perikkou et al., 2015), and the lack of adequate training and teaching resources (Resor et al., 2021) which has further constrained teachers' capacity to facilitate meaningful behavioural changes. The absence of specific training and credible teaching materials raises concerns about the accuracy and quality of nutrition information delivered to students.

Nonetheless, studies have demonstrated that providing technical support or professional development opportunities such as workshops, training, seminars, and teaching kits is effective in enhancing teachers' competencies in health promotion (Bales et al., 2025; Coccia et al., 2020; Halloran et al., 2018; Nanayakkara et al., 2024)). Teachers who receive nutrition-specific training are more likely to teach and sustain lessons on healthy habits compared to those who do not undergo such training (Perikkou et al., 2015). Beyond traditional teaching methods, web-based learning systems offer flexible and convenient learning environments, enabling teachers to acquire knowledge efficiently and effectively (Sheridan & Wen, 2021). In recent years, several studies have extended this evidence by showing that online or web-based training programmes can be equally effective in improving teachers' competencies in delivering nutrition education (Cohen et al., 1999; Katsagoni et al., 2019; O'Dea, 2016; Sindi et al., 2021). Online learning programmes are recommended as an effective form of professional development for preschool educators, as they provide access to up-to-date teaching approaches and materials without time or location constraints (Bruder et al., 2009).

Most childhood obesity interventions in Malaysia have primarily focused on older students (aged 7 to 11 years), with a particular emphasis on involving nutrition experts and parents in addressing weight-related issues (Chin et al., 2020; Gunasekaran et al., 2018; Md. Yusop et al., 2018). There remains a significant gap in interventions targeted specifically at preschool-aged children, particularly those that are teacher-led, despite evidence that early intervention is crucial for establishing the foundation for healthy habits (Hammersley et al., 2017; Sigman-Grant et al., 2014). Additionally, existing research has predominantly centred on face-to-face interventions, with little exploration of how these could be adapted for online platforms. The question of whether the effectiveness of web-based training interventions is comparable to that of physical modules remains underexplored.

To address this gap, eToyBox, an online learning platform tailored for preschool teachers, was developed as an adaptation of the ToyBox Study Malaysia intervention programme (2018) (Cheah et al., 2023; Reeves et al., 2018). This study used a three-arm cluster randomized controlled trial to compare the effectiveness of eToyBox and print-based learning

materials, relative to a control group (CG), in improving preschool teachers' knowledge, attitudes, and self-efficacy in promoting healthy behaviours in the classroom.

ToyBox Study Malaysia

The original ToyBox Study was developed in Europe to prevent obesity among preschool children by targeting multiple energy-balance related behaviours through an evidence-based, theory-driven approach (Manios, 2012). Grounded in the PRECEDE-PROCEED model and intervention mapping, it promotes water consumption, healthy snacking, increased physical activity (PA), and reduced sedentary time, and has been implemented across six European countries (Manios, 2012; Manios et al., 2014). Recognising the absence of obesity prevention programmes for kindergarten-aged children in Malaysia, an international collaboration involving the University of Roehampton (UK), University of Durham (UK), *Universiti Kebangsaan Malaysia*, *Universiti Malaysia Sarawak*, with the support of Harokopio University (Greece), initiated the ToyBox Study Malaysia.

To ensure cultural and contextual relevance, the original intervention materials were adapted for local implementation and translated into the Malay language. In 2018, the programme was delivered in both urban and rural settings across Kuala Lumpur, Selangor, and several districts in Sarawak (Cheah et al., 2023). Engaging preschool teachers, preschoolers and their parents, the intervention combined environmental modifications in the classroom and structured teacher training sessions, to facilitate behaviour change among the preschoolers. However, subsequent implementation efforts were hindered by the COVID-19 pandemic and movement restriction orders, limiting in-person activities.

To ensure sustainability and enhance accessibility and scalability, the printed modules were subsequently transformed into digital learning materials (eToybox). eToybox is an open-access, web-based learning management system (LMS) designed for preschool teachers. This platform was designed to broaden access to teaching resources and support the long-term integration of health-promoting practices by preschool teachers. Building upon the pioneering ToyBox Study Malaysia, which marked the first implementation of the ToyBox framework outside Europe, this digital adaptation addresses a critical gap in scalable early childhood obesity prevention efforts.

Methods

Study Participants Preschool teachers registered under the Community Development Department of Malaysia (KEMAS) across six regions in Peninsular Malaysia (Northern, Southern, Central, East Coast) and the states of Sabah

and Sarawak formed the sampling frame. Prior approval was obtained from KEMAS, which provided a list of randomly selected teachers from various districts in each state. From this list, purposive sampling was employed to select participants to ensure diverse geographical coverage across all six regions, prioritising a broad representation from both urban and rural settings despite varying teacher population densities.

The required sample size was calculated using Snedecor and Cochran's (1989) formula (Snedecor & Cochran, 1989). Reference data were drawn from a similar intervention by O'Dea (2016), which reported significant improvements in knowledge scores (mean increase from 24.27 ± 4.89 to 51.0 ± 5.61). Based on an estimated effect size of 0.5, a statistical power of 90% ($\beta = 0.10$), and a significance level of 5% ($\alpha = 0.05$), the calculation indicated a minimum of 45 respondents per group. To account for potential 15% drop-out rate, the target was increased to 52 respondents per group (control and intervention), and a total of 156 participants.

A control group was included to improve the study's internal validity and allow robust evaluation of changes in preschool teachers' knowledge, attitudes, and self-efficacy attributable to the intervention. Its inclusion helped control for potential confounding variables, such as socioeconomic status and unmeasured factors, thereby differentiating true intervention-related effects from changes due to external influences, selection bias, or temporal trends. Moreover, the control group provided a reference point for interpreting the relative effectiveness of the online and printed delivery formats.

A total of 175 preschool teachers were shortlisted from the KEMAS teacher registry based on their location within the selected districts. These teachers were then contacted via WhatsApp, whereby the study objectives and activities were explained through a digital recruitment flyer. The researcher addressed any queries before obtaining agreement to participate. This recruitment and consent procedure applied uniformly to all participants. Of those invited, 156 teachers responded positively and agreed to participate, yielding a response rate of 89.1%. Consent forms and information sheets were distributed using Google Forms. Participants were eligible if they owned a laptop, tablet, or smartphone with internet access and had not participated in earlier phases of the study.

eToyBox

The eToyBox modules (<https://etoymbox-study.my/>) were developed to extend the objectives of the earlier printed ToyBox Study Malaysia materials (<https://toybox-study.org.my/>). It aimed to provide teaching resources to help

preschool teachers deliver classroom activities that promote healthy behaviours among preschoolers and garner support from the home environment to ensure consistent behavioural reinforcement. The platform was designed as an accessible and flexible online learning environment to support preschool teacher uptake of the Toybox Study Malaysia modules. By delivering training content asynchronously, the platform enabled teachers to engage with the eToyBox materials at their own pace and on their own schedules, addressing common time and resources, which is a flexibility that is particularly salient in an adult learning context. The use of an online learning management system also allowed for standardized delivery of training content, integration of multimedia teaching resources, and scalability across geographically diverse regions. Collectively, these features were intended to enhance the feasibility and sustainability of the ToyBox Study Malaysia intervention when implemented at scale.

The eToyBox programme comprised interactive learning modules featuring infographics, e-storybooks, interactive quizzes, and instructional and demonstration videos designed to guide various sensory and physical games, experiments and animated Kangaroo stories. The programme was hosted on an open-source LMS (Chamilo), which provided all the necessary features to support an effective and user-friendly learning experience. These included organised course structures, file uploads (videos and documents), assessment tools, user progress tracking, and interactive functionalities that enabled participants to engage actively with the course materials.

The eToyBox platform consists of four core modules, each designed to promote specific aspects of healthy habits among preschoolers. It targets four primary energy balance-related behaviours: *Jom Minum* (water drinking), *Tingkah Laku Sedentari* (sedentary behaviours), *Makanan dan Snek Sihat* (healthy snacking), and *Jom Aktif* (physical activity). Each module was structured into three subtopics that provided a gradual and comprehensive implementation framework. An overview of each module, its subtopics, and corresponding further topics is presented here; full details are available in Supplementary Table 1.

The first subtopic was focused on setting up the kindergarten environment, offering practical recommendations to create conditions conducive to healthier behaviours. These included increasing access to healthy snacks and potable water, encouraging physical activity, and reorganising classrooms to support active breaks. For example, there are step-by-step guidelines on how to set up water stations to promote regular hydration; and how to modify classroom layouts, such as setting up standing activity stations and clear movement areas, to reduce sedentary behaviour in the classroom.

The second subtopic aimed to show the preschool teachers how to integrate eToybox activities into the existing curriculum, enabling a seamless implementation of Toybox Study Malaysia modules in the classroom. For instance, healthy recipe demonstrations in eToybox provided children with hands-on experiences in preparing healthier foods to increase acceptance; or introduced various engaging games and group exercise routines to incorporate movement into daily activities.

The third subtopic was centred on guiding the teachers on how to use the classroom activities in eToybox that were designed to build children's self-efficacy, knowledge, and skills for maintaining healthy habits. It featured interactive, engaging tasks that reinforce the behaviours introduced in earlier subtopics, including sensory play and experiments that supported cross-curricular teaching, integrating subjects such as science and mathematics. Additionally, animated videos (Kangaroo stories) were incorporated into language lessons to promote healthy habits while meeting broader educational objectives.

At the end of each module, bulletin and tip cards were included for preschool teachers to print or share these materials with parents. These resources summarised key messages and provided practical strategies to reinforce healthy behaviours at home and ensure consistency between school and home. Teachers also completed a 10-question online quiz at the end of each module, with a minimum score of 70% required to progress, with multiple attempts allowed.

Study Instrument

The ToyBox Teachers' Questionnaire, originally developed in the European ToyBox Study (Mouratidou et al., 2014) was translated into Bahasa Melayu and culturally adapted for this study. A systematic translation and validation process was undertaken to ensure its suitability for the Malaysian context (Cruchinho et al., 2024). This Bahasa Melayu version served as the primary instrument for assessing participants' knowledge, attitudes, and self-efficacy of the four healthy behaviours in their classrooms. The questionnaire comprised 47 items divided into four sections, each corresponding to one of the targeted health behaviours.

The questions that assessed nutrition and physical activity knowledge were specifically based on the information provided through the eToyBox programme. The knowledge scores were calculated by assigning 1 point for each correct response and 0 for each incorrect answer, with higher scores indicating greater knowledge. Responses for the attitude and self-efficacy domains were then measured using a 5-point Likert scale ranging from 1 ("Strongly Agree" or "Very Confident") to 5 ("Strongly Disagree" or "Very Not Confident").

Study Design

Figure 1 shows the study design flowchart. Participants selected were randomly assigned to one of three groups, including the Control Group (CG), Intervention Group I (IG-I), or Intervention Group II (IG-II). Cluster randomization approach was performed using a computer-generated random number sequence, with the preschool serving as the unit of randomization (cluster). This approach ensured that preschool teachers within the same preschool were assigned to the same study arm, thereby minimizing contamination

between intervention groups. Dedicated WhatsApp groups were created for each group to facilitate communication.

IG-I received the eToyBox intervention comprising four online training modules: (1) *Jom Minum* (water drinking), (2) *Tingkah Laku Sedentari* (sedentary behaviours), (3) *Makanan dan Snek Sihat* (healthy snacking), and (4) *Jom Aktif* (physical activity). IG-II received printed versions of the same modules, delivered by post before the intervention began. Both intervention arms followed a 13-week schedule, with the duration allocated for each module determined by the volume of its content (Table 1).

Fig. 1 Study Design

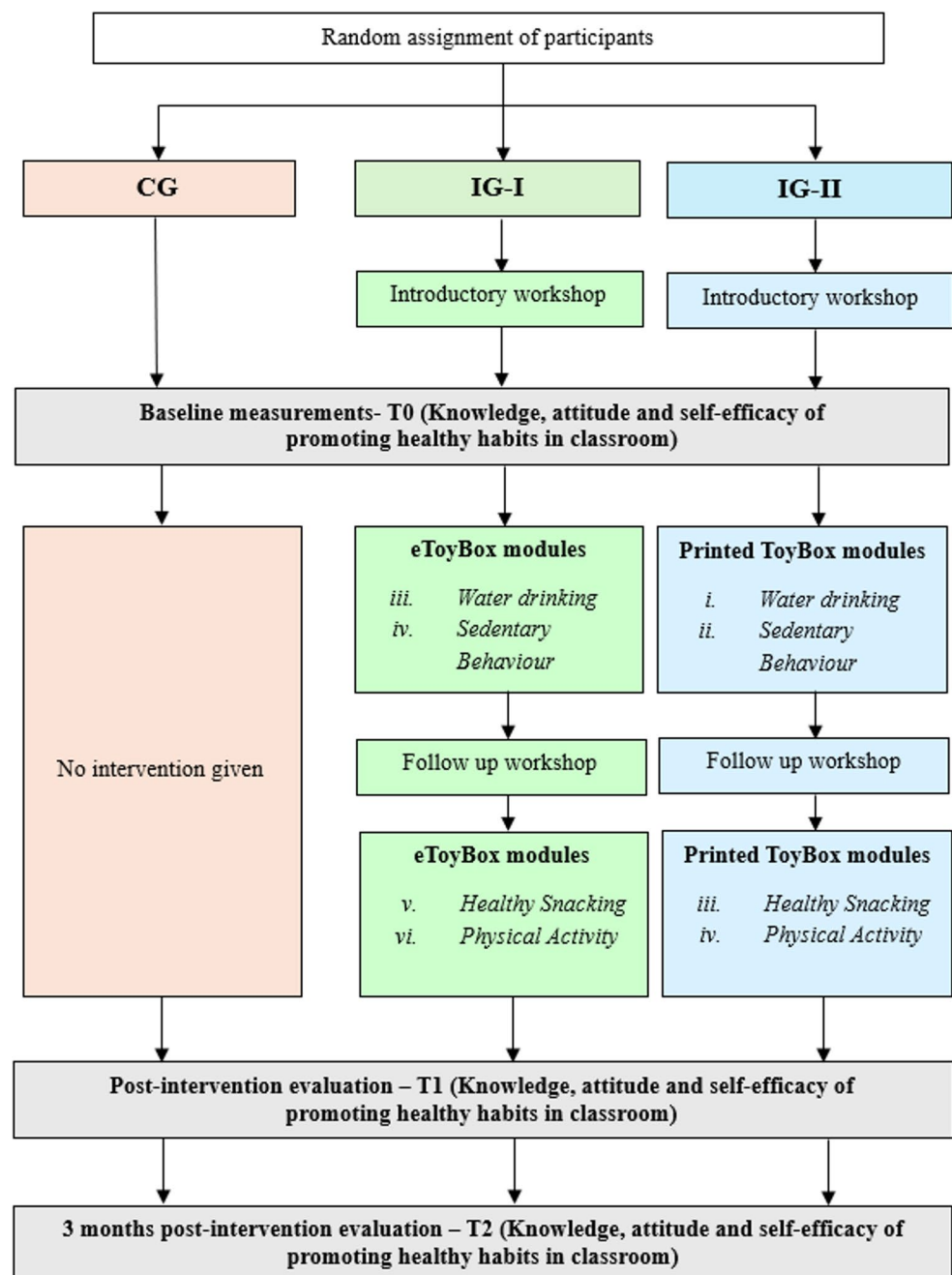


Table 1 Implementation timing of the eToyBox and ToyBox modules

Modules	Water consumption	Sedentary behaviour	Healthy Snacking	Physical Activity
Duration	2 weeks	3 weeks	4 weeks	4 weeks
Timing (nth Week)	1 st to 2nd week	3rd to 5th week	6th to 9th week	10th to 13th week

Table 2 Distribution of questions and maximum scores across domains

Modules	Knowledge	Attitude	Self-efficacy	Total items
Water Consumption	3	5	3	11
Healthy Snacking	5	5	4	14
Physical activity	3	5	4	12
Sedentary behaviour	3	3	4	10
Total items by each domain	14	18	15	47
Maximum aggregated score for each domain	14	90	75	-

An initial online workshop was conducted via Microsoft Teams and introduced the programme objectives and guided participants through the first two modules (water consumption and sedentary behaviour). Participants were also instructed on integrating these topics into classroom teaching. Baseline data (T0) on knowledge, attitudes, and self-efficacy in promoting healthy habits were collected during this session using the ToyBox Teachers Questionnaire.

Throughout the intervention, weekly WhatsApp reminders prompted participants from IG-I and IG-II to complete each module. A virtual midpoint workshop (Week 5) aimed to support implementation of Toybox Study Malaysia modules by providing an opportunity to the participants to discuss challenges and find solutions. At the same time, this virtual meeting also guided the participants through the remaining two modules (healthy snacking and PA). Post-intervention data (T1) were collected at the end of each module using the standard questionnaire, administered via an online form. T2 data collection was conducted three months after completing all modules. Meanwhile, CG participants did not receive any intervention but were assessed concurrently with the intervention groups to allow consistent comparisons. After the study concluded, CG participants were given access to the eToyBox platform.

Statistical Analysis

Statistical analysis was conducted using IBM SPSS Statistics for Windows version 29.0 (IBM Corporation, New York, USA). As the number of items varied across sections and

domains in the ToyBox Teacher's Questionnaire (Table 2), the total scores were converted into percentages to enable direct comparison. Percentage scores were calculated by dividing each participant's total score by the maximum possible score for that domain and multiplying by 100. The maximum possible aggregated scores were 14 for knowledge, 90 for attitudes, and 75 for self-efficacy, based on the total number of items multiplied by the highest Likert scale value. To aid interpretation, these percentages were categorised into four levels: "Very Poor" (0–24%), "Poor" (25–49%), "Moderate" (50–74%), and "High" (75–100%).

Both percentage and raw scores were used for different purposes. Percentages provided a standardized metric for descriptive summaries, enabling comparison across domains and intervention groups. Raw scores were retained for statistical analyses to preserve scale properties and ensure accurate calculation of p-values and effect sizes. Accordingly, percentages were used for descriptive reporting, while raw scores were used in inferential analyses.

Prior to analysis, the distribution of the data was evaluated for normality using Shapiro-Wilk test and visual inspection of histograms and evaluation of skewness and kurtosis. Since the data violated the assumption of normality, non-parametric tests were primarily employed. To minimize selection bias, baseline data for the overall scores for knowledge, attitudes, and self-efficacy related to promoting healthy habits were compared across the intervention groups (IG-I and IG-II) and the control group (CG) using the Kruskal-Wallis test. The outcome scores were reported as means with standard deviations.

Changes in outcomes over time were examined using multiple statistical approaches. Within-group changes in knowledge, attitudes, and self-efficacy across time points were evaluated using the Friedman test, followed by post hoc Wilcoxon signed-rank tests with Bonferroni correction. To determine if the magnitude of improvement differed between the eToyBox (IG-I) and Printed (IG-II) groups, time-by-group interaction effects were assessed using repeated measures ANOVA. Although the data were non-normally distributed, repeated measures ANOVA was employed for the interaction analysis because this test has been shown to be robust to deviations of normality, particularly when the assumption of sphericity is satisfied and sample sizes are adequate (Blanca et al., 2023). Mauchly's test of sphericity was used to check the assumption of sphericity; when violated ($p < 0.05$), Greenhouse-Geisser corrections were applied, otherwise results were reported based on sphericity-assumed estimates. Post hoc pairwise comparisons included Bonferroni adjustments to control for Type I errors.

Results

Participant Characteristics

Table 3 shows the sociodemographic characteristics of the study participants in this study. The study involved 138 participants divided into three groups: CG ($n=45$), IG-I ($n=46$), IG-II ($n=47$). The mean age across groups was approximately 33 years: 33.6 ± 6.85 years in CG, 33.4 ± 4.41 years in IG-I, and 33.4 ± 5.74 years in IG-II. More than 90% of participants in all groups were female.

The majority of the participants held pre-university qualifications (approximately 70% to 76%), such as the Malaysian Higher School Certificate (*Sijil Tinggi Persekolahan Malaysia, STPM*), diploma, or matriculation. This was followed by participants with a Bachelor's degree (approximately 13% to 27%) and a smaller proportion with a Certificate in Early Childhood Care and Education (around 2% to 11%). Most participants also had 10 or more years of teaching experience in the field (approximately 36% to 45%). Geographical distribution varied for all groups, the CG participants were nearly evenly split between urban (51.1%) and rural (48.9%) areas, while IG-I (76.1%) and IG-II (72.3%) were predominantly from rural areas.

A total of 156 preschool teachers were initially recruited and randomized into the three study arms ($n=52$ per group).

Of these, 138 participants (88.5%) completed all assessments at baseline, post-intervention, and follow-up and were included in the final analysis. The overall attrition rate was 11.5% ($n=18$). Primary reasons for withdrawal included heavy workload ($n=2$), transfer to new positions ($n=3$), change of employment ($n=1$), and unknown reasons ($n=12$). The dropout rates were comparable across groups: CG ($n=7$; 13.5%), IG-I ($n=6$; 11.5%), and IG-II ($n=5$; 9.6%). As attrition was low and evenly distributed, a complete-case analysis was performed, excluding participants with missing data at any time point. No adverse events or unintended effects were reported by the teachers in any of the study groups during the intervention or follow-up periods.

Preschool Teachers' Knowledge, Attitude and Self-Efficacy Before Intervention

At baseline, the overall scores for knowledge, attitude, and self-efficacy were compared across the three groups to ensure no significant differences existed between them (Table 4). Since all p -values were greater than 0.05, the knowledge ($p=0.161$), attitude ($p=0.556$) and self-efficacy ($p=0.220$) results confirmed that the participants were comparable across groups for these key measures prior to the intervention.

Table 5 shows the baseline distribution of knowledge, attitude, and self-efficacy levels across modules for all groups.

Table 3 Sociodemographic characteristics of study participants

	CG (<i>n</i> =45)		IG-I (<i>n</i> =46)		IG-II (<i>n</i> =47)	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Age (years old)	33.6±6.85		33.4±4.41		33.4±5.74	
Mean±SD						
Gender						
Male	4	8.9	2	4.35	1	2.1
Female	41	91.1	44	95.7	46	97.9
Education Level						
Certificate in Early Childhood Care and Education	2	4.4	1	2.2	5	10.6
STPM/Diploma/Matriculation	31	68.9	35	76.1	36	76.6
Bachelor's degree	12	26.7	10	21.7	6	12.8
Years of Teaching Experience						
1–3 years	12	26.7	9	19.6	8	17.0
4–6 years	6	13.3	11	23.9	6	12.8
7–9 years	11	24.4	6	13.0	12	25.5
10 years and above	16	35.6	20	43.5	21	44.7
Geographical location						
Urban areas	23	51.1	11	23.9	13	27.7
Rural areas	22	48.9	35	76.1	34	72.3
States						
Northern region	10	22.2	17	37.0	12	25.5
Central region	8	17.8	8	17.4	8	17.0
East region	5	11.1	6	13.0	5	10.6
Southern region	16	35.6	7	15.2	9	19.1
Sabah	4	8.9	4	8.7	11	23.4
Sarawak	2	4.4	4	8.7	2	4.3

Table 4 Comparison of baseline overall knowledge, attitude and self-efficacy scores across groups

Maximum score possible		CG (<i>n</i> =45)		IG-I (<i>n</i> =46)		IG-II (<i>n</i> =47)		<i>p</i> -value
		Mean	SD	Mean	SD	Mean	SD	
Knowledge	14	10.13	1.39	9.98	1.40	10.63	1.54	0.161
Attitude	90	72.65	7.15	74.0	5.67	73.64	6.71	0.556
Self-efficacy	75	57.76	5.14	56.76	7.79	55.85	7.97	0.220

Table 5 Baseline distribution of knowledge, attitude, and self-efficacy levels across modules for all groups

Outcome	Modules	Score distribution, <i>n</i> (%)				Overall score (Mean±SD)	Overall average score (Mean±SD)
		Very Poor	Poor	Moderate	High		
Knowledge	Drinking	0 (0)	7 (5.1)	82 (59.4)	49 (35.5)	76.8±18.7	74.0±9.80
	PA	0 (0)	0 (0)	96 (69.6)	42 (30.4)	76.8±15.3	
	Healthy Snacking	2 (1.45)	13 (10.9)	59 (42.7)	64 (46.4)	68.7±16.8	
	Sedentary Behaviour	0 (0)	21 (15.2)	67 (48.6)	50 (36.2)	73.7±22.7	
Attitude	Drinking	0 (0)	3 (2.2)	28 (20.3)	107 (77.5)	80.7±11.54	80.6±7.43
	PA	0 (0)	0 (0)	3 (2.2)	135 (97.8)	89.4±9.98	
	Healthy Snacking	0 (0)	0 (0)	28 (20.3)	110 (79.7)	80.5±8.65	
	Sedentary Behaviour	0 (0)	7 (5.1)	75 (54.3)	56 (40.6)	71.9±13.5	
Self-efficacy	Drinking	1 (0.72)	1 (0.72)	13 (9.4)	123 (89.1)	85.8±12.5	76.3±9.36
	PA	0 (0)	5 (3.6)	55 (39.9)	78 (56.5)	73.2±12.9	
	Healthy Snacking	0 (0)	0 (0)	18 (13.0)	120 (87.0)	82.8±10.1	
	Sedentary Behaviour	1 (0.72)	22 (15.9)	78 (56.5)	37 (26.8)	63.4±16.3	

The scores were graded based on the following percentage ranges:

Very poor: 0–24%; Poor: 25–49%; Moderate: 50–74%; High: 75–100%

The overall knowledge level across all healthy behaviours among participants was categorized primarily as “Moderate” (74.0%). The participants demonstrated the highest knowledge in PA and drinking modules, both categorized as “High” (76.8%). However, the healthy snacking module had the lowest overall score, classified as “Moderate” (68.7%), with two participants (1.45%) categorized into the “Very Poor” range.

The participants exhibited a positive attitude towards teaching all healthy behaviours, with all modules scoring above 80% in the “High” category, except for sedentary behaviour. This module was rated at a “Moderate” level (71.9%), with 7 participants (5.1%) categorized as “Poor.” The highest positive attitude was observed in PA, with nearly all participants (77.5%) categorized as “High.” On the other hand, participants reported the highest confidence in teaching topics related to water consumption (drinking), with an overall score of 85.8% and the majority of participants (89%) in the “High” category. Healthy snacking followed closely with an overall score of 82.8%, and most participants (87%) were categorized as “High.” Sedentary behaviour had the lowest overall score at 63.4% (“Moderate” level), with 22 participants (15.9%) categorized as “Poor.”

Preschool Teachers’ Knowledge, Attitudes, and Self-Efficacy After Intervention

Table 6 summarised the temporal changes in participants’ knowledge, attitudes, and self-efficacy scores across all

three groups (IG-I, IG-II, and CG) from baseline (T0) to immediately post-intervention (T1) and three months post-intervention (T2). CG showed minimal changes across all outcomes throughout the study period with no significant differences observed over time (knowledge: $p=0.182$; attitude: $p=0.674$; self-efficacy: $p=0.574$).

IG-I demonstrated the most substantial improvements. Knowledge scores increased markedly from baseline to immediately post-intervention (9.98 ± 1.41 to 12.48 ± 1.15), with a slight decline at three months (11.89 ± 1.52), yet the improvements were significant for overall and across all time points ($p<0.001$). Similarly, attitude and self-efficacy scores improved significantly following the intervention ($p<0.001$), and these improvements were maintained at the three-month follow-up.

However, IG-II showed a different pattern of change. No significant improvement in knowledge scores was observed from baseline to three months post-intervention (10.64 ± 1.54 to 11.11 ± 1.65 ; $p=0.123$). In contrast, both attitude (73.64 ± 6.71 to 76.75 ± 8.22 ; $p<0.05$) and self-efficacy (55.85 ± 7.97 to 61.09 ± 8.58 ; $p<0.05$) improved significantly from baseline (T0) to the three-month follow-up (T2). Although these within-group trajectories suggest positive changes following the intervention, between-group comparisons are required to determine whether these improvements can be attributed to the intervention itself.

Table 6 Changes in preschool teachers' knowledge, attitude, and self-efficacy scores across all three groups (CG, IG-I and IG-II)

Outcome	Groups	Time Points	Overall score (Mean±SD)	Overall change (p-value)	Pairwise comparisons	
					T0 to T1	T1 to T2
Knowledge	CG	T0	10.13±1.14	0.182	-	-
		T1	10.42±1.50			
		T2	10.62±1.65			
	IG-I	T0	9.98±1.41	<0.001*	<0.001*	<0.001*
		T1	12.48±1.15			
		T2	11.89±1.52			
	IG-II	T0	10.64±1.54	0.123	-	-
		T1	11.23±1.60			
		T2	11.11±1.65			
Attitude	CG	T0	72.64±7.16	0.674	-	-
		T1	71.89±6.96			
		T2	72.51±8.27			
	IG-I	T0	74.00±5.67	<0.001*	<0.001*	<0.001*
		T1	80.07±5.36			
		T2	80.58±7.33			
	IG-II	T0	73.64±6.71	0.028*	0.090	0.016 *
		T1	75.43±7.17			
		T2	76.75±8.22			
Self-efficacy	CG	T0	57.76±5.14	0.574	-	-
		T1	56.84±5.38			
		T2	57.42±5.84			
	IG-I	T0	56.76±7.79	<0.001*	<0.001*	<0.001*
		T1	62.63±5.10			
		T2	63.72±8.15			
	IG-II	T0	55.85±7.97	0.002*	0.002*	<0.001*
		T1	58.40±6.93			
		T2	61.09±8.58			

Friedman test within group analysis was applied followed by pairwise comparisons using Wilcoxon Signed-Rank test with Bonferroni correction for multiple comparisons

*Level of significance was set at 0.05 (two-tailed)

T0: Pre-intervention, T1: First follow-up, T2: Second follow-up (3 months post-intervention)

Effectiveness of eToyBox

To determine if the magnitude of improvement differed between the online and printed delivery formats, time-by-group interaction effects were examined (Table 7). Repeated measures ANOVA revealed significant interactions for all three outcomes: knowledge ($F=11.78$, $p<0.001$, partial $\eta^2=0.149$), attitude ($F=5.63$, $p<0.001$, partial $\eta^2=0.077$), and self-efficacy ($F=7.25$, $p<0.001$, partial $\eta^2=0.097$). The effect sizes were largest for knowledge, followed by self-efficacy and attitude.

When both intervention groups were compared directly, it was revealed that the eToyBox (IG-I) was significantly more effective than the printed modules group (IG-II) in enhancing teacher's attitude ($p<0.05$). While IG-I also achieved higher improvement scores than IG-II for knowledge and self-efficacy, these specific differences between the two intervention arms did not reach statistical significance ($p=0.131$ and $p=0.064$, respectively).

Compared to the CG, IG-I demonstrated significant improvements across all three measured domains ($p<0.05$). Similarly, IG-II significantly outperformed CG in knowledge and attitude ($p<0.05$); however, it showed no significant change in self-efficacy compared to CG ($p=0.974$). Collectively, these findings identify the eToyBox platform (IG-I) as the superior intervention model; not only did it produce significantly greater improvements in attitudes compared to the printed modules, but it also demonstrated a broader impact by being the sole intervention to significantly improve self-efficacy relative to the control group.

Discussion

This study evaluated the effectiveness of the eToyBox online learning management system in improving preschool teachers' knowledge, attitudes, and self-efficacy in promoting healthy classroom behaviours. The primary finding was that

Table 7 Comparative effectiveness of eToyBox (IG-I) versus printed modules (IG-II) and control group (CG) on teachers' knowledge, attitude, and self-efficacy

Outcome	df	F	Overall <i>p</i> -value	Partial Eta Squared	Group Comparison	Mean Difference (I–J)	Std. Error	Adjusted <i>p</i> -value	95% CI
Knowledge	4	11.78	<0.001	0.149	CG vs. IG1	−1.06	0.227	<0.001*	[−1.61, −0.51]
					CG vs. IG2	−0.60	0.225	0.026*	[−1.15, −0.05]
					IG1 vs. IG2	0.46	0.224	0.131	[−0.09, 1.00]
Attitude	3.660	5.630	<0.001	0.077	CG vs. IG1	−5.87	1.122	<0.001*	[−8.59, −3.15]
					CG vs. IG2	−2.92	1.116	0.030*	[−5.63, −0.22]
					IG1 vs. IG2	2.95	1.110	0.027*	[0.26, 5.64]
Self-Efficacy	3.719	7.251	<0.001	0.097	CG vs. IG1	−3.70	1.125	0.004*	[−6.42, −0.97]
					CG vs. IG2	−1.11	1.119	0.974	[−3.82, 1.61]
					IG1 vs. IG2	2.59	1.113	0.064	[−0.11, 5.29]

Repeated measure ANOVA was applied followed by pairwise comparisons using with Bonferroni correction (post-hoc test analysis) for multiple comparisons

* Level of significance was set at 0.05 (two-tailed)

while both online and printed based materials were comparably effective in improving preschool teachers' knowledge and self-efficacy, the online platform was significantly more effective in enhancing their attitudes towards the importance of promoting the energy balance related healthy behaviours.

At baseline, preschool teachers demonstrated a moderate level of knowledge in teaching healthy behaviours, consistent with previous studies reporting approximately 70% correct on items assessing their understanding of nutrition and physical activity (Habib et al., 2023; Katsagoni et al., 2019; Kupolati et al., 2015). Among the four healthy behaviours assessed, teachers demonstrated the lowest knowledge in healthy snacking, while showing the highest proficiency in water drinking and physical activity. This pattern aligns with previous findings indicating that, although teachers generally understand healthy eating principles, they often lack more specific knowledge, such as recommended daily nutrient intakes and appropriate portion sizes for fruits and vegetables (Rapson et al., 2021). Although the current study did not evaluate teachers' understanding of daily nutrient requirements, the majority of preschool teachers were less familiar with identifying food groups using tools like the Malaysian Healthy Plate (or known as #SukuSukuSeparuh or #QuarterQuarterHalf plate) and the Malaysian Food Pyramid, and also lacked knowledge regarding the appropriate timing and portion sizes for different food groups for preschoolers, similar to earlier findings (Sharma et al., 2013). Nonetheless, they demonstrated a good grasp of basic nutritional recommendations, such as the importance of consuming fibre-rich foods like fruits and vegetables.

Moreover, the participants in this study also demonstrated both a positive attitude and a high level of self-efficacy at baseline. Although nutrition knowledge is widely recognised as an important determinant of teachers' attitudes toward promoting healthy behaviours (Esdaile et al., 2024), this relationship is not always consistent. For

instance, Katsagoni et al. (2019) found that teachers' nutrition knowledge positively influenced their attitudes only at the pre-intervention stage, suggesting that knowledge alone may be insufficient to sustain attitudinal change. Without opportunities to apply what they know in practice, teachers may struggle to internalize the value of the content or face situational barriers that dampen their enthusiasm. Similarly, Shannon et al. (1981) reported weak associations between knowledge and attitudes before training, but stronger correlations across all attitudinal measures after a nutrition education intervention, including support for nutrition education in schools and commitment to teaching it in the classroom. This shift indicates that active engagement and experiential learning, rather than knowledge acquisition alone are essential for transforming cognitive understanding into lasting positive attitudes. Teachers' attitudes are more favourable when knowledge is reinforced through hands-on experience, peer discussion, and opportunities to observe positive changes in children's behaviours (Byrne et al., 2018; Hall et al., 2016; Metos et al., 2019).

Higher nutrition knowledge has also been consistently associated with greater self-efficacy in teaching health-related topics (Coccia et al., 2020; Fahlman et al., 2011). Teachers who understand the content are more confident in delivering it effectively. However, the relationship between knowledge and self-efficacy may evolve during training. Linnell et al. (2018) revealed that teachers' self-efficacy may decline after professional development sessions due to response shift bias, where teachers initially overestimate their confidence before realizing the complexity of the curriculum and instructional expectations. The lack of awareness among teachers of the depth of knowledge required or perceive challenges in implementation might have affected their attitudes, self-efficacy and motivation. Therefore, professional development programmes should provide content that is appropriately paced, relevant, and aligned with

teachers' real teaching contexts to sustain confidence and engagement. Online training platforms are particularly advantageous in this regard, as they allow teachers to learn at their own pace and exercise autonomy in selecting content most relevant to their teaching needs.

Moreover, eToyBox programme demonstrated significant improvements in all measures immediately after the intervention, with these effects sustained three months later. These findings align with existing studies, which shows that online learning programmes can effectively enhance nutrition knowledge, self-confidence, and attitudes in teaching healthy habits (Cohen et al., 1999; Katsagoni et al., 2019; O'Dea & Abraham, 2001). Traditionally, professional development programmes such as seminars, workshops, or collaborations with nutrition professionals have been proven effective in improving teachers' knowledge for delivering nutrition education (Esdaile et al., 2024; Otten et al., 2024). Our findings suggest that online training programmes that provide comprehensive asynchronous training for teachers and teaching resources, are equally effective in achieving these outcomes. With the modernization of pedagogical methods used in the classrooms, web-based training programs or digital teaching resources are particularly relevant given that teachers are increasingly relying on online information and digital games as teaching materials in their nutrition education efforts (Esdaile et al., 2024; Jones & Zidenberg-Cherr, 2015). The alignment between digital delivery of eToyBox and teachers' existing practices makes it a relatable and feasible choice that addresses their current needs and teaching preferences.

Despite similar knowledge trajectory patterns, within-group analysis revealed that only eToyBox produced a significant improvement from baseline, characterised by an immediate post-intervention increase that declined at three months, whereas printed modules showed no significant changes over time. This may reflect the distinct learning dynamics of each approach. Online learning management systems like eToyBox promote rapid knowledge acquisition through time-efficient, multimedia content (Mayer, 2005), whereas printed materials require longer, more focused engagement, potentially supporting deeper processing (Heng & Chu, 2023). While there are no direct comparisons exist between asynchronous printed and online learning knowledge retention, some evidence suggests online methods may yield slightly lower long-term retention due to how information is absorbed (Arnold et al., 2023). Nonetheless, the immediate and substantial knowledge gains associated with eToyBox highlight its value as a time-efficient educational tool.

Overall, eToyBox demonstrated more consistent and stronger effects than printed modules in enhancing teachers' attitudes, with significant improvements observed immediately post-intervention and at three months, compared with

improvement at follow-up only in the printed modules group. This delayed effect may be attributed to teachers needing more time to familiarize themselves with the printed materials and to envision how the suggested classroom activities could be implemented in their own settings. In contrast, eToyBox offered immediate access to ready-to-use teaching resources, including animated videos, classroom activities, infographic guides, and e-storybooks, which required less time for teachers to prepare, both in terms of understanding the content and planning how to integrate it into their classrooms. Consequently, access to user-friendly, easily implementable resources, and engaging multimedia materials provided by the eToyBox platform appeared to encourage more positive attitudes among teachers toward teaching healthy behaviours, as they felt better equipped and more confident to apply these strategies effectively in their classrooms (Aydin et al., 2022; Hall et al., 2016; Metos et al., 2019).

Strengths and Limitations

The study employed a robust and well-structured intervention framework. To the authors' knowledge, this is the first study to compare the effectiveness of a nutrition training programme by integrating a control group and two intervention groups: one utilizing asynchronous online learning (the eToyBox platform) and the other using asynchronous printed materials (the printed ToyBox modules). This design enabled a comparative evaluation of the digital eToyBox programme against its conventional counterpart, allowing for an in-depth analysis of their respective impacts on teachers' knowledge, attitudes, and self-efficacy in promoting healthy behaviours. This comprehensive approach provides valuable insights into the effectiveness of both intervention strategies within the context of early childhood education.

However, the findings may not be fully generalizable to preschools in other regions or countries with different cultural or educational contexts. Future research could expand to more diverse samples or international settings to evaluate the programme's broader applicability. Finally, the 3-month follow-up captured short-term changes but may not reflect long-term effects on teachers' knowledge, attitudes, or teaching practices. Longer follow-up studies are needed to assess the sustainability of these outcomes and the lasting impact on professional development.

Conclusion

The eToyBox programme was effective in improving teachers' attitudes towards promoting healthy eating and physical activity behaviours. While the online platform showed similar effects as printed modules on knowledge and

self-efficacy; however, this study underscores the critical importance of providing training and teaching resources, regardless of format to support teachers in promoting healthy behaviours. Knowledge and self-efficacy are closely intertwined, as self-efficacy stems from acquiring accurate and reliable content knowledge, effective pedagogical knowledge to communicate this information, and process knowledge to adapt and implement organizational policies within the classroom context (Bales et al., 2025). Although both intervention approaches had different trajectories, they proved equally effective in building teachers' competencies over time. Therefore, both tangible and digital resources are effective tools for enhancing teachers' self-perceived competence in delivering nutrition and physical activity lessons (Fahlman et al., 2011; Kaschalk-Woods et al., 2021; Nanayakkara et al., 2024; Stage et al., 2016).

To ensure these improvements are sustained and translated into practice, ongoing support from school administrators and educational authorities is important, including mentorship, time allocation for implementation, and policy reinforcement that encourages regular use of training outcomes. While the formats may differ in their duration and sustainability of impact, integrating these resources within supportive institutional frameworks can strengthen their effectiveness and promote long-term improvements in classroom nutrition and health education.

Study Implication and Future Recommendation

This study contributes to the less explored area of evaluating the effectiveness of online/web-based programmes in enhancing teachers' capabilities in health promotion. It also provides valuable insights for policymakers and curriculum developers aiming to strengthen school-based health promotion. The demonstrated effectiveness of both digital and printed resources suggests that flexible, multi-format approaches can be integrated into teacher training programmes to accommodate different learning preferences and school contexts. Given the demonstrated effectiveness of these interventions, the broad uptake and integration of the ToyBox Study Malaysia (TSM) framework and the eToyBox platform should be encouraged within Malaysian kindergartens. Building upon this implementation, future studies should expand this research by examining and comparing the impact of both the eToyBox and printed module approaches on children's health outcomes. This could include assessing anthropometric indicators such as BMI, as well as evaluating children's nutrition and physical activity knowledge, attitudes, and self-efficacy. Such research would provide valuable insights into how different teacher training methods ultimately influence children's health behaviours and overall well-being.

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Data Availability The datasets generated and/or analyzed during the current study are not publicly available due to data ownership agreements with participating researchers and respondents. Data are however available from the corresponding author (Poh BK at pbkoon@ukm.edu.my) upon reasonable request and with permission of the funder Newton Fund Impact Scheme (NFIS) (MRC: MR/V00607X/1) and the Malaysian Industry-Government Group for High Technology (MIGHT) (Project ID: 537125688).

Declarations

Ethics Approval and Consent to Participate Ethical approval for this study was obtained from the Universiti Kebangsaan Malaysia Research Ethics Committee (UKM PPI/111/8/JEP-2021-692). Permission to conduct the study was also obtained from the Community Development Department, Ministry of Rural and Regional Development, Malaysia. Informed consent was obtained from the preschool teachers using a form prepared in the Malay language before participating in the study. All methods were performed in accordance with the relevant guidelines and regulations.

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References

- Arnold, M., Goldschmitt, M., & Rigotti, T. (2023). Dealing with information overload: A comprehensive review. *Frontiers in Psychology*. <https://doi.org/10.3389/fpsyg.2023.1122200>
- Aydin, G., Margerison, C., Worsley, A., & Booth, A. (2022). Australian teachers' perceptions and experiences of food and nutrition education in primary schools: A qualitative study. *Australian Journal of Teacher Education*, 47(2), 61–75. <https://doi.org/10.14221/ajt.e.2022vv47n2.5>
- Bales, D. W., Cotwright, C. J., Lee, J. S., Celestin, N., Parrott, K., & Akin, J. (2025). Promoting healthy eating and physical activity in the early care and education setting as a strategy to improve teacher knowledge and self-efficacy. *Early Childhood Education Journal*. <https://doi.org/10.1007/s10643-025-01851-9>
- Barnes, C., McCrabb, S., Stacey, F., Nathan, N., Yoong, S. L., Grady, A., Sutherland, R., Hodder, R., Innes-Hughes, C., Davies, M.,

- & Wolfenden, L. (2021). Improving implementation of school-based healthy eating and physical activity policies, practices, and programs: A systematic review. *Translational Behavioral Medicine*, 11(7), 1365–1410. <https://doi.org/10.1093/tbm/ibab037>
- Blanca, M., Arnau, J., García-Castro, F., Alarcón, R., & Bono, R. (2023). Non-normal data in repeated measures ANOVA: Impact on type I error and power. *Psicothema*, 1(35), 21–29. <https://doi.org/10.7334/psicothema2022.292>
- Bruder, M. B., Mogro-Wilson, C., Stayton, V. D., & Dietrich, S. L. (2009). The national status of in-service professional development systems for early intervention and early childhood special education practitioners. *Infants & Young Children*, 22(1), 13–22.
- Byrne, J., Rietdijk, W., & Pickett, K. (2018). Teachers as health promoters: Factors that influence early career teachers to engage with health and wellbeing education. *Teaching and Teacher Education*, 69, 289–299. <https://doi.org/10.1016/j.tate.2017.10.020>
- Chatterjee, P., & Nirgude, A. (2024). A systematic review of school-based nutrition interventions for promoting healthy dietary practices and lifestyle among school children and adolescents. *Cureus*. <https://doi.org/10.7759/cureus.53127>
- Cheah, W. L., Poh, B. K., Ruzita, A. T., Lee, J. A. C., Koh, D., Reeves, S., Essau, C., Summerbell, C., Noor Hafizah, Y., Anchang, G. N. J., & Gibson, E. L. (2023). Process evaluation of a kindergarten-based intervention for obesity prevention in early childhood: The Toybox study Malaysia. *BMC Public Health*, 23(1), 1082. <https://doi.org/10.1186/s12889-023-16023-w>
- Chin, Y. S., Tee, E. S., Hashim, Z., Raqi, R. A., & Karim, N. A. (2020). Effectiveness of a nutrition education intervention for primary school children: the Healthy Kids programme, Malaysia. In *Malaysian Journal of Medicine and Health Sciences* (Vol. 16, Number SUPP6).
- Clarke, J., Fletcher, B., Lancashire, E., Pallan, M., & Adab, P. (2013). The views of stakeholders on the role of the primary school in preventing childhood obesity: A qualitative systematic review. *Obesity Reviews*, 14(12), 975–988. <https://doi.org/10.1111/obr.12058>
- Coccia, C., Tamargo, J., & Macchi, A. K. (2020). Effects of nutrition knowledge, personal health and self-efficacy on food-related teaching practices of elementary school pre-service teachers. *Health Education Journal*, 79(8), 974–986. <https://doi.org/10.1177/0017896920946061>
- Cohen, N. L., Laus, M. J., Volpe, S. L., Dun, A. T., Sternheim, M. M., & Cluff, C. (1999). Nutrition Science Online: Professional development of secondary school teachers using the internet. *Journal of Family and Consumer Sciences Education*, 17(1). <http://awsd.com/scripts/webbbs/>
- Cotton, W., Dudley, D., Peralta, L., & Werkhoven, T. (2020). The effect of teacher-delivered nutrition education programs on elementary-aged students: An updated systematic review and meta-analysis. *Preventive Medicine Reports*, 20, Article 101178. <https://doi.org/10.1016/j.pmedr.2020.101178>
- Cruchinho, P., López-Franco, M. D., Capelas, M. L., Almeida, S., Bennett, P. M., Miranda da Silva, M., Teixeira, G., Nunes, E., Lucas, P., & Gaspar, F. (2024). Translation, cross-cultural adaptation, and validation of measurement instruments: A practical guideline for novice researchers. *Journal of Multidisciplinary Healthcare*, Volume 17, 2701–2728. <https://doi.org/10.2147/JMDH.S419714>
- Esdaille, E. K., Wharton, L., Vidgen, H., & Gallegos, D. (2024). Teacher perspectives on the socio-ecological barriers and enablers to food and nutrition education in primary schools: A scoping review. *Public Health Nutrition*, 27(1), Article e175. <https://doi.org/10.1017/S1368980024001812>
- Fahlman, M., McCaughy, N., Martin, J., & Shen, B. (2011). Efficacy, intent to teach, and implementation of nutrition education increases after training for health educators. *American Journal of Health Education*. <https://doi.org/10.1080/19325037.2011.10599185>
- Gunasekaran, D. D., Abd Talib, R., Safii, N. S., Sharif, R., Ahmad, M., & Poh, B. K. (2018). Juara Sihat™: Study design of a school-based childhood obesity nutrition education programme in Kuala Lumpur, Malaysia. *Jurnal Sains Kesihatan Malaysia*, 16, 119–127. <https://doi.org/10.17576/jskm-2018-17>
- Habib, M. A., Alam, M. R., Rahman, T., Chowdhury, A. I., & Shill, L. C. (2023). Knowledge, attitudes, and practices (KAP) of nutrition among school teachers in Bangladesh: A cross-sectional study. *PLoS One*. <https://doi.org/10.1371/journal.pone.0283530>
- Hall, E., Chai, W., & Albrecht, J. A. (2016). A qualitative phenomenological exploration of teachers' experience with nutrition education. *American Journal of Health Education*, 47(3), 136–148. <https://doi.org/10.1080/19325037.2016.1157532>
- Halloran, K. M., Gorman, K., Fallon, M., & Tovar, A. (2018). Nutrition knowledge, attitudes, and fruit and vegetable intake as predictors of Head Start teachers' classroom mealtime behaviors. *Journal of Nutrition Education and Behavior*, 50(4), 340–348. <https://doi.org/10.1016/j.jneb.2017.10.015>
- Hammersley, M. L., Jones, R. A., & Okely, A. D. (2017). Time2b-Healthy – An online childhood obesity prevention program for preschool-aged children: A randomised controlled trial protocol. *Contemporary Clinical Trials*, 61, 73–80. <https://doi.org/10.1016/j.cct.2017.07.022>
- Heng, Q., & Chu, L. (2023). Self-efficacy, reflection, and resilience as predictors of work engagement among English teachers. *Frontiers in Psychology*. <https://doi.org/10.3389/fpsyg.2023.1160681>
- Jones, A. M., & Zidenberg-Cherr, S. (2015). Exploring nutrition education resources and barriers, and nutrition knowledge in teachers in California. *Journal of Nutrition Education and Behavior*, 47(2), 162–169. <https://doi.org/10.1016/j.jneb.2014.06.011>
- Kansra, A. R., Lakkunarajah, S., & Jay, M. S. (2021). Childhood and adolescent obesity: A review. *Frontiers in Pediatrics*. <https://doi.org/10.3389/fped.2020.581461>
- Karpouzis, F., Anastasiou, K., Lindberg, R., Walsh, A., Shah, S., & Ball, K. (2025). Effectiveness of school-based nutrition education programs that include environmental sustainability components, on fruit and vegetable consumption of 5–12 year old children: A systematic review. *Journal of Nutrition Education and Behavior*, 57(7), 627–642. <https://doi.org/10.1016/j.jneb.2025.02.008>
- Kaschalk-Woods, E., Fly, A. D., Foland, E. B., Dickinson, S. L., & Chen, X. (2021). Nutrition curriculum training and implementation improves teachers' self-efficacy, knowledge, and outcome expectations. *Journal of Nutrition Education and Behavior*, 53(2), 142–150. <https://doi.org/10.1016/j.jneb.2020.11.011>
- Katsagoni, C. N., Apostolou, A., Georgoulis, M., Psarra, G., Bathrellou, E., Filippou, C., Panagiotakos, D. B., & Sidossis, L. S. (2019). School teachers' nutrition knowledge, beliefs, and attitudes before and after an e-learning program. *Journal of Nutrition Education and Behavior*, 51(9), 1088–1098. <https://doi.org/10.1016/j.jneb.2019.07.001>
- Kupolati, M. D., Gericke, G. J., & MacIntyre, U. E. (2015). Teachers' perceptions of school nutrition education's influence on eating behaviours of learners in the Bronkhorstspuit district. *South African Journal of Education*. <https://doi.org/10.15700/saje.v35n2a1049>
- Linnell, J. D., Zidenberg-Cherr, S., Scherr, R. E., & Smith, M. H. (2018). Building the capacity of classroom teachers as extenders of nutrition education through extension: Evaluating a professional development model. *Journal of Human Sciences and Extension*. <https://doi.org/10.54718/lxjk7332>
- Manios, Y. (2012). The 'ToyBox-study' obesity prevention programme in early childhood: An introduction. *Obesity Reviews*. <https://doi.org/10.1111/j.1467-789X.2011.00977.x>

- Manios, Y., Androutsos, O., Katsarou, C., Iotova, V., Socha, P., Geyer, C., Moreno, L., Koletzko, B., & De Bourdeaudhuij, I. (2014). Designing and implementing a kindergarten-based, family-involved intervention to prevent obesity in early childhood: The ToyBox-study. *Obesity Reviews*, 15(S3), 5–13. <https://doi.org/10.1111/obr.12175>
- Mayer, R. E. (2005). Cognitive Theory of Multimedia Learning. *The Cambridge Handbook of Multimedia Learning* (pp. 31–48). Cambridge University Press. <https://doi.org/10.1017/CBO9780511816819.004>
- Md. Yusop, N. B., Mohd Shariff, Z., Hwu, T. T., Abd Talib, R., & Spurrier, N. (2018). The effectiveness of a stage-based lifestyle modification intervention for obese children. *BMC Public Health*. <https://doi.org/10.1186/s12889-018-5206-2>
- Metos, J. M., Sarnoff, K., & Jordan, K. C. (2019). Teachers' perceived and desired roles in nutrition education. *Journal of School Health*, 89(1), 68–76. <https://doi.org/10.1111/josh.12712>
- Mouratidou, T., Miguel, M. L., Androutsos, O., Manios, Y., De Bourdeaudhuij, I., Cardon, G., Kulaga, Z., Socha, P., Galcheva, S., Iotova, V., Payr, A., Koletzko, B., & Moreno, L. A. (2014). Tools, harmonization and standardization procedures of the impact and outcome evaluation indices obtained during a kindergarten-based, family-involved intervention to prevent obesity in early childhood: The ToyBox study. *Obesity Reviews*, 15(S3), 53–60. <https://doi.org/10.1111/obr.12183>
- Nanayakkara, J., Margerison, C., & Worsley, A. (2024). Ways to improve secondary school teachers' confidence in teaching food and nutrition subjects. *Education Inquiry*, 15(3), 407–422. <https://doi.org/10.1080/20004508.2022.2116865>
- O'Dea, J. A. (2016). Evaluation of nutrition and physical activity knowledge, attitudes, self efficacy and behaviors in teachers and children after implementation of the "Healthy Active Kids" online program in Australian elementary schools. *Health*, 08(04), 293–303. <https://doi.org/10.4236/health.2016.84031>
- O'Dea, J. A., & Abraham, S. (2001). Knowledge, beliefs, attitudes, and behaviors related to weight control, eating disorders, and body image in Australian trainee home economics and physical education teachers. *Journal of Nutrition Education*, 33(6), 332–340. [https://doi.org/10.1016/S1499-4046\(06\)60355-2](https://doi.org/10.1016/S1499-4046(06)60355-2)
- Otten, C., Nash, R., & Patterson, K. (2024). Professional development in health education for primary school teachers: A systematised review of the literature. *Professional Development in Education*, 50(5), 809–831. <https://doi.org/10.1080/19415257.2022.2038233>
- Perikkou, A., Kokkinou, E., Panagiotakos, D. B., & Yannakoulia, M. (2015). Teachers' readiness to implement nutrition education programs: Beliefs, attitudes, and barriers. *Journal of Research in Childhood Education*, 29(2), 202–211. <https://doi.org/10.1080/02568543.2015.1009202>
- Rapson, J. P., Conlon, C. A., & Ali, A. (2021). Early childhood education teachers' nutrition knowledge for 2-5-year-old children in childcare: A narrative review. *Journal of Food and Nutritional Health*, 2(1), 7–11. <https://doi.org/10.47275/2692-5222-110>
- Reeves, S., Poh, B. K., Essau, C., Summerbell, C., Cheah, W. L., Koh, D., Lee, J. A. C., Ruzita, A. T., & Gibson, E. L. (2018). ToyBox study Malaysia: Improving healthy energy balance and obesity-related behaviours among pre-schoolers in Malaysia. *Nutrition Bulletin*, 43(3), 290–295. <https://doi.org/10.1111/nbu.12340>
- Resor, J., Hegde, A. V., & Stage, V. C. (2021). Pre-service early childhood educators' perceived barriers and supports to nutrition education. *Journal of Early Childhood Teacher Education*, 42(4), 345–361. <https://doi.org/10.1080/10901027.2020.1740841>
- Shannon, B., Marbach, E. S., Graves, K., & Sims, L. S. (1981). Nutrition knowledge, attitudes, and teaching effectiveness of K-6 teachers. *Journal of Nutrition Education*, 13(4), 145–149. [https://doi.org/10.1016/S0022-3182\(81\)80168-9](https://doi.org/10.1016/S0022-3182(81)80168-9)
- Sharma, S., Dortch, K. S., Byrd-Williams, C., Truxillio, J. B., Rahman, G. A., Bonsu, P., & Hoelscher, D. (2013). Nutrition-related knowledge, attitudes, and dietary behaviors among Head Start teachers in Texas: A cross-sectional study. *Journal of the Academy of Nutrition and Dietetics*, 113(4), 558–562. <https://doi.org/10.1016/j.jand.2013.01.003>
- Sheridan, K. M., & Wen, X. (2021). Evaluation of an online early mathematics professional development program for early childhood teachers. *Early Education and Development*, 32(1), 98–112. <https://doi.org/10.1080/10409289.2020.1721402>
- Sigman-Grant, M., Byington, T. A., Lindsay, A. R., Lu, M., Mobley, A. R., Fitzgerald, N., & Hildebrand, D. (2014). Preschoolers can distinguish between healthy and unhealthy foods: The All 4 Kids study. *Journal of Nutrition Education and Behavior*, 46(2), 121–127. <https://doi.org/10.1016/j.jneb.2013.09.012>
- Sindi, A., Stanfield, J., & Sheikh, A. (2021). Technology in education: Attitudes towards using technology in nutrition education. *International Journal of Advanced Computer Science and Applications*. <https://doi.org/10.14569/IJACSA.2021.0120208>
- Snedecor, G. W., & Cochran, W. G. (1989). *Statistical Methods* (8th Edition). Iowa State University Press.
- Snelling, A. M., Ernst, J., & Belson, S. I. (2013). Teachers as role models in solving childhood obesity. *Journal of Pediatric Biochemistry*, 3(1), 55–60. <https://doi.org/10.3233/JPB-120074>
- Stage, C., Roseno, A., Hodges, C. D., Hovland, J., Diaz, S., & Duffrin, M. W. (2016). Implementation of a food-based science curriculum improves fourth-grade educators' self-efficacy for teaching nutrition. *American Journal of Health Education*, 47(3), 155–162. <https://doi.org/10.1080/19325037.2016.1157534>
- UNICEF. (2019). *The State of the World's Children 2019: Children, Food and Nutrition. Growing Well in a Changing World*.
- World Health Organization. (2024, March 1). *Obesity and overweight*. World Health Organization. <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>

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