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The Effectiveness of Integrating Scientific Nutrition Education into Physical Education on Nutrition Knowledge and Healthy Behavior Intentions among Junior High School Students

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Abstract: This study aims to analyze the effectiveness of an experimental approach integrating scientific nutrition education into physical education learning in improving nutrition knowledge and healthy behavior intentions among junior high school students. The study used a quasi-experimental design with a pretest–posttest control group model, involving 40 seventh-grade students at Beijing No. 3 Middle School (Xicheng District, Beijing, China) who were divided into an experimental group and a control group through class-based randomization. The experimental group followed an integrated "physical training + scientific nutrition" curriculum for 10 weeks, while the control group received conventional physical education. The research instruments included nutrition knowledge tests and healthy behavior intention questionnaires that met the criteria for validity and reliability. Data analysis was performed using Multivariate Analysis of Covariance (MANCOVA) as the main analysis, followed by univariate ANCOVA, to control for differences in students' initial abilities. The results of the multivariate analysis of covariance (MANCOVA) indicated a significant multivariate effect of the teaching mode on students' nutrition knowledge and healthy behavior intention after controlling for pretest scores (Wilks' $\Lambda = 0.338$, $F = 34.21$, $p < 0.001$). This finding provides quantitative evidence that the integrated physical training and scientific nutrition learning approach significantly improved students' learning outcomes compared to the conventional physical education model. These findings indicate that integrating scientific nutrition concepts into authentic physical training experiences can build strong links between cognitive understanding, physical experience, and health behavior reflection. This study concludes that the integration of scientific nutrition education based on educational technology is an effective and strategic approach to improving health literacy and encouraging sustainable healthy behavior change among junior high school students.

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Introduction

Physical education is a fundamental component in the junior high school education system because it plays a direct role in shaping students' physical fitness, health literacy, and healthy lifestyle behaviors. The quality of physical education learning determines the school's ability to prepare a generation that is not only physically active but also capable of making health decisions based on scientific knowledge, an increasingly urgent demand amid rising issues of nutritional imbalance, declining fitness, and the risk of non-communicable diseases among adolescents (Wang et al., 2025). Although various curriculum policies have emphasized a holistic and health-oriented approach to physical education, learning practices in schools have not fully reflected these demands. This urgency is also reinforced by China's national education policy, particularly the "Double Reduction" policy and national initiatives aimed at strengthening youth physical fitness, which encourage schools to promote balanced learning environments that integrate physical activity, health literacy and students' overall well-being.

One of the main issues in physical education lies in the contradiction between the orientation of physical activity and the development of science-based health literacy. The evaluation of physical education is still dominated by measurements of physical performance and fitness achievements, while aspects of nutritional understanding and health decision-making are not systematically integrated (Regmi et al., 2024; Watkins et al., 2024). This situation has given rise to the phenomenon of "physically active but low health literacy," where students are able to participate in exercises but do not understand the scientific rationale behind nutritional needs, body recovery, and health risk prevention. Several studies indicate a gap between students' involvement in physical activities and their ability to apply health knowledge in daily life, particularly regarding diet and energy management (Irab et al., 2024; Yetkin, 2025). On the other hand, nutrition education in schools is often presented separately, is theoretical in nature, and is not directly linked to students' physical experiences, thus failing to establish a connection between knowledge and practice (Patimah, 2023). Such an approach to learning tends to result in superficial understanding and makes it difficult to encourage sustainable behavioral change. Additionally, physical education learning also faces the dilemma of formalization, where the integration of scientific content is only symbolic without empirically tested instructional design (Perry et al., 2025; Tafuri et al., 2025). As a result, students may remember nutrition concepts separately but are unable to use them to independently design healthy lifestyles. This condition emphasizes the need for an experimental approach that can bridge the gap between physical activity, scientific nutrition knowledge, and the transformation of students' health behavior (Oliveira, 2022; Pierre et al., 2021).

In practice, the integration of educational technology may involve the use of nutrition-tracking applications synchronized with students' physical exercise intensity, enabling learners to monitor calorie intake, energy expenditure, hydration levels, and recovery patterns. Such technology allows students to analyze the relationship between diet and physical performance in real time, transforming abstract nutrition concepts into experiential learning that supports reflective decision-making and the development of sustainable, healthy behaviors. The use of digital media, such as exercise videos, motion animations, or multimedia presentations, generally stops at a demonstrative function and has not been meaningfully integrated into the problem-solving and health decision-making-based learning process (Mancin et al., 2025; Wardani et al., 2021). Students are rarely facilitated to use technology as a tool to explore the relationship between physical activity, energy needs, and nutritional intake, so learning has not been able to foster procedural and reflective understanding. The literature shows that without the right pedagogical approach, technology integration does not necessarily improve the quality of learning or behavioral change (Amoore et al., 2023; Coppoolse et al., 2020). A critical gap in physical education today lies in students' weak investigative understanding of the scientific mechanisms behind physical exercise and nutrition. Many students simply follow exercise instructions and dietary recommendations normatively without understanding the rationale, influencing variables, or health consequences. This pattern results in students who are procedurally compliant but not adaptive in independently designing or evaluating healthy behaviors. In the context of 21st-century health literacy demands, physical education requires an integrative learning model

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that explicitly develops students' procedural understanding, critical reasoning, and reflective abilities so that they are able to construct evidence-based health decisions, rather than simply following instructions (Liu, 2025; Putra et al., 2022).

Although the integration of nutrition education into physical education learning is increasingly recommended as an innovative approach to improve students' health literacy, existing implementations still show fundamental pedagogical weaknesses. Many integration practices merely add nutrition material as supplementary information or short lectures, without an instructional framework that systematically links nutrition knowledge, physical activity experiences, and healthy behavior formation (Farel, 2024; Syahroni, 2020; Zulfikhar et al., 2024). In practice, educational technology components are often reduced to presentation media or supporting videos, which help convey information but do not guide students through reflective processes such as energy needs analysis, meal planning, body response evaluation, and health strategy adjustment (Harahap et al., 2025). Furthermore, previous research tends to treat physical education learning outcomes homogeneously, with a limited focus on physical fitness, while cognitive and affective domains such as nutritional knowledge, healthy behavior intentions, and cross-context knowledge transfer receive less empirical attention (Ayuni et al., 2024; Perez-garcia et al., 2026). In the context of junior high school education, these limitations are exacerbated by a tradition of learning oriented toward fitness tests and rigid exercise routines, leaving very little room for independent inquiry and student health decision-making (aya, 2025). In response to this gap, in this model, educational technology functions as a learning support system that connects nutritional knowledge, physical exercise experience, and behavioral reflection. Digital tools such as nutrition-tracking applications and interactive micro-learning platforms allow students to relate dietary intake to exercise intensity and physical performance, thereby transforming nutrition concepts into an integrated, measurable, and meaningful learning process.

Research Method

This study used a quasi-experimental design with a pretest–posttest control group model, which was chosen to test the effectiveness of integrating scientific nutrition education into physical education learning in the context of junior high schools (Mancin et al., 2025). This design allows for a direct comparison between the experimental group, which received the integrated "physical training and scientific nutrition" curriculum, and the control group, which followed conventional physical education learning, without disrupting the natural class structure. The research flow included group assignment, pretest administration, learning intervention implementation, posttest, and multivariate data analysis. The independent variable in this study was the learning model, while the dependent variables included nutrition knowledge and healthy behavior intention, with pretest scores used as covariates to control for differences in students' initial abilities.

The research subjects consisted of 40 seventh-grade students from two parallel classes at Beijing No. 3 Middle School (Xicheng District, Beijing, China). Through class-based randomization, students were divided into an experimental group (N = 20) and a control group (N = 20). The learning intervention was carried out for 10 weeks with a frequency of twice a week and a total of 20 hours of learning. The experimental group followed an integrated curriculum that linked nutrition concepts to real physical exercise experiences through micro-learning, contextual discussions, and health behavior reflection, while the control group received routine physical education based on physical exercise and teacher

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instruction. Teacher equality, time, facilities, and the learning environment were maintained to minimize treatment bias.

To ensure the consistency and fidelity of the intervention, several preparatory procedures were conducted before the implementation of the learning program. A teaching guide was first developed by the researchers based on the integrated "physical exercise and scientific nutrition" learning model, containing detailed descriptions of learning objectives, weekly topics, instructional procedures, and strategies for integrating nutrition concepts into physical exercise activities. Prior to the intervention, the physical education teacher participated in a short orientation and training session conducted by the research team to familiarize them with the instructional design, the weekly learning structure presented in Table 1, and the use of educational technology to connect nutrition knowledge with students' physical activity experiences. During this session, examples of learning activities and discussion strategies were explained to ensure that the instructor clearly understood the goals and procedures of the intervention. In addition, periodic classroom observations were conducted throughout the implementation period to monitor whether the learning activities were carried out according to the teaching guide and to maintain consistency in the delivery of the integrated learning model.

Table 1. Weekly Learning Plan for the Integration of Scientific Nutrition Education in Physical Education at Beijing No. 3 Middle School (Xicheng District, Beijing, China)

Weekly	Subject Content	Objectives and Focus
Week 1	Basics of Healthy Eating: Classification and Function of Nutrients	This course introduces basic knowledge about nutrition, helping students understand the main nutrients in food and their functions, as well as their relationship to health.
Week 2	The Relationship Between Diet and Exercise: Energy Balance and Nutritional Supplementation	Guiding students to understand how diet affects athletic performance, particularly the impact of dietary choices before and after exercise on physical fitness.
Week 3	Water intake and athletic performance: Importance and methods of supplementation	This lesson explains the role of water in sports, analyzes the negative effects of dehydration on athletic performance, and teaches students how to properly hydrate.
Week 4	Protein and Muscle Recovery: Strategies for Enhancing Strength and Recovery	By explaining the function of protein and combining it with strength training, the importance of protein in muscle repair is emphasized.
Week 5	Carbohydrates and Endurance Training: Energy Storage and Maintenance	Helping students understand the role of carbohydrates and master energy replenishment methods in endurance sports training.
Week 6	Healthy Eating	Students design three meals a day based on what they have

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Weekly	Subject Content	Objectives and Focus
	Practices: Designing a Healthy Meal Plan	learned, practice balanced eating patterns, and provide feedback through group discussions.
Week 7	Healthy snacks and post-workout food choices	Teaching students to choose healthy and nutritious snacks after exercise to aid muscle recovery.
Week 8	Combining physical exercise with nutrition: The synergistic effects of strength and endurance training	This study explores ways to enhance strength and endurance through diet, combining physical exercise methods, to promote comprehensive physical fitness development in students.
Week 9	Exercise and Feedback: Personal Health Management and Goal Setting	Students are encouraged to develop a personal health management plan based on what they have learned over the previous eight weeks.
Week 10	Summary and Assessment: Review of Nutrition and Exercise Combination	By reviewing the course content, students' knowledge acquisition is assessed, and a course summary is conducted.

Table 1 illustrates the weekly learning structure in the integrated curriculum of scientific nutrition education and physical education implemented over ten weeks. The material is arranged progressively, starting from an introduction to basic nutrition concepts to their application in meal planning and students' personal health management. Each week links nutrition knowledge to relevant physical activities, such as energy balance, hydration, muscle recovery, and endurance training. This approach allows students to build conceptual understanding and practical experience in a continuous manner, thereby supporting improved health literacy, awareness of the relationship between diet and exercise, and the systematic formation of healthy lifestyle behaviors.

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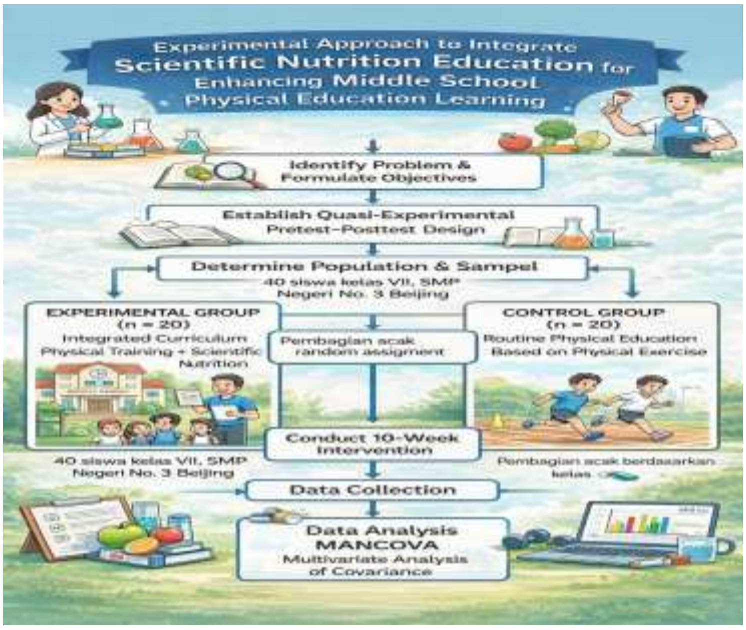

Figure 1. Flowchart of the Quasi-Experimental Research Design for Integrating Scientific Nutrition Education into Middle School Physical Education

Data collection was conducted using nutritional knowledge tests and healthy behavior intention questionnaires The research instruments consisted of a nutrition knowledge test and a healthy behavior intention questionnaire. The nutrition knowledge test was developed based on key concepts of adolescent nutrition and physical activity and was reviewed by three experts in nutrition education and physical education to evaluate its content relevance and clarity. The content validity of the test items was assessed using the Content Validity Index (CVI), which indicated a high level of agreement among experts (CVI = 0.91), suggesting that the instrument adequately represented the intended construct. Meanwhile, the healthy behavior intention questionnaire was designed to measure students' intentions to adopt healthy dietary and physical activity behaviors. The internal consistency reliability of this questionnaire was tested using Cronbach's Alpha, resulting in a coefficient of $\alpha = 0.87$, which indicates good reliability. These results demonstrate that the instruments used in this study met acceptable standards of validity and reliability for educational research. Data analysis was performed using SPSS 26.0, beginning with statistical assumption tests, including Shapiro Wilk normality tests, Levene variance homogeneity tests, and multivariate outlier checks. MANCOVA was used as the main analysis to test the synergistic effects of the intervention on both dependent variables simultaneously by controlling for pretest scores, thereby increasing the precision of the estimates and reducing the risk of Type I error. Furthermore, univariate ANCOVA was used to identify the specific effects of the intervention on each dependent variable, with effect sizes reported using partial η^2 to assess the practical significance of the research results.

Results and Discussion

The results of this study show a clear pattern regarding the difference in impact between integrated physical education and nutrition learning and conventional physical education on the structure of student learning outcomes. Although both groups experienced an increase from pretest to posttest, the experimental group that followed the integrated "physical training + scientific nutrition" curriculum showed a much more significant increase

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in nutrition knowledge and healthy behavior intentions. The MANCOVA findings indicate a strong synergistic effect of the learning intervention, confirming that the integration of cognitive content and physical experience can build a more meaningful learning path than a purely physical exercise approach. Theoretically, this improvement can be understood as the formation of a "new cognitive-behavioral pathway," in which students not only understand nutritional concepts declaratively but also relate them to the bodily sensations, fatigue, recovery, and physical performance they experience directly in physical education. In conventional learning, student activities tend to be limited to repetitive exercises and achieving physical targets, so that learning stops at the procedural level without internalizing the meaning of health. In contrast, integrated learning design encourages students to reflect on the cause-and-effect relationship between diet and physical activity, in line with constructivism theory and Bloom's taxonomy, which place application and reflection as prerequisites for behavioral change. Thus, the significant improvement in both dependent variables is not merely the result of information transfer, but evidence of knowledge reconstruction towards more conscious and sustainable health behaviors.

Table 2. Pre-Test and Post-Test Scores of the Experimental Group and Control Group (M ± SD)

Variable	Group	Pre-Test Mean	Pre-test SD	Post-Test Mean	Posttest SD
Nutrition Knowledge	Experimental	12.65	1.15	16.73	1.26
Nutrition Knowledge	Control	12.22	0.8	13.43	0.7
Health Behavior Intention	Experimental	40.57	2.29	49.34	3.28
Health Behavior Intention	Control	39.87	0.98	41.81	1.04

Table 2 shows a comparison of the mean values and standard deviations of the pretest and posttest for the variables of Nutrition Knowledge and Health Behavior Intention between the experimental group and the control group. For the variable of nutrition knowledge, both groups had relatively comparable initial abilities at the pretest stage, with a mean of 12.65 in the experimental group and 12.22 in the control group. However, after the intervention, the experimental group experienced a much greater increase, with a posttest average of 16.73, compared to the control group, which only increased to 13.43. A similar pattern was seen in the variable of healthy behavior intention. The pretest scores of the two groups were relatively balanced, but in the posttest, the experimental group showed a significant jump to an average of 49.34, while the control group increased more modestly to 41.81. This difference in improvement indicates that physical education integrated with scientific nutrition education is more effective in improving both students' understanding of nutrition and their intention to adopt healthy behaviors than conventional physical education. These findings are consistent with previous research demonstrating that the integration of nutrition education with physical activity-based learning significantly improves students' health literacy, nutritional knowledge, and behavioral intentions, as students are able to directly relate scientific concepts to their physical experiences during exercise (Oliveira, 2022; Mancin et al., 2025). Furthermore, interdisciplinary health education programs that combine physical activity and nutrition have been reported to strengthen students' motivation to adopt healthier lifestyles and support the development of long-term health-related behaviors (Perry et al., 2025; Wang et al., 2025).

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Table 3. Results of Multivariate Covariance Analysis (MANCOVA)

Test Indicator	Wilks' Lambda	F Value	p Value	Partial η²
Teaching Mode (Experimental Group vs. Control Group)	0.338	34.21	< 0.001	0.662

Table 3 shows the results of Multivariate Analysis of Covariance (MANCOVA) which tested the effect of learning mode on a combination of dependent variables, namely nutritional knowledge and intention to behave healthily. Wilks' Lambda value of 0.338 indicates a strong multivariate difference between the experimental group and the control group. The F value of 34.21 with $p < 0.001$ indicates that the difference is statistically significant after controlling for pretest scores. In addition, the partial η^2 value of 0.662 indicates a very large effect size, which means that most of the combined variation in both dependent variables can be explained by differences in learning modes. These results confirm the effectiveness of the integrated learning approach compared to conventional learning. Previous research has demonstrated that integrating nutrition education into physical activity-based learning environments can significantly enhance students' health literacy, nutritional knowledge, and behavioral intentions toward healthy lifestyles, as the learning process connects scientific concepts with authentic physical experiences (Oliveira, 2022; Mancin et al., 2025). In addition, interdisciplinary health education programs that combine nutrition and physical activity have been reported to promote deeper cognitive engagement and support the development of long-term healthy behaviors among students (Perry et al., 2025; Wang et al., 2025).

Table 4. ANCOVA Analysis Results for Nutrition Knowledge

Source	F Value	p-value	Partial η²
Teaching Mode	96	< 0.001	0.722

Table 4 presents the results of the Analysis of Covariance (ANCOVA) that tested the effect of learning mode on the dependent variable after controlling for initial scores. The F value = 96.00 with $p < 0.001$ indicates that the difference between the experimental group and the control group is statistically significant. This indicates that the learning mode has a significant effect on the improvement in learning outcomes as measured. In addition, the partial η^2 value of 0.722 indicates a very large effect size, meaning that most of the variation in learning outcome scores can be explained by differences in learning mode. These findings confirm that the integrated learning approach is far more effective than conventional learning. This result is consistent with previous research indicating that the integration of nutrition education into physical activity-based learning environments can significantly improve students' health literacy, nutritional knowledge, and intentions to adopt healthy lifestyles, as such approaches connect scientific concepts with authentic physical experiences (Oliveira, 2022; Mancin et al., 2025). In addition, interdisciplinary health education programs that combine physical activity and nutrition have been found to strengthen students' engagement in learning and encourage the adoption of long-term healthy behaviors (Perry et al., 2025; Wang et al., 2025).

Table 5. ANCOVA Analysis Results for Health Behavior Intentions

Source	F Value	p-value	Partial η²
Teaching Mode	34.38	< 0.001	0.482

Table 5 presents the results of the Analysis of Covariance (ANCOVA) that tested the effect of learning mode on students' health behavior intentions after controlling for

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differences in initial scores. The F value = 34.38 with $p < 0.001$ indicates that the difference between the experimental group and the control group is statistically significant. This confirms that the application of physical education integrated with scientific nutrition education has a real impact on increasing students' intention to adopt healthy behaviors. In addition, the partial η^2 value of 0.482 indicates a large effect size, which means that almost half of the variation in students' health behavior intentions can be explained by differences in the learning modes applied.

Based on the overall quantitative and qualitative findings, the significant increase in students' nutrition knowledge and healthy behavior intentions can be understood as the result of an integrated learning mechanism that systematically strengthens the relationship between cognition, physical experience, and behavioral reflection. These findings are consistent with previous studies conducted in both Asian and global contexts. For instance, Oliveira (2022) reported that interdisciplinary educational interventions integrating nutrition and physical activity significantly improved students' knowledge and attitudes toward healthy lifestyles. Similarly, Perry et al. (2025) found that integrating nutrition education within middle school physical activity programs strengthened students' understanding of the relationship between diet and exercise while promoting healthier behavioral intentions. In the Asian context, Patimah and Idrus (2023) demonstrated that school-based nutrition–health interventions among adolescents significantly improved nutritional knowledge and health awareness. In addition, Mancin et al. (2025) showed that integrated and active learning approaches in nutrition education enhanced learners' engagement and conceptual understanding of health-related topics. Compared with these studies, the present research provides further evidence that combining scientific nutrition education with authentic physical exercise experiences within an educational technology-supported framework can simultaneously enhance both cognitive outcomes and behavioral intentions among junior high school students. MANCOVA and ANCOVA data show large effect sizes (partial $\eta^2 = 0.722$ for nutrition knowledge and 0.482 for health behavior intentions), indicating that the changes that occurred were not marginal but pedagogically substantive. The integration of micro-learning about nutrition with real physical exercise gave students cognitive autonomy in understanding why and how eating patterns affect their physical performance. This autonomy encourages intrinsic engagement and situational interest, so that students perceive learning as a challenge relevant to their daily lives, not just a curriculum requirement. When students reflect on their experiences of fatigue, recovery, and exercise performance in relation to nutritional intake, cognitive cohesion is formed between declarative, procedural, and contextual knowledge. This cohesion enables the transfer of knowledge across situations and strengthens the "cognition-motivation-behavior" chain. Therefore, the findings of this study confirm that physical education enriched with scientific nutrition education and supported by educational technology can shift learning from a purely physical orientation to the development of sustainable health literacy. The implication is that physical education curricula need to consciously reduce the dominance of routine instruction and make room for exploration, reflection, and health-based decision-making based on student experience.

Conclusion

Based on the entire research process, from design to data analysis, it can be concluded that the integration of scientific nutrition education into physical education learning in junior high schools is an effective and relevant learning approach to improve students' health literacy. The results of the quasi-experimental study show that the integrated curriculum

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significantly improves nutrition knowledge and health behavior intentions, with a large effect size as evidenced by MANCOVA and ANCOVA analyses. These findings confirm that the improvement that occurred was not merely the result of information transfer, but rather the result of a learning mechanism that systematically linked cognitive understanding with students' physical experiences. Through the integration of nutrition concepts into authentic physical exercise activities, students were able to build a meaningful understanding of the relationship between diet, physical performance, and personal health management. Educational technology support strengthens this process by providing micro-learning, contextual tasks, and reflective feedback that enhance engagement and learning coherence. Unlike conventional physical education, which tends to focus solely on physical exercise, this integrated model promotes holistic development that encompasses cognitive, affective, and behavioral aspects. Thus, this study provides strong empirical evidence that the integration of technology-based scientific nutrition education is a strategic approach to reforming physical education learning toward a more systematic, health literacy-oriented, and sustainable approach at the junior high school level.

Recommendation

Based on the findings of this study, several recommendations can be made for the development of learning practices and further research. Physical education teachers are advised to gradually integrate scientific nutrition education into physical learning activities, not as additional material, but as an integral part of the physical training process. The use of educational technology, such as nutrition micro-learning, online quizzes, and task-based reflection, needs to be optimized to increase student engagement and strengthen the relationship between knowledge and health behavior. Schools also need to provide continuing professional development programs for teachers so that their pedagogical and technological literacy competencies are in line with the integrated learning approach. In addition, the learning evaluation system should not only assess physical fitness, but also nutrition knowledge and healthy behavior intentions. For further research, it is recommended to expand the sample size, involve different school contexts, and use a longitudinal design to assess the sustainability of changes in student health behavior in the long term.

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