



Original article. Integrated framework for holistic student development: physical literacy, nutrition, and playground design in ASEAN.

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Integrated framework for holistic student development: physical literacy, nutrition, and playground design in ASEAN

Marco integrado para el desarrollo integral del alumno: alfabetización física, nutrición y diseño de patios de recreo en la ASEAN

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Abstract

Holistic student development in ASEAN (Association of Southeast Asian Nations) educational contexts demands integrated approaches that simultaneously address physical literacy, nutrition literacy, and supportive play environments. This study aimed to develop and empirically validate an integrated physical literacy, nutrition literacy, and playground-based framework. A four-phase sequential mixed-methods design was applied, including expert consultation, document analysis, prototype development, and quantitative validation. Construct validation involved 1415 elementary students and was analyzed using descriptive statistics, correlation, regression, and structural equation modeling. Students demonstrated high levels of holistic development ($M = 78.2$), physical literacy ($M = 76.4$), creativity in play ($M = 74.3$), and nutrition literacy ($M = 72.1$), with daily physical activity showing moderate levels ($M = 68.9$). All predictor variables were significantly associated with holistic student development ($r = 0.69-0.77$, $p < 0.01$), with creativity in play emerging as the strongest correlate. The findings provide robust empirical support for the integrated multidimensional framework as an integrated, culturally responsive model for enhancing children's physical, cognitive, and socio-emotional development.

Keywords: physical literacy; nutrition; playground; sustainable development goals; Physical Education

Resumen

El desarrollo integral de los alumnos en los contextos educativos de la ASEAN (Asociación de Naciones del Sudeste Asiático) exige enfoques integrados que aborden simultáneamente la alfabetización física, la alfabetización nutricional y los entornos de juego propicios. El objetivo de este estudio fue desarrollar y validar empíricamente un marco integrado de alfabetización física, alfabetización nutricional y basado en el patio de recreo. Se aplicó un diseño secuencial de métodos mixtos en cuatro fases, que incluyó consultas a expertos, análisis de documentos, desarrollo de prototipos y validación cuantitativa. La validación del constructo contó con la participación de 1415 alumnos de primaria y se analizó mediante estadísticas descriptivas, correlación, regresión y modelos de ecuaciones estructurales. Los alumnos mostraron altos niveles de desarrollo holístico ($M = 78,2$), alfabetización física ($M = 76,4$), creatividad en el juego ($M = 74,3$) y alfabetización nutricional ($M = 72,1$), mientras que la actividad física diaria presentó niveles moderados ($M = 68,9$). Todas las variables predictivas se asociaron significativamente con el desarrollo holístico de los alumnos ($r = 0,69-0,77$, $p < 0,01$), destacando la creatividad en el juego como la variable más fuertemente correlacionada. Los resultados proporcionan un sólido respaldo empírico al marco multidimensional integrado como modelo integrado y culturalmente sensible para mejorar el desarrollo físico, cognitivo y socioemocional de los niños.

Palabras clave: alfabetización física; nutrición; patio de recreo; objetivos de desarrollo sostenible; Educación Física



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Introduction

Physical inactivity, poor nutrition, and limited access to inclusive play environments have emerged as interconnected global challenges affecting children's development, particularly in rapidly urbanizing regions such as ASEAN (Tsang et al., 2023). In the context of higher education, digital interventions have been explored to improve mental health (Cereda, 2026; Hensel, 2022). Social support and sociocultural adjustment play important roles in the mental health of international students, with sociocultural adjustment being a stronger predictor of mental health outcomes than social support, although the latter is crucial for overall well-being (Razgulin et al., 2023; Soenyoto et al., 2025).

Multidimensional approaches integrating physical literacy, nutrition, and play environment design are essential for promoting holistic child development by addressing interconnected health and educational domains. Physical literacy interventions emphasize both the quantity and quality of physical activity to enhance physical competence and cognitive flexibility (Annas et al., 2022; Li et al., 2022). This highlights the importance of preventive strategies incorporating nutrition and physical activity to improve educational outcomes (Adi et al., 2021; Culajara, 2023). Inclusive play environments further support equitable access and diverse experiences, helping reduce social and physical disparities (Rumini et al., 2024; Yildirim et al., 2022).

Research on physical literacy, nutrition, and playground design is critical in ASEAN due to its role in shaping children's health and development. Physical literacy encompassing motivation, competence, and knowledge provides a foundation for lifelong physical activity. However, its integration into early childhood education in Indonesia remains limited, constraining motor skill development and health outcomes (Cahyati et al., 2025). Interventions combining the quantity and quality of physical activity have been shown to improve children's competence and understanding (Li et al., 2022). In parallel, innovative playground designs with diverse surfaces and open structures increase moderate-to-vigorous physical activity and user engagement compared to traditional layouts (D. A. Cohen et al., 2023). Collectively, these findings highlight the need to integrate physical literacy and playground design within



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supportive physical education policies across ASEAN, considering its diverse cultural and contextual characteristics (Carl et al., 2022; Gu, 2021).

Research indicates that healthy eating habits are positively correlated with academic success (Özenoğlu et al., 2024). Similarly, food and nutrition literacy (FNLIT) among younger students is directly associated with healthier eating behaviors and improved academic performance, with FNLIT functioning as a mediator in reducing overweight and obesity through healthy dietary choices (Doustmohammadian et al., 2022). In adolescents, dietary patterns significantly influence school performance, with high consumption of high-fat, salt, and sugar (HFSS) foods associated with poorer academic outcomes, while consumption of staple foods correlates with better performance across various subjects (Zagkos et al., 2023).

The role of playgrounds in promoting children's health and development is well established. Playgrounds with diverse features enhance fundamental movement skills (e.g., balance, agility, coordination) while supporting creative exploration through active play and problem-solving (Pawlowski et al., 2023; Schipperijn et al., 2024). Elements such as sandboxes further foster cognitive and social development through naturalistic play (Leri et al., 2024). As creativity evolves from individual to socially mediated processes, playgrounds provide critical environments for both independent and collaborative engagement (Dumas et al., 2024). However, modern playground designs that integrate child-friendly technology and support holistic development remain limited in ASEAN and are often not tailored to local child characteristics.

The ASEAN region provides a promising context for research and innovation in physical literacy, nutrition, and playground design, supported by rapid socio-economic transformation and strong collaborative networks. Urbanization and regional innovation systems, including China–ASEAN cooperation, demonstrate the capacity to integrate technological and knowledge resources for advancing health and physical activity initiatives (Chen et al., 2023; Wu & Liu, 2024). Cross-sector collaboration, reflected in tourism, public health, and academic partnerships, further supports the development of community-based wellness programs and equitable health outcomes (Annamalah et al., 2023; Yee & Tan, 2023). In addition, the region's commitment to sustainable development and environmental innovation



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provides a strong foundation for designing eco-friendly and inclusive playgrounds (Wei & Lihua, 2023). Collectively, these conditions position ASEAN as a strategic setting for developing integrated, scalable models aligned with SDGs in education and health.

The integration of physical education and environmental education has been shown to promote conservation values. Low-carbon recreational education and outdoor learning significantly enhance environmental awareness and attitudes by engaging students in sustainable physical activities (Pasek et al., 2022; Zhou et al., 2024). Community-based conservation initiatives further demonstrate the combined benefits of physical activity and environmental stewardship for well-being and biodiversity (Crone et al., 2024). Collectively, these findings highlight the potential of physical education to support sustainability through the promotion of environmentally responsible behaviors.

Contemporary research increasingly recognizes that physical education should integrate motor competence, psychological engagement, and active participation to support holistic child development. Innovative pedagogical strategies, including meaningful task organization and gamified learning experiences, have been shown to enhance students' motivation and regular physical activity participation. Nevertheless, these educational approaches are generally implemented independently and rarely integrated with nutrition literacy and supportive playground environments within a unified developmental framework. Consequently, a comprehensive model capable of explaining the interaction among these domains remains insufficiently established (Esqueda Valerio et al., 2024; Viciana et al., 2025).

Despite the growing literature, a critical gap remains in explaining how physical literacy, nutrition literacy, and playground environments jointly influence holistic student development through a clear causal mechanism. Existing studies are largely fragmented or correlational, creating a disconnect between theoretical constructs and practical outcomes.

This study addresses this gap by developing and empirically validating an integrated, mechanism-based framework linking these domains in ASEAN contexts. A structural model is proposed in which daily physical activity acts as a mediating mechanism translating competencies into developmental outcomes.



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The study contributes by extending physical literacy theory through a behavioral mediation pathway and by introducing a contextualized ASEAN-based framework that incorporates sociocultural and environmental characteristics.

To our knowledge, this study represents the first empirical investigation in the ASEAN context that integrates physical literacy, nutrition literacy, playground design, and daily physical activity within a unified structural model explaining holistic student development through behavioral mediation mechanisms.

Methodology

Research Design

This study employed a four-phase sequential mixed-methods design (Figure 1), integrating exploratory qualitative procedures with confirmatory quantitative testing to develop and validate three interrelated educational prototypes: (1) a physical literacy assessment tool, (2) a nutrition literacy digital application, and (3) a modular playground design model. The mixed-methods approach was chosen to address the multidimensional and cross-cultural nature of student development and to ensure that the resulting prototypes were adaptable across diverse ASEAN educational contexts (Suárez-Orozco, 2019).

Participants

Participants were involved across different phases in accordance with the research and development (R&D) methodology. Expert participants consisted of academics and practitioners in physical literacy, nutrition science, physical education, and child-centered play design from ASEAN countries.



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TABLE 1. Demographic and Anthropometric Characteristics of Study Participants

Variable	Pilot Sample (n = 300)	Main Sample (n = 1,115)
Age (years)	10.4 ± 1.1	10.6 ± 1.0
Age Range	9–12	9–12
Height (cm)	138.5 ± 8.7	139.2 ± 8.3
Weight (kg)	34.6 ± 7.9	35.2 ± 8.1
BMI (kg/m ²)	17.9 ± 3.1	18.2 ± 3.2
Variable	Pilot Sample (n = 300)	Main Sample (n = 1,115)
BMI Category (%)	Underweight: 12.3%	Underweight: 11.8%
	Normal: 68.7%	Normal: 69.5%
	Overweight/Obese: 19.0%	Overweight/Obese: 18.7%
Educational Level	Grades 4–6	Grades 4–6
Gender (Boys/Girls)	152 / 148	568 / 547

The empirical component of this study involved two distinct student samples with clearly differentiated roles. First, a pilot sample of 300 elementary school students was engaged during the initial construct validation stage. This pilot phase aimed to evaluate item clarity, internal consistency, and preliminary construct behavior of the Physical Literacy, Nutrition Literacy, Daily Physical Activity, Creativity in Play, and Holistic Student Development instruments. Findings from this phase informed item refinement prior to large-scale implementation.

Second, a large inferential sample of 1,115 elementary school students participated in the main quantitative validation phase. This sample was used for descriptive analysis, Pearson correlation, multiple regression, and structural equation modeling (SEM) to examine direct, indirect, and mediated relationships among constructs within the integrated conceptual framework. The large sample size ensured adequate statistical power and model stability for multivariate and structural analyses.

Students represented diverse grade levels and school contexts, enhancing variability across physical, cognitive, behavioral, and creative domains and supporting the generalizability of findings within ASEAN educational settings.



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A four-phase sequential mixed-methods design was employed to capture the complexity of holistic student development across physical, cognitive, behavioral, and environmental domains. This design was intentionally selected to ensure both contextual depth (qualitative exploration) and empirical robustness (quantitative validation), aligning with best practices in educational and sport science research.

Phase I- Expert Identification and Instrument Initiation

Phase I focused on establishing a transnational expert network as the foundation for prototype development. Experts were purposively selected based on recognized affiliations and scientific contributions in physical literacy, nutrition science, and child-centered play design. The International Physical Literacy Association (IPLA) supported the development of culturally grounded physical literacy indicators, while the Asian Nutrition Society for Sport and Health (ANSSH) contributed to framing nutrition literacy components relevant to the emerging free school lunch policies in the region. The Malaysian Society of Body Composition provided technical input for ergonomic and developmental considerations in playground design. A snowball sampling strategy was used to expand the pool of regional experts, enabling multisector insights and ensuring that prototype development was contextually appropriate for primary school students across ASEAN. This study was conducted in accordance with the Declaration of Helsinki and ethical research standards for studies involving children. Ethical approval was obtained from the Institutional Review Board (IRB) / Ethics Committee of Universitas Negeri Semarang (Approval Number: 1038/UN37/KEPK/2025). Written informed consent was obtained from parents or legal guardians before student participation, while verbal assent was obtained from all participating children. Data confidentiality and anonymity were strictly maintained throughout all phases of data collection, analysis, and reporting. Participants were informed of their right to withdraw from the study at any time without academic or social consequences.



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Phase II- National Review and Comparative Analysis

In the second phase of the study, each participating country conducted a structured national review designed to capture both the conceptual foundations and practical realities of physical literacy, nutrition literacy, and playground provision within their local contexts. This phase produced two complementary outputs. The first was a two-page narrative review summarizing the national landscape of the three domains. These reports synthesized empirical research findings, current policy directions, and on-the-ground implementation practices, providing an integrated overview of how each country approaches student development through movement, nutrition, and active play. The narrative format enabled experts to highlight unique contextual features, emerging initiatives, and challenges faced in school-based implementation. The second output consisted of an Analytical Matrix Table in which experts systematically categorized their findings into two overarching dimensions: (a) theoretical and research-based perspectives, and (b) policy and practical implementation perspectives. This dual structure allowed for a balanced and comparative appraisal of conceptual alignment and operational realities across educational systems, ensuring that insights were grounded in both academic evidence and institutional practice. All documents were compiled and discussed in preparatory virtual meetings, where representatives from each country collaboratively reviewed similarities, differences, and region-specific nuances. This cross-national dialogue was essential for building a shared regional understanding and enhancing the comparability of insights across diverse ASEAN contexts. The synthesis generated during this phase established a robust foundation for the subsequent development and refinement of the integrated framework prototypes.

Phase III- Document Analysis and Prototype Development

In phase III, all national submissions were systematically examined through a rigorous comparative (Dalglish et al., 2020). To ensure analytical rigor and intercultural neutrality, the study employed a transnational double-review protocol in which two independent researchers from different countries reviewed each document separately and then compared their interpretations. The analysis proceeded through four structured stages. First, during the familiarization stage, reviewers conducted multiple readings of all documents- initially for



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broad comprehension and subsequently for detailed methodological and contextual understanding. Second, in the extraction stage, key quotations, conceptually relevant statements, and policy insight were identified and coded into inductively generated thematic subcategories. The third stage involved cross-country thematic synthesis, during which reviewers systematically compared patterns of convergence and divergence across national reports. The synthesis enabled the identification of shared regional challenges, context-specific adaptations, and varying levels of policy and research integration among ASEAN countries. In the final stage, iterative refinement was conducted through multi-round collaborative discussions, ensuring that thematic categories were consistent, analytically sound, and representative of regional diversity. The cross-national synthesis derived from this process served as the foundation for developing three prototype instruments (Table 1). Each prototype was constructed to reflect the educational diversity of the ASEAN region while maintaining a coherent and scalable structure suitable for regional implementation.

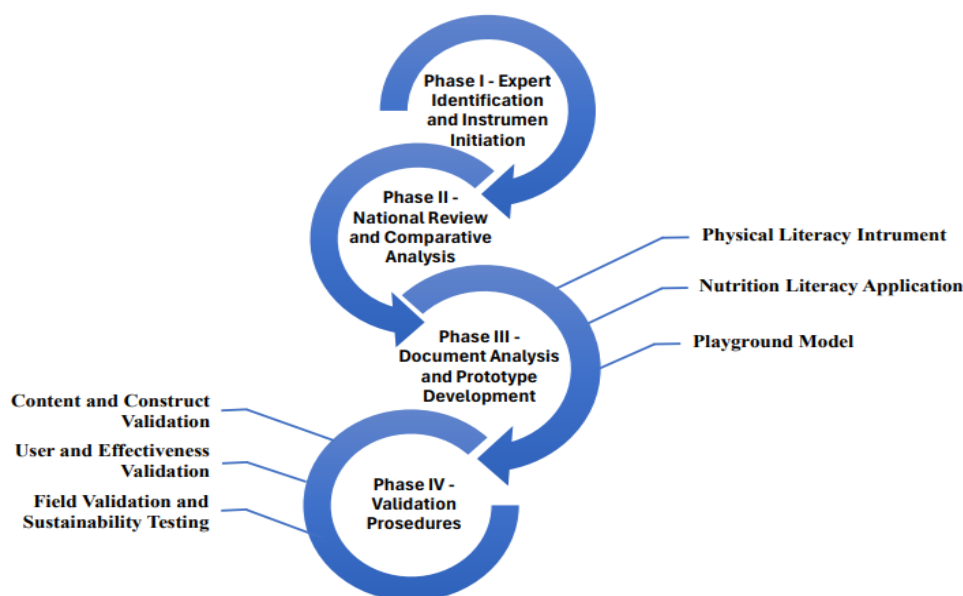


FIGURE 1. Four-Phase Sequential Mixed Methods Approach



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TABLA 2. Structural and Functional Summary of the Prototypes

Prototype	Domains	Key Components	Objective
Physical Literacy	Physical competence Cognitive understanding Motivation& self-confidence	Digital wearables Self-assessment tools Task-based skill tests	To assess and guide individualized physical education interventions.
Nutrition Literacy	Knowledge Behaviour Attitude	Mobile app Literacy questionnaire ASEAN-based visual tools	To improve students' awareness and behavior toward healthy nutrition.
Playground Model	Physical, Cognitive, and Social interaction	Modular stations IoT activity sensors Eco-friendly, child-safe materials	To promote physical activity, creativity, and social-emotional learning through active play.

Phase IV- Validation Procedures

In the fourth phase, Construct validation was initially conducted using data from the pilot sample of 300 students. Descriptive statistics, item–total correlations, and internal consistency indices were examined to assess construct clarity, coherence, and reliability. Items failing to meet acceptable psychometric criteria were revised or removed before large-scale testing.

Inferential Validation and Model Testing (Main Study Phase)

The refined instruments were subsequently implemented with the full inferential sample of 1,115 students. Data from this phase were used to conduct Pearson correlation analysis, multiple regression modeling, and structural equation modeling (SEM). Daily Physical Activity was specified as a mediating variable between Physical Literacy and Holistic Student Development, allowing examination of both direct and indirect behavioral pathways.

Data Analysis (Adjusted for Sample Roles)

To ensure reproducibility, all analytical procedures were pre-defined and systematically executed. Instrument development followed a structured validation pipeline including pilot testing, item analysis, reliability testing (Cronbach's alpha), and construct validation before



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large-scale implementation. Statistical analyses were conducted using standardized procedures in SPSS and AMOS, with clearly defined thresholds for significance and model fit indices, enabling replication in similar educational contexts. Pilot data ($n = 300$) were analyzed to establish internal consistency and construct readiness, while inferential data ($n = 1,115$) were used for hypothesis testing and model estimation. Normality assumptions were evaluated using skewness and kurtosis indices. Statistical significance was set at $p < 0.05$, and SEM model fit was assessed using χ^2 , CFI, TLI, RMSEA, and SRMR.

Results

All reported inferential statistical results (correlation, regression, and SEM) are based on the main validation sample ($n = 1,115$), while pilot data ($n = 300$) were used exclusively for instrument refinement and preliminary validation. Descriptive statistics revealed consistently positive outcomes across all developmental domains (Tabel 2). Holistic student development demonstrated the highest mean score ($M=78.2$, $SD=4.80$, classified as Very High. Physical Literacy ($M = 76.4$), creativity and Play Intelligence ($M= 74.3$), and Nutrition Literacy ($M=72.1$) fell within the Moderate-High to High categories, while Daily Physical Activity showed a moderate mean level ($M=68.9$), indicating potential areas for behavioral enhancement. These patterns are visually represented in Figure 2, which highlights the relative strength of cognitive-creative and movement-related factors in supporting holistic development.

TABLE 3. Research Variables and Statistical Analysis

Variable	Mean (M)	SD	Interpretation
Physical Literacy	76.4	5.2	High
Nutrition Literacy	72.1	6	Moderate-High
Daily Physical Activity	68.9	5.7	Moderate
Creativity & Play Intelligence	74.3	5.9	High
Holistic Student Development	78.2	4.8	Very High

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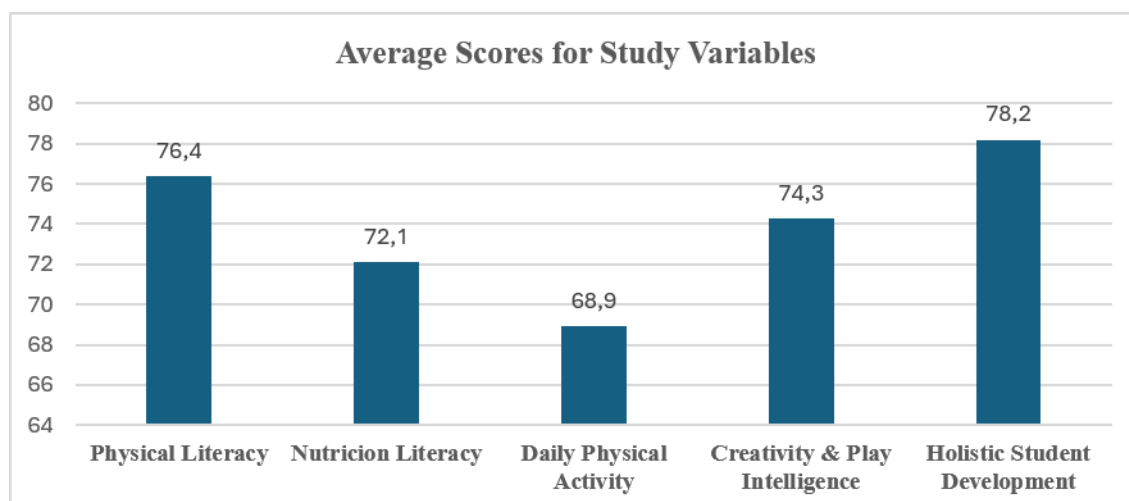


FIGURE 2. Bar Chart of Average Scores for Study Variables

Pearson correlation analysis (Table 3) showed that all relationships among the core variables were statistically significant and aligned with the theoretical expectations of the proposed integrated framework. The strongest association was observed between Creativity in Play and Holistic Students Development ($r=0.77$, $p<0.001$), indicating that creative and imaginative play substantially contributes to students' overall developmental outcomes. Physical Literacy also demonstrated a strong positive relationship with Holistic Student Development ($r=0.74$, $p=0.001$), underscoring the importance of movement competence and motivation.

Daily Physical Activity exhibited a similarly strong correlation with Holistic Student Development ($r=0.71$, $p=0.002$), suggesting that consistent engagement in physical activity meaningfully supports well-being. Nutrition Literacy demonstrated a moderately strong yet significant association ($r=0.69$, $p=0.003$), highlighting the relevance of nutrition-related knowledge and habits in holistic growth. Additionally, Physical Literacy was moderately correlated with Daily Physical Activity ($r=0.66$, $p=0.005$), confirming the hypothesized behavioural pathway within the framework. Collectively, these correlations provide evidence for the conceptual integration of physical, cognitive, behavioural, and creative components within the model.



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TABLE 4. Correlation Analysis between Variables

Variable 1	Variable 2	Correlation Coefficient (r)	Significance (p-value)
Physical Literacy	Holistic Development	0.74	0.001
Nutrition Literacy	Holistic Development	0.69	0.003
Daily Physical Activity	Holistic Development	0.71	0.002
Creativity in Play	Holistic Development	0.77	0.000
Physical Literacy	Daily Physical Activity	0.66	0.005

Note: All correlations are Pearson's r coefficients. Values > 0.50 indicate strong associations.

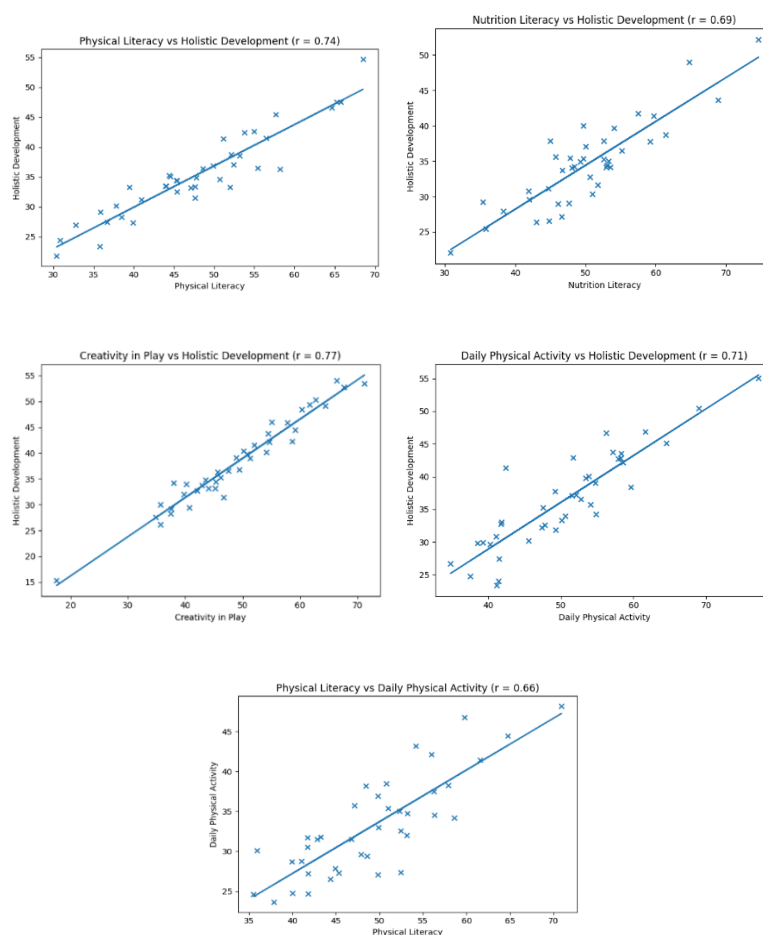


FIGURE 3. Correlation analysis

A multiple regression analysis was performed to determine the combined influence of the four predictor variables- Physical Literacy, Daily Physical Activity, Creativity & Play



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Intelligence, and Nutrition Literacy – on Holistic Student Development. The overall model was statistically significant, $F(4,110) = 48.7$, $p < 0.001$, explaining 61% of the variance in Holistic Student Development ($R^2 = 0.61$; Adjusted $R^2 = 0.59$), indicating a moderately strong predictive capacity. Standardised coefficients revealed that Physical literacy was the strongest predictor, showing a substantial contribution to holistic development ($\beta = 0.39$, $p < 0.001$). The effect size of physical literacy ($\beta = 0.39$) indicates a substantial contribution relative to other predictors. Daily Physical Activity contributed significantly ($\beta = 0.28$, $p < 0.001$), demonstrating that habitual movement patterns play a substantial role in shaping developmental outcomes. Creativity & Play Intelligence also showed a moderate yet significant effect ($\beta = 0.25$, $p < 0.001$), suggesting that creative engagement enhances socio-emotional and cognitive dimensions of development. Nutrition Literacy contributed a smaller but meaningful effect ($\beta = 0.17$, $p = 0.009$). These results confirm that holistic development is driven by a combination of movement competence, habitual activity, creative engagement, and nutrition-related behaviors, validating the multidimensional structure of the proposed integrated framework.

TABLE 5. Multiple Regression Predicting Holistic Student Development

Predictor	β (standardized)	t	p
Physical Literacy	0.39	5.82	<0.001
Daily Physical Activity	0.28	4.11	<0.001
Creativity & Play Intelligence	0.25	3.87	<0.001
Nutrition Literacy	0.17	2.64	0.009

Model fit: $R = 0.78$; $R^2 = 0.61$; Adjusted $R^2 = 0.59$, $F(4,110) = 48.7$, $p < 0.001$

To further explore the interrelationships among the variables, a structural equation model was estimated with Daily Physical Activity positioned as a mediator between Physical Literacy and Holistic Student Development. The model demonstrated a robust fit to the data, $\chi^2(3) = 4.52$, $p = 0.21$; CFI=0.99; TLI=0.98; RMSEA= 0.05; SRMR=0.03, indicating that the structural relationships were consistent with theoretical expectations.

Standardised path coefficients revealed a significant direct and indirect effect of Physical Literacy on Holistic Student Development. Physical Literacy predicted Daily Physical

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Activity ($\beta=0.44$; $p<0.001$), which in turn predicted Holistic Student Development ($\beta=0.32$, $p<0.01$). The direct effect from Physical Literacy to Holistic Student Development remained significant ($\beta=0.29$, $p<0.001$), confirming partial mediation. Creativity & Play Intelligence exerted a strong direct influence on Holistic Student Development ($\beta=0.37$, $p<0.001$), while Nutrition Literacy showed a smaller but significant effect ($\beta=0.21$, $p<0.01$). The SEM accounted for approximately 65% of the variance in Holistic Student Development, providing robust empirical support for the integrated, multidomain structure model.

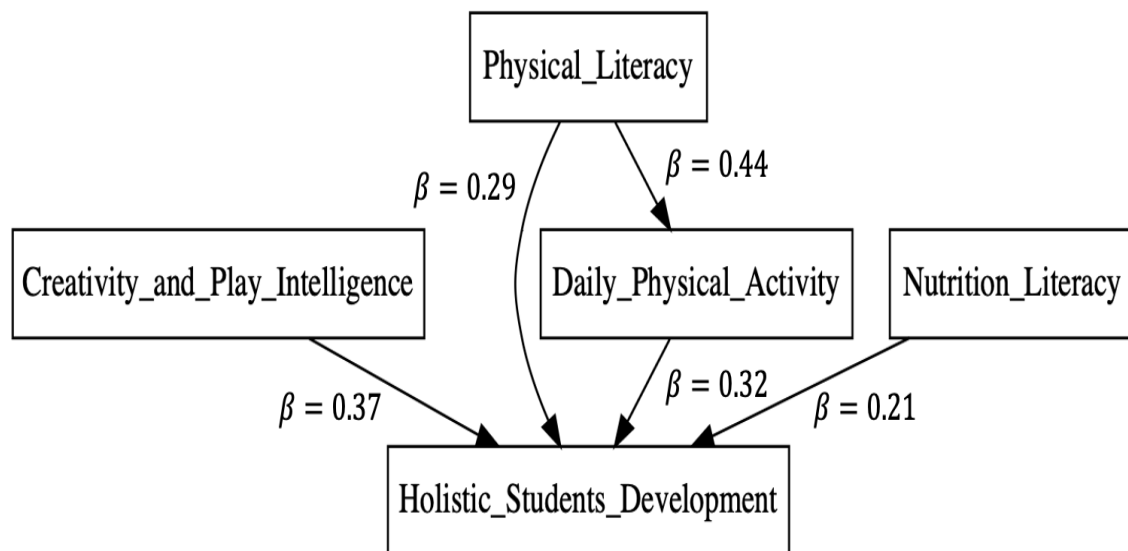


FIGURE 4. Path Diagram of the Integrated Framework Model

Figure 4 illustrates the structural relationships among the core constructs of the integrated framework. Daily Physical Activity functions as a partial mediator between Physical Literacy and Holistic Student Development, highlighting the behavioral pathway through which movement competence translates into broader developmental outcomes. Model fit indices exceeded recommended thresholds, indicating strong theoretical and empirical alignment.

Discussion

The study addresses the urgent need for an integrated approach to physical education, nutrition, and the development of children's play environments in Southeast Asia. The increased



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use of digital devices and low levels of physical activity are the main causes of declining physical and mental health among children (Adi et al., 2023). This is reinforced by research data showing the highest average score on the holistic development variable of students at 78.2, followed by physical literacy (76.4) and play creativity (74.3). These scores indicate that the integrated approach implemented successfully supports significant improvements across various aspects of student development. By integrating physical literacy, nutrition, and playgrounds into a single model, this approach addresses unresolved holistic challenges in the ASEAN education system. The integration of these three components demonstrates a cross-sectoral, complementary, and contextual approach. Physical literacy encompasses not only motor skills but also students' understanding and motivation to be physically active throughout their lives (Young et al., 2020). The high physical literacy score (76.4, high category) indicates that this approach successfully builds students' movement competencies and interest in physical participation, aligning with the goals of modern sustainable physical education. This approach aligns with global trends in physical education that prioritize physical competencies as the foundation for a healthy lifestyle throughout life.

The physical literacy instrument in this study was developed using wearable technology and simple physical practice tests, enabling teachers to objectively measure students' progress (Adi & Kusuma, 2024; Yuwono et al., 2025). This instrument addresses gaps in physical education practices where measurement tools are often qualitative and poorly documented. The nutrition literacy aspect of this study was conveyed through an interactive app based on ASEAN culture. Although it had a slightly lower average score (72.1), nutrition literacy remained in the moderate-high category, indicating that local visual approaches such as the “ASEAN healthy plate” are effective in reinforcing students' basic understanding of balanced eating patterns. The visualization of the locally distinctive “healthy plate” helps students understand balanced eating patterns appropriate to their context (Doustmohammadian et al., 2022; Özenoğlu et al., 2024). Nutrition literacy has been proven to contribute to academic performance and obesity prevention in school-age children.

Innovative playground design models add significant value in supporting students' physical and social development. They achieved a score of 74.3 and showed a very strong



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correlation with students' holistic development ($r = 0.77$; $p < 0.01$), making them the most influential component in supporting students' multidimensional development. The integration of climbing zones, balance paths, and creative play areas aligns with the principles of inclusive play, which has been shown to enhance children's motor skills (Cahyati et al., 2025; E. K. Cohen et al., 2023). This design addresses the limitations of conventional playgrounds, which often lack physical stimulation. IoT sensors on the playground enable real-time monitoring of students' physical activity, providing concrete data for teachers and parents (Bhakti et al., 2024; Cornish et al., 2020; Zhao et al., 2021). This technology bridges the need for data with a pedagogical approach, turning the play area into a living laboratory for physical learning.

Layered validation on three prototypes was conducted to ensure their effectiveness and acceptability. Quantitative findings also showed a strong correlation between daily physical activity and student development ($r = 0.71$), as well as a correlation between physical literacy and physical activity ($r = 0.66$), confirming that good physical literacy can enhance students' engagement in daily physical activities. Content validation by experts ensures that the instruments align with educational objectives and the characteristics of ASEAN students (Cornish et al., 2020; Zhao et al., 2021). Meanwhile, small-scale trials indicate that students experience significant improvements in understanding and motivation. Collaboration among countries in this study serves as a best practice example in developing a cross-cultural model. The involvement of institutions such as IPLA and ANSSH reflects the importance of knowledge transfer and approaches that are not centered on a single country (Annamalah et al., 2023; Wu & Liu, 2024). This also forms the basis for a regional learning model in the ASEAN region. The findings of this study can serve as a reference in the formulation of physical education and nutrition policies. Evidence-based policy documents such as this are urgently needed in the process of educational reform in developing countries (Dalglish et al., 2020; Lalog, 2025). This study offers instruments and implementable evidence for policymakers to adopt.

The identification of daily physical activity as a mediating variable provides critical theoretical implications, suggesting that competencies alone are insufficient to drive developmental outcomes without behavioral enactment. This finding challenges linear models



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of physical literacy that assume direct effects and instead supports a process-based perspective in which behavior acts as the operational bridge between competence and outcome.

This research directly supports the achievement of several Sustainable Development Goals (SDGs) indicators, particularly SDG 3, SDG 4, and SDG 11. Physical health and inclusive education are key requirements for a productive future generation (Wei & Lihua, 2023; Zhou et al., 2024). Innovations in educational design like this are important for accelerating the transformation of education based on sustainability. This model also has high replicability because it is designed in a modular and flexible manner. By referring to the specific needs of each ASEAN country, this model can be developed without compromising local cultural values (Xu, 2023). This approach reinforces the principles of relevant and contextual education.

From a theoretical perspective, the findings of this study strengthen the argument that physical and nutritional literacy are important prerequisites for student learning well-being. This positive relationship is reflected in the correlation between physical literacy and holistic development ($r = 0.74$), as well as nutritional literacy and student development ($r = 0.69$), both of which are statistically significant ($p < 0.005$), reinforcing the theoretical foundation that fitness and nutrition impact academic achievement and overall well-being. This relationship is reinforced by studies showing a correlation between physical activity and academic outcomes (Zagkos et al., 2023). Therefore, physical education is not merely a practical subject but an integral part of quality-of-life development. Playground design also fosters cognitive and creative aspects of students through free play and social interaction. This aligns with creative development theory, which states that play spaces can facilitate the growth of imagination and cooperation (Dumas et al., 2024; Leri et al., 2024). This research provides empirical evidence that physical education should be oriented toward cross-domain learning. The participation of teachers and students in user validation is a strength in itself. In many studies, user involvement enhances the relevance and sustainability of an educational product. This demonstrates that education is not only for students but also with students.

The success of this model also shows that technology does not conflict with physical education but can strengthen it. The use of appropriate technology such as pedometers and



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nutrition apps promotes the development of data-driven approaches Digital transformation in physical education is inevitable in the era of the 4th Industrial Revolution. Overall, this research provides a strong, practical, and culturally appropriate model for physical education and nutrition. This model has the potential to be widely adapted in ASEAN and other regions facing similar challenges (Suárez-Orozco, 2019; Pasek et al., 2022). This integrated framework represents a significant advancement.

These findings extend existing physical literacy theory by demonstrating that movement competence alone is insufficient to promote holistic development unless accompanied by sustained behavioral engagement and supportive learning environments. This interpretation aligns with ecological and behavioral perspectives that conceptualize child development as the product of dynamic interactions between individual competencies and environmental opportunities. Consequently, pedagogical innovations that encourage active participation, meaningful movement experiences, and game-based learning may facilitate higher motivation and regular physical activity engagement, reinforcing the role of physical education as a multidimensional educational platform that supports lifelong healthy behaviors and holistic child development (Akkoyun et al., 2024; Viciania et al., 2025).

This study has several limitations. First, the study focused primarily on elementary school students within selected ASEAN educational contexts, which may limit the generalizability of findings to other regions and educational systems. Second, the cross-sectional nature of the quantitative phase restricts causal inference among the proposed constructs despite the structural modelling approach. Third, the instruments were validated within specific sociocultural contexts and may require further adaptation for different populations. Finally, the study did not examine long-term behavioral change following implementation of the integrated framework.

Conclusion

This study successfully developed and empirically validated an integrated ASEAN-based framework linking physical literacy, nutrition literacy, playground creativity, and daily physical activity to holistic student development. The findings demonstrated significant



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positive relationships among all variables, supporting the multidimensional nature of children's physical, cognitive, and social development and confirming the mediating role of daily physical activity within the proposed structural model. The study extends current literature by providing a mechanism-based explanation of how physical literacy, nutrition literacy, and supportive play environments jointly contribute to holistic development, moving beyond fragmented and purely correlational approaches. In doing so, it addresses an important scientific gap and offers a contextually relevant framework for ASEAN educational settings. From a practical perspective, these findings provide evidence for curriculum developers, school administrators, and educational policymakers to integrate physical literacy, nutrition literacy, and creative playground design into elementary education and school health promotion policies. Investment in inclusive playground infrastructure and interdisciplinary physical education programs may support healthier lifestyles, active learning, and sustainable child development across ASEAN countries.

Although the framework demonstrated promising validity, the study was limited by its relatively small sample size, cross-sectional design, and restricted implementation context. Future longitudinal and multi-country studies are recommended to evaluate the long-term effectiveness, scalability, and policy implementation of the proposed framework. Overall, the primary objective of developing and validating an integrated mechanism-based model for promoting holistic student development in ASEAN schools has been successfully achieved, providing both theoretical advancement and practical guidance for future educational innovation and policy development.



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