Media of Health Research

Vol. 4 No. 3, August 2026, pages: 823-835

e-ISSN 2987-7784

DOI: https://doi.org/10.70716/mohr.v4i3.636

Modeling Psychosocial Pathways of Adolescent Fruit and Vegetable Intake Through Nutrition Literacy and Digital Gamification in School Settings: A Theory-Based Quasi-Experimental Study

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Article History

Manuscript submitted:
07 June 2026
Manuscript revised:
12 August 2026
Accepted for publication:
13 August 2026
Manuscript published:
15 August 2026

Keywords

adolescents;
digital gamification;
fruit and vegetable intake;
nutrition literacy;
psychosocial pathways.

Abstract

Adolescent fruit and vegetable (FV) intake remains below recommended levels. In Indonesia, only 2.3% of adolescents aged 10–14 years met recommended intake in the 2023 Indonesian Health Survey. Low nutrition literacy and limited psychosocial support contribute to this problem, while school interventions rarely integrate digital gamification with behaviour-change theories. This study develops a conceptual model linking digital gamification, nutrition literacy, and psychosocial pathways to adolescent FV intake and provides empirical evidence through a school-based intervention. Grounded in the ANIMOE health-promotion model and integrating the Transtheoretical Model, PRECEDE-PROCEED framework, and Social Cognitive Theory, this mixed-method quasi-experimental pretest-posttest control-group study involved 103 junior high school students in Jambi City, Indonesia (intervention n=52; control n=51). FV intake was assessed using a Food Frequency Questionnaire. Within-group changes were analysed using the Wilcoxon signed-rank test ($p<0.05$). The intervention significantly increased nutrition knowledge (13.62 to 18.88), attitude (89.03 to 110.42), and FV intake (3.00 to 4.91 servings/day; all $p<0.05$), while controls showed no significant changes. Behavioural intention progressed across TTM stages, with the modal stage shifting from contemplation to action. Parental support and teacher reinforcement also improved. The theory-based gamified intervention improved cognitive, motivational, and behavioural determinants of adolescent FV intake. The proposed model provides a framework for structural validation, while schools represent settings for nutrition promotion.

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How to Cite: Handayani, I., Siregar, I. S., & Wahyuni, S. (2026). Modeling Psychosocial Pathways of Adolescent Fruit and Vegetable Intake Through Nutrition Literacy and Digital Gamification in School Settings: A Theory-Based Quasi-Experimental Study. *Media of Health Research, 4*(3), 823-835. https://doi.org/10.70716/mohr.v4i3.636

Introduction

Adequate consumption of fruits and vegetables is a foundation of a balanced diet and a recognised protective factor against the global burden of non-communicable disease. The World Health Organization recommends a minimum intake of 400 grams of fruits and vegetables per day, an amount associated with reduced risk of cardiovascular disease, certain cancers, type 2 diabetes, and obesity (WHO, 2020). Pooled epidemiological evidence shows an inverse dose-response relationship between fruit and vegetable intake and all-cause and cause-specific mortality, with the largest risk reductions occurring as populations move from very low to moderate intake (Aune et al., 2017). Despite this evidence, intake remains inadequate across most regions of the world, and adolescents are among the most consistently underperforming age groups.

Global school-based survey data indicate that most adolescents fail to meet recommended intake levels (Beal et al., 2019). In the United States, only 32% of children and adolescents met fruit recommendations and 17% met vegetable recommendations between 2015 and 2018 (Wambogo et al., 2020). Among Iranian high-school adolescents, more than seven in ten consumed fruit fewer than twice daily (Ziaei et al., 2020), and similar shortfalls have been documented in South Asian and sub-Saharan African settings (Singh et al., 2019; Seidu et al., 2021). In Indonesia, the pattern is more severe: the 2023 Indonesian Health Survey found that only 2.3% of the population, and a comparably small fraction of adolescents aged 10-14 years, met the recommended intake, with adolescents instead favouring fast foods and sugar-sweetened beverages (SKI, 2023). A systematic review of Indonesian adolescent eating behaviour reached the same conclusion, identifying low fruit and vegetable intake as a pervasive nutritional problem (Rachmi et al., 2020). Because adolescence is the developmental window in which lifelong dietary habits are consolidated, this shortfall carries consequences that extend well beyond the immediate growth period.

Inadequate intake is attributed, in part, to limited nutrition knowledge and, more broadly, to low nutrition literacy - the capacity to obtain, process, understand, and apply nutrition information when making dietary decisions (Velardo, 2015; Krause et al., 2018). Nutrition literacy operates not in isolation but through a network of psychosocial mechanisms, including attitude, self-efficacy, and behavioural intention, and is itself reinforced or constrained by the social environment of peers, parents, and teachers (Fleary et al., 2020; Cho & Kim, 2018). Conventional health-promotion campaigns in Indonesia, such as the GERMAS healthy-living movement and the "My Healthy Plate" guideline, have relied mainly on didactic delivery and static print media; their limited effect on adolescent behaviour signals the need for strategies that are more interactive, developmentally appropriate, and theory-driven.

Digital media and gamification have emerged as promising responses. Gamification - the use of game design elements such as points, challenges, feedback, rewards, and progression in non-game contexts (Deterding et al., 2011) - improves motivation, engagement, and learning outcomes across educational and health domains (Hamari et al., 2014; Sailer & Homner, 2020). In nutrition specifically, game-based and serious-game interventions have improved knowledge, attitudes, and dietary practice among children and adolescents (Thompson et al., 2015; Ogunsile & Ogundele, 2016; Baranowski et al., 2003), and digital health applications have been linked to increased fruit and vegetable consumption (Kim et al., 2020). The argument advanced here is that school-based educational games can strengthen the proximal drivers of healthy eating by raising motivation, sustaining engagement, increasing behavioural intention, and translating intention into healthy eating behaviour.

Three gaps remain. First, most game-based nutrition interventions have been evaluated atheoretically, treating the game as a delivery medium rather than as a mechanism embedded within a behaviour-change architecture (Riebl et al., 2015). Second, where behaviour-change theory has been applied, single frameworks have typically been used in isolation, although the Transtheoretical

Model, the PRECEDE-PROCEED framework, and Social Cognitive Theory each address a distinct and complementary segment of the change process. Third, few studies have specified the psychosocial pathways - the sequence of mediating constructs - through which a gamified intervention is expected to influence intake; intervention effects are usually reported as a single before-and-after contrast without articulating the underlying mechanism. This study addresses these gaps by drawing on the ANIMOE health-promotion model, a school-based model developed through design-and-development research that integrates the Transtheoretical Model and the PRECEDE-PROCEED framework to improve adolescent fruit and vegetable consumption (Handayani et al., 2018; Wijayanti et al., 2021).

The contribution of this study is its integration of three elements that prior research has treated separately: nutrition literacy as a higher-order competency, digital gamification as a theory-anchored delivery mechanism, and a fully specified set of psychosocial pathways as the mediating architecture linking the two to fruit and vegetable intake. Rather than asking only whether a gamified intervention works, the study specifies how it is expected to work and tests, through a school-based quasi-experimental evaluation, whether the intervention improves the constructs the model identifies as the drivers of intake. Accordingly, the objectives are: (1) to develop a conceptual model linking digital gamification, nutrition literacy, and psychosocial pathways to adolescent fruit and vegetable intake; (2) to provide initial empirical evidence on the model's constructs through a theory-based, school-based quasi-experimental evaluation of the ANIMOE intervention; and (3) to derive theoretical and policy implications for gamified nutrition promotion in school settings and to set out an agenda for the full structural validation of the model.

Materials and Methods

Research Design

This study used a mixed-method, school-based design with two components. The principal component was a quasi-experimental pretest-posttest control-group evaluation of a gamified nutrition intervention. A supporting qualitative component used interviews and focus group discussions to contextualise the quantitative findings. The intervention - the ANIMOE health-promotion model (Analysis, Implementation, Monitoring, Evaluation) - was developed through design-and-development research following the ADDIE procedure and integrates the Transtheoretical Model and the PRECEDE-PROCEED framework. The conceptual model and its twelve hypotheses (Section 3) are advanced as a framework for subsequent structural validation; the quasi-experimental design reported here tests whether the gamified intervention significantly improved the cognitive, motivational, social, and behavioural constructs the model identifies as the determinants of intake.

4.2 Population and Sample

The study population comprised junior high school students in Jambi City, Indonesia. Two state junior high schools with comparable baseline characteristics were selected. The intervention group was drawn from SMP Negeri 6 Jambi City (n=52) and the control group from SMP Negeri 11 Jambi City (n=51), giving a total analytic sample of 103 students. Within each school, participants were drawn from two intact classes - a grade 7 and a grade 8 class - and were selected using a randomisation procedure. An additional school, SMP Negeri 7 Jambi City, was used during the development phase for one-to-one and small-group trials of the intervention prototype. The comparability of the intervention and control groups across age, sex, parental education, parental occupation, and family income was verified at baseline, allowing post-intervention differences to be attributed to the intervention rather than to group composition.

4.3 Sampling Technique

A purposive, school-level strategy was used to select the two comparable schools, after which intact classes were enrolled and individual participants drawn at random within those classes. Eligible participants were early-adolescent students, predominantly aged 12-13 years, enrolled in the selected classes, present on all measurement occasions, and whose parents provided informed consent. Students absent during one or more intervention cycles were excluded from the corresponding analyses.

4.4 Variables and Instruments

Data were collected with a multi-instrument battery. The variables measured empirically in the quasi-experimental component were:

1. Nutrition knowledge, assessed with a multiple-choice test covering balanced nutrition, recommended intake, the health benefits of fruits and vegetables, and the consequences of inadequate intake; this measure represents the functional component of nutrition literacy.
2. Attitude toward fruit and vegetable consumption, measured with a Likert-scale questionnaire.
3. Behavioural intention, operationalised through the TTM stage-of-change questionnaire, which locates each adolescent on the precontemplation-to-maintenance continuum.
4. Parental support and teacher reinforcement, measured with Likert-scale subscales of the reinforcing-factor questionnaire, together with the perceived availability of fruits and vegetables at home and school.
5. Fruit and vegetable intake (FVI), measured with a semi-quantitative Food Frequency Questionnaire (FFQ) recording the frequency and number of servings consumed, expressed as average servings per day.

The remaining constructs of the conceptual model - the interactive and critical dimensions of nutrition literacy, self-efficacy, and peer influence - are specified within the model and are recommended for direct measurement in the structural validation study proposed in Section 8.

Validity and Reliability

The intervention model and all instruments underwent a three-round expert-validation process involving specialists in public health nutrition, health education and behavioural science, and instructional media, establishing content validity. The gamified prototype was further refined through one-to-one and small-group trials before field implementation. Instrument reliability was examined through pilot testing prior to the main study, with internal consistency assessed against a Cronbach's alpha threshold of 0.70; instruments adapted from previously validated research retained their original items. The FFQ was a semi-quantitative instrument validated for the measurement of habitual fruit and vegetable intake in this population.

Ethical Clearance

This study was conducted in accordance with established ethical principles for research involving human participants. Ethical approval was obtained from the Health Research Ethics Committee of Universitas Bunda Thamrin, Medan, Indonesia (Approval No. 020/KEPK-UBT/EC/VI/2026). Permission to conduct the study was also granted by the participating schools and the relevant educational authorities.

Data Analysis

Descriptive statistics summarised participant characteristics and the distribution of study variables. The distributional assumptions of the outcome variables were examined, and because several variables departed from normality, non-parametric tests were used. Within-group pretest-posttest differences in knowledge, attitude, and intake were analysed with the Wilcoxon signed-rank test, with statistical significance set at $p<0.05$; the parallel control group, which received conventional

instruction only, provided the comparison condition against which intervention-group change was interpreted. Categorical shifts - the TTM stage distribution and the reinforcing-factor categories - were summarised as frequencies and percentages. Qualitative data from interviews and focus group discussions with students and teachers were analysed thematically and triangulated with the quantitative results. The twelve hypothesised pathways of the conceptual model were not tested inferentially in this study; their formal estimation through partial least squares structural equation modelling (PLS-SEM), including assessment of construct reliability, convergent validity, discriminant validity via the heterotrait-monotrait ratio, and the significance of direct and indirect effects, is set out as the recommended next step (Hair et al., 2022; Henseler et al., 2015).

Results and Discussion

Demographic Characteristics

The analytic sample comprised 103 early-adolescent students: 52 in the intervention group and 51 in the control group. The two groups were comparable at baseline in age, sex, parental education, parental occupation, and family income, supporting the internal validity of between-group comparisons. Most participants were aged 12-13 years, consistent with the early-adolescent stage targeted by the model. In the intervention group the majority were female (59.6%), whereas the control group was more evenly divided; in both groups the modal age was 13 years (46.1% and 47.2%, respectively). Most families in both groups reported a monthly income in the IDR 2,500,000-5,000,000 range, and the majority of mothers were not in paid employment. Table 1 summarises the demographic profile.

Table 1. Demographic characteristics of participants

Characteristic	Intervention (n=52)		Control (n=51)	
	n	%	n	%
Sex				
Male	21	40.4	26	50.9
Female	31	59.6	25	49.1
Age (years)				
11	3	5.7	4	7.8
12	22	42.3	19	37.2
13	24	46.1	24	47.2
14	3	5.7	4	7.8
Father's education (modal category)				
Intervention: completed junior secondary	32	61.5		
Control: completed senior secondary			24	47.0

Mother's education (modal category)				
Intervention: completed senior secondary	26	50.0		
Control: completed diploma/bachelor			25	49.1
Mother not in paid employment	34	65.4	27	52.9
Family income IDR 2.5-5.0 million/month	17	32.7	22	43.1

Note. Source: ANIMOE study, Jambi City, Indonesia. For parental education and income, the modal category of each group is shown; the full distributions are available in the primary dataset. Baseline characteristics did not differ meaningfully between groups.

Effect of the Gamified Intervention

The gamified ANIMOE intervention produced significant improvements in the intervention group across all measured outcomes, whereas the control group, which received only conventional instruction, showed no significant change. Nutrition knowledge in the intervention group rose from a mean of 13.62 to 18.88 ($p<0.001$), and the proportion of students in the good knowledge category increased from 25.0% to 90.4%. Attitude scores rose from 89.03 to 110.42 ($p=0.001$). Behavioural intention, expressed as the TTM stage distribution, shifted: before the intervention the largest group of students was at the contemplation stage (40.4%), whereas afterwards the largest group had advanced to the action stage (57.7%). Intake behaviour improved correspondingly, with mean vegetable servings rising from 1.48 to 2.40 ($p<0.001$), mean fruit servings from 1.48 to 2.50 ($p<0.001$), and combined fruit and vegetable intake from 3.00 to 4.91 servings per day ($p<0.001$). Reinforcing factors also strengthened in the intervention group: the proportion of students reporting high parental support rose from 63.5% to 82.7% and high teacher reinforcement from 50.0% to 71.2%. None of the corresponding changes in the control group reached statistical significance. Table 2 summarises these findings.

Table 2. Pretest-posttest outcomes by group

Outcome	**Intervention (n=52)**			**Control (n=51)**		
	Pre	**Post**	**p**	**Pre**	**Post**	**p**
Knowledge (mean score)	13.62	18.88	0.000	13.03	13.53	0.257
Attitude (mean score)	89.03	110.42	0.001	88.96	88.54	0.420
Vegetable intake (servings/day)	1.48	2.40	0.000	1.43	1.68	0.505
Fruit intake (servings/day)	1.48	2.50	0.000	1.82	1.64	0.082

Combined FV intake (servings/day)	3.00	4.91	0.000	3.25	4.50	0.188

Note. p-values from Wilcoxon signed-rank tests; $p<0.05$ indicates a significant within-group change. Source: ANIMOE study.

Preliminary Evidence for the Proposed Model

The quasi-experimental findings provide initial empirical support for the conceptual model, although they do not constitute a formal test of its directional pathways. The intervention moved every measured construct of the model in the predicted direction and did so coherently: the gamified intervention was accompanied by a marked gain in nutrition knowledge, the functional indicator of nutrition literacy; this co-occurred with a significant improvement in attitude; behavioural intention advanced along the TTM continuum from contemplation toward action; and fruit and vegetable intake increased significantly, while the reinforcing factors of parental support and teacher reinforcement strengthened in parallel. The absence of comparable change in the control group indicates that this pattern is attributable to the intervention rather than to maturation or secular trends. Table 3 maps each segment of the proposed model onto the corresponding empirical evidence. These results justify the model as a coherent framework and motivate the structural validation set out in Section 8, in which the directional and mediating relationships can be estimated formally.

Table 3. Alignment between the proposed model and the quasi-experimental evidence

Model segment	Empirical indicator	Observed change (intervention vs. control)	Related hypotheses
Digital gamification → nutrition literacy	Nutrition knowledge test	Significant rise in intervention (13.62→18.88; good-category 25.0%→90.4%); no significant change in control	H1
Nutrition literacy → attitude	Attitude questionnaire	Significant rise (89.03→110.42, p=0.001); control unchanged	H3
Psychosocial factors → behavioural intention	TTM stage of change	Modal stage advanced from contemplation (40.4%) to action (57.7%); control stable	H5, H6, H11
Behavioural intention → FV intake	FFQ (servings/day)	Combined intake rose 3.00→4.91 (p<0.001); no significant change in control	H7
Reinforcing factors → FV intake	Parental and teacher support scales	High parental support 63.5%→82.7%; high teacher reinforcement 50.0%→71.2%	H9, H10

Note. The quasi-experimental design supports the intervention's effect on the model's constructs; it does not test the inter-construct paths, whose formal estimation requires structural equation modelling. Hypotheses H2, H4, H8, and H12 involve constructs (self-efficacy, interactive/critical nutrition literacy) not measured directly in this study and remain to be tested in the proposed validation.

Discussion

The findings support the central proposition of the conceptual model: a gamified, theory-based intervention improves adolescent fruit and vegetable intake by acting on an ordered set of cognitive, affective, and social determinants rather than on intake in isolation. The discussion interprets the quasi-experimental evidence in relation to the literature and the integrated framework.

Gamification and Nutrition Literacy

The intervention produced a substantial gain in nutrition knowledge, the functional component of nutrition literacy, with the mean score rising from 13.62 to 18.88 and the proportion of students in the good knowledge category increasing from one quarter to nine in ten, while the control group remained unchanged. This is consistent with evidence that game-based and serious-game interventions improve nutrition knowledge among adolescents (Thompson et al., 2015; Ogunsile & Ogundele, 2016; Wongprawmas et al., 2023). The mechanism is interpretable through the engagement properties of gamification: challenge, immediate feedback, reward, and progression sustain attention and convert passive exposure into active processing (Deterding et al., 2011; Sailer & Homner, 2020). Framing the outcome as nutrition literacy rather than knowledge alone matters, because earlier school-based game interventions that raised knowledge without building applied literacy often failed to change behaviour (Wijayanti et al., 2021). The interactive and critical dimensions of literacy were not measured here and should be assessed directly in future work.

Psychosocial Pathways and Adolescent Behaviour Change

The model positions nutrition literacy as the gateway to an internal psychosocial pathway in which literacy strengthens attitude and self-efficacy, which raise behavioural intention, the strongest proximal driver of intake. The quasi-experimental data are consistent with this sequence. Attitude improved significantly in the intervention group, and behavioural intention advanced along the Transtheoretical Model continuum, with the modal stage moving from contemplation to action - a shift that mirrors the path from the psychosocial constructs to intention and is consistent with the stage logic of the model (Prochaska & Velicer, 1997). Self-efficacy was not measured directly in this evaluation; the observed attitudinal and intention gains are nonetheless consistent with the social-cognitive pathway, in which efficacy beliefs mediate the translation of competence into action (Bandura, 1986, 2004), and they reinforce the case for measuring self-efficacy explicitly in the structural validation study.

The Role of the School and Social Support

Parental support and teacher reinforcement strengthened markedly in the intervention group, the share of students reporting high parental support rising from 63.5% to 82.7% and high teacher reinforcement from 50.0% to 71.2%. This is consistent with evidence that parental modelling and provision of fruits and vegetables are among the most reliable correlates of adolescent intake (Parks et al., 2018; Ghazy Elsayed et al., 2020) and confirms the status of these factors as reinforcing determinants in the PRECEDE-PROCEED framework (Green & Kreuter, 2005). The pattern indicates why the school is a strategic setting: it is the one environment in which the gamified intervention, the teacher reinforcement structure, and a route to parental engagement can be activated together.

Relevance to TTM and the PRECEDE-PROCEED Framework

The study illustrates the value of integrating, rather than choosing between, behaviour-change frameworks. The Transtheoretical Model accounts for the temporal progression captured by behavioural intention and for the stage-matched logic of the intervention; the PRECEDE-PROCEED framework supplies the diagnosis that separates predisposing factors (knowledge, attitude), enabling factors (nutrition literacy), and reinforcing factors (parental, teacher, and peer support); and Social

Cognitive Theory supplies the reciprocal-determinism logic that positions self-efficacy and the social environment as co-determinants of behaviour. The coherent, simultaneous improvement of knowledge, attitude, intention, intake, and reinforcing support is the pattern this synthesis predicts, and it advances the ANIMOE model from a description of intervention phases toward an explanatory account of how those phases produce change.

Implications for School Health Policy

The findings carry practical implications for healthy-school policy. Because the intervention acts through nutrition literacy and psychosocial readiness, isolated knowledge-transfer campaigns are unlikely to be sufficient; nutrition promotion should be designed to build applied literacy and to engage the full psychosocial pathway. The parallel strengthening of reinforcing factors implies that school nutrition policy should formally incorporate parental engagement and teacher capacity-building rather than treating them as optional adjuncts. Embedding a model such as ANIMOE within relevant subjects, such as science and physical education, and within the School Health Unit programme would provide a structured and sustainable delivery channel consistent with existing curricular structures.

Theoretical and Practical Contributions

Theoretically, the study contributes a synthesised, testable model that integrates three established frameworks and positions nutrition literacy as the pivotal enabling mediator between a gamified environmental input and adolescent behaviour - a specification absent from prior atheoretical or single-theory game-based studies. Practically, it provides school health practitioners with a validated gamified intervention and a pathway model that identifies where the intervention exerts its effect, enabling the design of programmes that deliberately target literacy, attitude, intention, and the reinforcing environment.

Limitations

Several limitations should be acknowledged. The directional and mediating pathways of the conceptual model were not tested inferentially; the quasi-experimental design establishes that the intervention improved the model's constructs but cannot estimate the strength of the inter-construct relationships, which requires structural equation modelling. Self-efficacy, the interactive and critical dimensions of nutrition literacy, and peer influence were not measured directly. The study was conducted in two schools in a single city, which constrains generalisability; behaviour was measured up to the action stage but not the maintenance stage, leaving the durability of change untested; and the Food Frequency Questionnaire, although validated, is subject to self-report bias. These limitations define the agenda for the validation study recommended below.

Conclusion

This study developed a conceptual model linking digital gamification, nutrition literacy, and psychosocial pathways to adolescent fruit and vegetable intake, and evaluated a theory-based gamified intervention in junior high school settings. Three conclusions follow. First, a gamified intervention is an effective means of strengthening nutrition literacy: nutrition knowledge rose substantially and significantly in the intervention group, with no comparable change in the control group. Second, the intervention improved the psychosocial determinants of consumption in a coherent pattern - attitude improved, behavioural intention advanced from contemplation to action, fruit and vegetable intake increased significantly, and parental support and teacher reinforcement strengthened - which is consistent with the proposed model, in which gamification influences intake indirectly through nutrition literacy and psychosocial readiness. Third, the school is a strategic setting for adolescent health promotion, because it is the single environment in which a gamified

intervention, teacher reinforcement, and a route to parental engagement can be activated together. The study advances the ANIMOE model from a staged intervention procedure toward an explanatory pathway framework and demonstrates the value of integrating the Transtheoretical Model, the PRECEDE-PROCEED framework, and Social Cognitive Theory in gamified school nutrition promotion. The directional pathways of the model now require formal structural validation.

Recommendations

Based on these conclusions, future research and practice should focus on four priorities. First, the conceptual model should be structurally validated using a larger and multi-site sample through partial least squares structural equation modelling. All proposed constructs, including self-efficacy, peer influence, and the interactive and critical dimensions of nutrition literacy, should be measured directly. Model evaluation should include construct reliability, convergent validity with composite reliability above 0.70 and average variance extracted above 0.50, discriminant validity using the heterotrait-monotrait ratio below 0.85, and the significance of direct and indirect effects (Hair et al., 2022; Henseler et al., 2015). Second, schools and education authorities should integrate digital game-based learning into the school health curriculum. Gamified nutrition-literacy modules, such as the ANIMOE model, can be incorporated into relevant subjects and School Health Unit programmes to support continuous nutrition education. Third, school nutrition programmes should strengthen family and teacher involvement. Parental engagement activities and teacher capacity-building should accompany student-focused interventions to reinforce healthy eating behaviours across the school and home environments. Fourth, future studies should use longitudinal designs to examine whether behavioural changes are maintained beyond the action stage. Researchers should combine Food Frequency Questionnaires with multiple-pass 24-hour dietary recalls to improve dietary assessment and causal inference. Comparative trials between face-to-face and fully digital gamified interventions are also recommended to identify the most effective delivery approach.

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