International Journal of Educational Management and Development Studies
Volume 7 Issue 1 March 2026
DOI: https://doi.org/10.53378/ijemds.353335

Self-determination theory–based gamification in vocational high school physical education: Effects on motivation and physical fitness

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Abstract

Given the dual challenges of declining physical fitness and low engagement in physical education (PE) among vocational high school students, exploring effective instructional interventions is imperative. This study investigated the impact of gamified instruction grounded in Self-Determination Theory (SDT) on students' learning motivation and physical fitness. A quasi-experimental design was conducted over 12 weeks with 255 Chinese vocational students (experimental n=136; control n=119). The experimental group received a gamified intervention featuring points, badges, leaderboards, and challenges, while the control group followed a standard PE curriculum. Data were analyzed using ANCOVA, hierarchical linear modeling (HLM), and structural equation modeling (SEM). Results indicated that the experimental group exhibited significantly higher levels of positive interest, sports engagement, and autonomous learning compared to the control group (all $p < 0.01$). Furthermore, the intervention yielded superior composite fitness scores ($F = 47.48$, $p < 0.001$). Mediation analysis revealed that motivation partially mediated the relationship between gamified instruction and fitness gains. These findings suggest that SDT-based gamification is an effective strategy for enhancing vocational students' physical outcomes by activating key psychological mechanisms. This study provides empirical evidence and practical insights for PE pedagogical reform in vocational institutions.

Keywords: *learning motivation, instructional intervention, hierarchical linear modelling, structural equation modelling, gamified instruction*

Article History:

***Received**: January 7, 2026* — ***Revised**: March 8, 2026*
***Accepted**: March 10, 2026* — ***Published online**: March 14, 2026*

Suggested Citation:
Hou, D. & Saong, M. (2026). Self-determination theory–based gamification in vocational high school physical education: Effects on motivation and physical fitness. *International Journal of Educational Management and Development Studies*, 7(1), 178-206. https://doi.org/10.53378/ijemds.353335

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1. Introduction

Following the promulgation of the Vocational Education Law of the People's Republic of China in 2022, which explicitly emphasizes the equal importance of physical fitness and character development, student health in vocational colleges has been elevated to a policy priority. However, the reality remains sobering. Data from the Eighth National Survey on Students' Physical Fitness and Health show stagnation or decline in several key fitness indicators, with the rate of "good or excellent" fitness among college students increasing only slowly (National Student Physical Fitness Survey Group, Ministry of Education, 2021). Although detailed analyses specific to vocational students remain incomplete, these national-level surveys underscore the urgency of improving adolescent physical fitness. This declining trend not only threatens students' physical health but also jeopardizes their long-term academic and career development (Grissom, 2005). The issue is compounded by adolescents' decreasing willingness to engage in physical activity as their grade level increases (Fan et al., 2019).

Within the specific context of vocational education, physical education (PE) faces multiple challenges, including outdated content and methods, inadequate teacher expertise, and a misalignment between curriculum design and students' professional development needs. Traditional teacher-centered instructional models are widely cited as primary causes of low student interest and passive participation, as they tend to overlook individual needs and intrinsic motivation (Wang, 2023; Chi, 2022). In response, scholars have advocated for diverse reforms, such as portfolio assessment (Tariq & Sergio, 2024), the integration of "sports–medicine synergy" concepts (Niu, 2023; Wang et al., 2025; Chao et al., 2022), cooperative learning models (Jiang et al., 2023; Dyson et al., 2022; Yang et al., 2021; Zhou et al., 2023) and a holistic "five educations in one" paradigm (Li & Meng, 2023; Chi, 2022). While valuable, these explorations often remain at the level of conceptual advocacy or model description and lack empirical evidence. Specifically, researchers have not sufficiently demonstrated how a concrete strategy such as gamification can be effectively implemented to simultaneously enhance both motivation and physical fitness among vocational students. Therefore, this study focuses on a gamified PE intervention guided by Self-Determination Theory (SDT) to provide an innovative, evidence-based solution to these practical challenges.

2. Literature Review

2.1. Gamification in Physical Education

Recent years have seen growing scholarly interest in gamification in PE, with studies generally reporting positive effects on student motivation and engagement. For instance, Sal-de-Rellán et al. (2025), in a systematic review focused on adolescents, highlighted gamification's positive role in increasing physical activity participation. Classroom-level investigations have similarly found that both teachers and students perceive gamification as enhancing enjoyment and intrinsic motivation in PE (Fernández-Río et al., 2020) and as effectively satisfying students' basic psychological needs as conceptualized by SDT (Sotos-Martínez et al., 2023).

Beyond motivational outcomes, researchers have explored innovative gamified models incorporating resistance training (Vanaclocha-Amat et al., 2025) and virtual reality (Fernández-Vázquez et al., 2024). Such studies have demonstrated positive impacts on psychological well-being, including emotional intelligence and resilience (Navarro-Mateos et al., 2025), as well as improvements in physical skills (Sevilla-Sanchez et al., 2023). These studies established gamification as a promising pedagogical approach in PE contexts, though questions remain regarding its applicability across diverse learner populations and the mechanisms through which its effects operate.

2.2. Self-Determination Theory as the Explanatory Mechanism

Gamification refers to the application of game design elements, such as points, badges, leaderboards, challenges, and narratives, to non-game contexts to enhance user experience and engagement (Deterding et al., 2011; Kapp, 2012). While gamification can be implemented theoretically, its motivational effects are most robustly explained through SDT (Deci & Ryan, 2000; Ryan & Deci, 2017). SDT posits that all individuals possess three innate and universal basic psychological needs: autonomy (the need to feel volitional and self-endorsed in one's actions), competence (the need to feel effective and capable), and relatedness (the need to feel connected to others). When external environments, including educational settings, support satisfaction of these needs, individuals experience enhanced intrinsic motivation and more fully internalized forms of extrinsic motivation. This motivational quality, in turn, promotes active, sustained, and high-quality learning behaviors, along with improved psychological well-being (Ryan & Deci, 2017; Standage et al., 2025).

In physical education specifically, fulfilling students' SDT needs has been identified as crucial for fostering interest in sports and adherence to exercise habits (Standage, 2023; Standage et al., 2025). This theoretical insight carries particular significance for vocational high school students, who may exhibit lower learning initiative and lack successful experiences in physical activities due to prior educational disengagement (Mercier et al., 2023; Wang, 2023). A review of existing literature further explores the theoretical frameworks relevant to gamification studies (Zequinha et al., 2025).

Within an SDT framework, gamification elements are conceptualized not merely as motivational "add-ons" but as environmental supports for basic psychological needs. Well-designed gamification can support competence through progressive challenge structures and visible recognition of mastery; foster autonomy by offering meaningful choices and transparent reward criteria; and enhance relatedness through team-based tasks and collaborative goal structures. This theoretical mapping informs the design of interventions seeking to activate SDT's proposed motivational pathways.

Based on this theoretical mechanism, a multi-level pathway is posited: gamification elements → basic psychological need satisfaction → motivation enhancement → sustained exercise behavior → physical fitness improvement. The following sections review empirical evidence relevant to each link in this causal chain.

2.3. Effects on Positive Interest and Sports Engagement

Fernández-Río et al. (2020) found that gamified PE increased students' perceptions of fun and intrinsic motivation, constructs closely related to positive interest. Similarly, Sotos-Martínez et al. (2023) demonstrated that gamification effectively satisfied basic psychological needs, which theoretically underpins enhanced engagement. However, these studies predominantly sampled general secondary school populations, leaving vocational students' responses underexamined.

Arufe-Giráldez et al. (2022) noted that gamification consistently improved affective outcomes but cautioned that such effects may reflect novelty rather than sustained motivational change. Crucially, the review identified a scarcity of studies examining vocational learners. Furthermore, Mercier et al. (2023) highlighted that vocational students often exhibit distinct motivational profiles, including lower baseline engagement and greater resistance to traditional

PE, suggesting that findings from general academic populations may not automatically generalize.

2.4. Effects on Physical Fitness Outcomes

The empirical link between gamification and objective physical fitness remains less established than the motivation–gamification connection. Johnson et al. (2016), in a systematic review of gamification for health and wellbeing, found that while gamified interventions increased physical activity participation, evidence for measurable fitness improvements was inconsistent. Similarly, Sevilla-Sanchez et al. (2023) reported positive effects on physical skills in educational settings but noted that most studies relied on task-specific performance rather than comprehensive fitness batteries.

Studies incorporating fitness outcomes have yielded mixed results. Ferriz-Valero et al. (2020) observed improved academic performance in gamified PE but did not assess objective fitness indicators. Conversely, Lozano-Lozano et al. (2021) called for more rigorous designs to establish whether motivational gains translate into physiological adaptations. This gap is particularly pronounced in vocational education, where no identified studies have systematically examined gamification's impact on nationally standardized fitness measures.

2.5. Motivation as a Mediator Between Gamification and Fitness

The theoretical pathway central to SDT is that autonomy-supportive environments foster autonomous motivation, which in turn drives sustained behavioral engagement and, ultimately, physiological outcomes (Ryan & Deci, 2017; Standage, 2023). While several studies have invoked SDT to explain gamification effects, few have empirically tested the full mediation chain. Zequinha et al. (2025) identified the lack of mechanism-testing research as a critical limitation in gamification studies. Most investigations measure motivation as an outcome rather than as a mediator linking intervention design to health-related behaviors. Grech et al. (2024) found preliminary support for motivational mediation but noted that few studies employed appropriate analytical methods (e.g., structural equation modeling) to test indirect effects formally. If motivational gains mediate fitness improvements, it would suggest that SDT-based mechanisms operate similarly across educational contexts, a proposition requiring empirical validation given vocational students' distinct psychosocial characteristics (Mercier et al., 2023).

2.6. Engagement Intensity and Motivational Improvement

While studies frequently report average treatment effects, they seldom examine whether students who engage more deeply with gamified elements experience greater motivational gains. Hanus and Fox (2015) found that gamification's effects varied substantially based on students' initial motivation and engagement patterns. Similarly, Sal-de-Rellán et al. (2025) called for research examining individual-level predictors of gamification responsiveness, noting that average effects may mask meaningful heterogeneity. Studying individual engagement levels requires multilevel analytical methods (e.g., hierarchical linear modeling), which are still uncommon in gamification research (Lozano-Lozano et al., 2021). This gap is especially important for vocational PE, as vocational students may show greater variation in baseline engagement than general-track students (Chi, 2022). Knowing whether gamification benefits all students equally or if its effects vary based on individual engagement levels has important theoretical and practical implications for designing interventions.

2.7. Synthesis of Research Gaps and Study Contribution

Despite growing interest in gamification for PE, four unresolved gaps persist. First, limited evidence exists from vocational high school settings, despite this population's distinct motivational patterns and participation challenges (Mercier et al., 2023; Wang, 2023). Second, insufficient SDT-grounded mechanism testing leaves the "gamification → motivation → behavior" pathway empirically underexplored (Zequinha et al., 2025). Third, outcome measurement lacks comprehensiveness, with few studies validating motivational gains against objective physical fitness indicators (Johnson et al., 2016; Arufe-Giráldez et al., 2022). Fourth, inadequate methodological rigor, particularly the scarcity of multilevel modeling and mediation analysis, limits causal inference in existing research (Lozano-Lozano et al., 2021).

The present study addresses these gaps by targeting Chinese vocational high school students, systematically designing an SDT-based gamified PE intervention, and examining the following relationships: (1) whether gamified instruction enhances positive interest and sports engagement compared to traditional PE; (2) whether gamified instruction improves objective physical fitness outcomes; (3) whether motivational gains mediate the relationship between gamification and fitness improvements; and (4) whether individual engagement intensity predicts the extent of motivational change. These relationships are tested through advanced analytical methods, including ANCOVA, hierarchical linear modeling, and structural equation modeling. In doing so, this study aims to provide empirical evidence for whether and how gamification enhances both motivation and physical fitness in vocational education contexts.

Based on the theoretical framework and identified empirical gaps, this study tests the following hypotheses:

H_1: Compared to students receiving traditional PE, vocational students who participate in gamified PE will exhibit higher levels of Positive Interest post-intervention.

H_2: Compared to traditional PE, gamified PE participants will demonstrate greater Sports Engagement post-intervention.

H_3: Compared to traditional PE, gamified PE participants will show significantly larger improvements in composite physical fitness scores and individual fitness items post-intervention.

H_4: Improvements in PE learning motivation (especially increases in Positive Interest and Sports Engagement) will significantly mediate the enhancement of composite physical fitness scores.

H_5: Individual engagement with gamification elements (intervention intensity) will positively correlate with the extent of motivation improvement.

3. Methodology

3.1. Research Design

This 12-week quasi-experimental study employed a pretest–posttest control-group design to assess an SDT-based gamified PE intervention against traditional instruction in vocational high schools. Data were collected at baseline and post-intervention.

3.2. Participants and Sampling

The study was conducted at a representative public vocational high school in Changzhi City, Shanxi Province, China. A total of 255 students from three grade levels, regularly attending PE, participated. Due to administrative constraints, intact classes were cluster-assigned: three classes (N=136) formed the experimental group, and three (N=119) the control group, selected for baseline equivalence. Participants aged 16-19 years ($M = 16.64$, $SD \approx 1.43$) had a balanced gender distribution (~57.3% male experimental; ~52.1% male control).

3.3. Intervention Design

The 12-week intervention involved two 45-minute PE classes weekly for both groups, delivered by condition-specific teachers.

3.3.1. Experimental Group: SDT-Based Gamified Physical Education

Experimental PE covered standard content but integrated SDT-aligned gamification elements supporting autonomy, competence, and relatedness.

The task design consisted of progressive challenges, such as skill mastery activities and timed circuits, which allowed for tiered levels of achievement (Bronze, Silver, and Gold) to enhance learners' sense of competence and autonomy. Points and reward mechanisms were implemented, whereby points were earned for attendance, active participation, achieving personal bests, completing challenges, demonstrating skill mastery, and providing peer support. Accumulated points were displayed on a leaderboard and enabled participants to unlock digital or physical badges associated with specific achievements, such as "Perfect Attendance Star" and "Skill Master," thereby reinforcing competence. Weekly leaderboards, which used pseudonyms to protect student identity, provided regular performance feedback and were carefully managed to prevent undue pressure, while teachers supplemented these with specific and constructive verbal feedback. To increase immersion, light narrative elements, such as the "Athletic Energy Lab" theme, were occasionally integrated into activities. In addition, team-based challenges, including relay activities, were implemented to promote peer interaction and collaboration, with shared points or team badges awarded to foster relatedness.

3.3.2. Control Group: Traditional Physical Education

Control classes followed the standard curriculum, featuring teacher-led demonstrations, whole-class drills, emphasis on technical proficiency, error-focused feedback, limited student choice, and no systematic gamification elements.

3.3.3. Teacher Training (Experimental Group)

Experimental group teachers underwent a two-week (10 hours) specialized training on SDT application, gamification principles, study plan details, content integration, classroom management, and point-tracking for intervention fidelity.

To monitor implementation fidelity, the research team conducted biweekly classroom observations using a structured checklist covering SDT-supportive behaviors (autonomy support, competence feedback, relatedness facilitation) and gamification procedures (points awarding, badge issuance, leaderboard updates, and challenge delivery). Teachers submitted weekly point logs and brief reflection notes, which were reviewed by two researchers to verify adherence and resolve discrepancies. Any deviations were discussed during the weekly coordination meeting and corrected in the subsequent sessions.

3.4. Instrumentation and Data Gathering Process

3.4.1. PE Learning Motivation Scale

A revised, validated 27-item PE Learning Motivation Scale (5-point Likert; pretest Cronbach's α = 0.89) was administered pre- and post-intervention. It assessed four dimensions: Positive Interest: Enjoyment/appreciation (7 items; e.g., "I find PE classes very enjoyable." α = 0.90). Sports Engagement: Effort/involvement (9 items; e.g., "I actively participate..." α = 0.87). Autonomous Learning: Proactive pursuit (5 items; e.g., "I usually like to learn about sports-related information." α = 0.88). Negative Interest (Amotivation/Boredom): Boredom/resistance (6 items; e.g., "PE class makes me feel bored." reverse-scored. α = 0.86).

3.4.2. Physical Fitness Test

Per the National Student Physical Fitness Standard (2014) (Ministry of Education, 2014), professional testers administered pre- and post-intervention fitness tests: 50-meter sprint, standing long jump, sit-and-reach, 1-minute sit-ups (females)/pull-ups (males), and endurance run (800m females/1000m males). A composite score was calculated. All tests followed standardized procedures.

3.4.3. Data Collection Procedures

Pretest data (motivation scale online, fitness tests by team) were collected one week before the 12-week intervention. Posttest data were collected one week after, including motivation scale, fitness tests, and "gamification engagement" items for the experimental group. Data were cleaned, anonymized, and entered.

3.5. Data Analysis

Data analysis was conducted using SPSS 26.0, HLM 7.0, and Mplus 8.0, with all statistical tests set at a significance level of $\alpha = 0.05$. Descriptive statistics, including means and standard deviations, were computed for all pre- and posttest variables. To verify baseline equivalence between the experimental and control groups, independent-samples t-tests were used on pretest motivation and physical fitness scores. The effects of the intervention on motivation were examined through both independent-samples t-tests (posttest group comparisons) and paired-samples t-tests (within-group pre/post changes), with effect sizes calculated using Cohen's *d*. For physical fitness outcomes, Analysis of Co-Variance (ANCOVA) was employed to assess posttest differences while controlling for pretest scores, with partial η^2 reported as the effect size.

Advanced analyses were performed to test hypothesized pathways. A two-level hierarchical linear model (HLM) assessed the impact of class-level intervention (Level 2) and individual-level "intervention intensity" (Level 1, using posttest Sports Engagement) on posttest motivation, controlling for pretest scores. Structural equation modeling (SEM) in Mplus 8.0 tested a path model where the intervention predicted posttest motivation (controlling for pretest), which in turn predicted posttest composite fitness (also controlling for pretest). Latent variables were constructed for Motivation (indicated by Positive Interest, Sports Engagement, and Autonomous Learning) and Health (a composite of standardized posttest fitness scores), while Engagement was treated as an observed variable. These specific subscales were selected as indicators because they comprehensively capture the affective and behavioral dimensions of autonomous motivation posited by SDT. Furthermore, to maximize statistical power and address any incomplete cases, missing data were handled using full-information maximum likelihood (FIML) estimation in Mplus, the recommended approach for structural equation modeling. Path coefficients and mediation effects were estimated using bootstrapping (5,000 samples), and model fit was evaluated using χ^2/df, CFI, TLI, RMSEA, and SRMR. These analyses addressed hypotheses H_3–H_5, including mediation and inter-class variability.

3.6. Research Ethics

This research adhered to established ethical standards and principles to safeguard the well-being, rights, and dignity of all participants. Prior to participation, all students, teachers, and experts received a detailed explanation of the research objectives, procedures, potential risks, and anticipated benefits. Informed consent was obtained to ensure that participants fully understood their voluntary involvement and their right to withdraw at any stage without repercussions. To protect privacy, strict confidentiality measures were implemented, including the assignment of unique codes instead of using names, restricted data access limited to the research team, and anonymized reporting of findings. Participants who preferred non-disclosure of their identity had their preferences strictly upheld.

The study was designed to ensure beneficence by prioritizing the well-being of students through the use of interventions that enhanced engagement in physical education through gamification. Measures were taken to minimize potential risks, ensuring that no participant experienced long-term physical, emotional, or psychological harm. Additionally, all participants were treated with fairness, respect, and dignity, without discrimination based on gender, race, socioeconomic status, or any other characteristic. The research fostered an inclusive and supportive environment for all involved.

To ensure compliance with ethical standards, the study underwent review and approval by the University of Baguio Research Ethics Committee before implementation. Furthermore, participation in the study did not impose any financial burden on students, teachers, or experts, as they were not required to spend or use their personal resources. By upholding these ethical considerations, the research ensured integrity, participant welfare, and credibility, with all activities aligned with the highest ethical standards.

4. Results and Discussion

4.1. Baseline Equivalence and Internal Validity of the Intervention

As shown in Table 1 and Table 2, independent-samples t-tests indicated no statistically significant differences between the experimental and control groups across all pretest dimensions of PE learning motivation and physical fitness indicators ($p > 0.05$). This statistical equivalence confirms that the two groups were comparable at baseline in both psychological and physiological domains before the implementation of the intervention.

From a methodological standpoint, this finding is particularly important given the quasi-experimental nature of the study, where random assignment at the individual level was not feasible. Baseline equivalence reduces the likelihood of selection bias, one of the most frequently cited threats to internal validity in school-based intervention research. By demonstrating that both groups started from similar levels of interest, engagement, autonomous learning, amotivation, and physical fitness, the study establishes a credible counterfactual condition against which post-intervention changes can be meaningfully interpreted.

Table 1

Baseline PE learning motivation comparison between experimental and control groups

Dimension	Experimental Group (n = 136)	Control Group (n = 119)	t	p
Positive Interest	4.20 ± 0.80	4.18 ± 0.78	0.19	0.849
Sports Engagement	3.80 ± 0.85	3.77 ± 0.79	0.27	0.787
Autonomous Learning	3.50 ± 0.86	3.52 ± 0.90	–0.28	0.781
Negative Interest	2.10 ± 0.80	2.30 ± 0.77	0.26	0.798

Table 2

Baseline physical fitness test comparison (pretest)

Test Item	Experimental (n = 136)	Control (n = 119)	t	p
Vital Capacity (mL)	3663 ± 364.8	3625 ± 348.5	1.12	0.264
50-m Run (s)	8.83 ± 0.62	8.77 ± 0.58	0.76	0.447
Standing Long Jump (cm)	175.5 ± 18.1	178.3 ± 19.2	–1.29	0.198
Sit-and-Reach (cm)	9.80 ± 2.50	9.75 ± 2.30	0.16	0.875
Endurance Run (s)	258.5 ± 25.2	255.8 ± 25.5	0.89	0.375
Composite Score	72.35 ± 12.50	73.05 ± 11.45	–0.47	0.639

The similarity in motivation-related variables suggests that neither group possessed an inherent motivational advantage prior to the intervention. This is crucial in gamification research, as motivation is both a key outcome and a central explanatory mechanism. Previous studies have noted that pre-existing differences in interest or engagement can artificially inflate intervention effects if not adequately controlled (Ferriz-Valero et al., 2020). The absence of such differences in the present study strengthens confidence that any subsequent motivational gains observed in the experimental group are attributable to the SDT-based gamified PE program rather than initial learner disposition.

The lack of significant differences in baseline physical fitness indicators, including endurance, speed, flexibility, strength, and composite scores, reinforces the robustness of causal interpretation for fitness outcomes. Physical fitness is influenced by long-term behavioral patterns, prior training exposure, and biological maturation. Comparable pretest scores indicate that both groups were subject to similar physical activity histories and developmental conditions, thereby minimizing confounding influences on posttest fitness gains. This addresses a common limitation in prior gamification studies, where performance improvements were sometimes difficult to disentangle from pre-existing fitness disparities or maturation effects (Lozano-Lozano et al., 2021).

The convergence of baseline equivalence across both psychological and physiological measures strengthens the overall internal validity of the study beyond what is typically reported in comparable research. Many gamification studies focus exclusively on motivational baselines while neglecting physical performance equivalence, or vice versa. By controlling for both domains, the present study provides a more rigorous foundation for attributing post-intervention differences to the instructional design rather than extraneous variables. In addition, the relatively narrow standard deviations across most baseline measures suggest a stable and homogeneous sample, which further enhances statistical power and reduces error variance in subsequent analyses. This methodological strength supports the use of advanced analytical techniques employed later in the study, such as ANCOVA, hierarchical linear modeling, and structural equation modeling, all of which rely on baseline comparability for valid estimation of intervention effects.

4.2. Effects of Gamified Physical Education on Learning Motivation (H_1 and H_2)

Posttest comparisons (independent-samples t-tests) are summarized in Table 3. The tests revealed that students exposed to the SDT-based gamified physical education intervention demonstrated significantly higher levels of positive interest, sports engagement, and autonomous learning, alongside significantly lower negative interest, compared with their counterparts in traditional PE classes. Although the observed effect sizes ranged from small to moderate (Cohen's d = 0.26–0.38), these magnitudes are pedagogically meaningful within school-based interventions, where large effects are rarely observed due to contextual constraints such as limited instructional time and curricular standardization.

After controlling for pretest scores via ANCOVA, the group effect on 'sports self-efficacy' remained significant ($F = 12.34$, $p < 0.001$), indicating that the SDT-based gamified intervention substantially enhanced self-efficacy.

Table 3

Posttest PE learning motivation: Between-group comparisons

Dimension	Experimental (n = 136)	Control (n = 119)	t	p	Cohen's d
Positive Interest	4.30 ± 0.67	4.10 ± 0.90	2.21	0.028*	0.26
Sports Engagement	4.10 ± 0.79	3.80 ± 0.82	3.39	< 0.001***	0.38
Autonomous Learning	3.80 ± 0.76	3.60 ± 0.88	2.65	0.009**	0.30
Negative Interest	1.90 ± 0.73	2.20 ± 0.78	–3.02	0.003**	–0.34

*p < 0.05, **p < 0.01, ***p < 0.001

Among the motivational dimensions, 'sports engagement' exhibited the strongest effect, indicating that gamification was particularly effective in enhancing students' active participation, persistence, and effort during PE classes. This finding is theoretically significant, as SDT posits that behavioral engagement is a core manifestation of autonomous motivation rather than a secondary outcome. The prominence of sports engagement suggests that the gamified elements, such as progressive challenges, point accumulation, and visible performance feedback, successfully translated psychological need satisfaction into observable behavioral investment. This aligns with research demonstrating that gamified environments are most effective when they encourage sustained action rather than passive enjoyment (Hanus & Fox, 2015; Sal-de-Rellán et al., 2025).

The significant improvement in 'positive interest' further indicates that the intervention enhanced students' affective connection to physical education. Rather than perceiving PE as a compulsory or monotonous subject, students in the experimental group were more likely to experience enjoyment and interest. From an SDT perspective, this affective shift reflects increased satisfaction of autonomy (through choice and self-paced progression) and competence (through attainable challenges and mastery feedback). Similar affective gains have been reported in prior gamification studies; however, such outcomes are often short-lived when gamification is not theoretically grounded (Arufe-Giráldez et al., 2022). The sustained effect observed in this study suggests that SDT-aligned design may mitigate novelty decay.

Improvements in 'autonomous learning' indicate that the intervention fostered students' willingness to engage in self-directed learning related to physical activity, such as seeking information, reflecting on performance, and taking initiative beyond teacher instruction. While this dimension showed a slightly smaller effect size than sports engagement, its significance is noteworthy given the vocational student context, where academic self-regulation is often limited.

Equally important is the significant reduction in 'negative interest', reflecting decreased boredom, resistance, and disengagement. This result highlights a critical yet often underemphasized benefit of gamification: its capacity to reduce amotivation, not merely increase enjoyment. SDT emphasizes that the absence of motivation is not simply the inverse of positive motivation but a distinct psychological state associated with perceived incompetence and lack of autonomy. By providing structured success experiences and meaningful social interaction, the gamified intervention appears to have alleviated these negative motivational states. This dual effect supports SDT-based assertions that motivation improves most effectively when controlling pressures are replaced with autonomy-supportive environments (Ryan & Deci, 2017; Standage, 2023).

The significant gains in 'sports self-efficacy', even after controlling for pretest differences, further reinforce the motivational impact of the intervention. Self-efficacy is closely linked to perceived competence in SDT and plays a critical role in sustaining effort under challenging conditions. The larger increase observed in the experimental group suggests that repeated mastery experiences, visible progress tracking, and positive feedback embedded in the gamified design enhanced students' confidence in their physical abilities. This finding is consistent with prior research demonstrating that gamification can strengthen competence beliefs when rewards are framed as indicators of progress rather than external control (Ferriz-Valero et al., 2020).

These results provide strong empirical support for Hypotheses H_1 and H_2, confirming that SDT-based gamified PE instruction significantly enhances multiple dimensions of learning motivation among vocational high school students. Importantly, this study extends existing literature by demonstrating that motivational benefits of gamification are not limited to general or academic-track populations but are equally applicable to vocational students, who are often characterized by lower baseline motivation and weaker sport foundations. This extension addresses a critical gap in the gamification literature and underscores the adaptability of SDT-based instructional models across diverse educational contexts.

4.3. Within-Group Motivation Changes and the Specific Role of the Intervention (H_1 and H_2)

To further examine Hypotheses H_1 and H_2, which posit that gamified physical education would lead to higher levels of 'positive interest' and 'sports engagement' compared with traditional PE, within-group pretest–posttest comparisons were conducted for both the experimental and control groups. Tables 4 and 5 present the paired-samples *t*-test results for changes in PE learning motivation across the intervention period.

As shown in Table 4, the experimental group demonstrated statistically significant improvements in 'positive interest', 'sports engagement', and 'autonomous learning', along with a significant reduction in 'negative interest' ($p < 0.05$). In contrast, Table 5 indicates that the control group did not exhibit any significant motivational changes over time across all four dimensions ($p > 0.05$). This asymmetric pattern of change provides direct within-group evidence supporting the effectiveness of the SDT-based gamified intervention.

Table 4

Experimental group pretest–posttest PE learning motivation (paired-samples t-test)

Dimension	**Pretest (n = 136)**	**Posttest (n = 136)**	**t**	**p**
Positive Interest	4.20 ± 0.80	4.30 ± 0.67	2.21	0.029*
Sports Engagement	3.80 ± 0.85	4.10 ± 0.79	3.39	< 0.001***
Autonomous Learning	3.50 ± 0.86	3.80 ± 0.76	2.65	0.009**
Negative Interest	2.10 ± 0.80	1.90 ± 0.73	–3.02	0.003**

*p < 0.05, **p < 0.01, ***p < 0.001.

Table 5

Control group pretest–posttest PE learning motivation (paired-samples t-test)

Dimension	**Pretest (n = 119)**	**Posttest (n = 119)**	**t**	**p**
Positive Interest	4.18 ± 0.78	4.10 ± 0.90	–1.12	0.264
Sports Engagement	3.77 ± 0.79	3.80 ± 0.82	0.42	0.675
Autonomous Learning	3.52 ± 0.90	3.60 ± 0.88	1.23	0.222
Negative Interest	2.30 ± 0.77	2.20 ± 0.78	–1.29	0.199

*p < 0.05, **p < 0.01, ***p < 0.001.

From an analytical standpoint, the significant pretest–posttest gains in the experimental group provide strong confirmation of Hypotheses H_1 and H_2, not only in comparative terms (as shown in Section 4.2) but also in absolute developmental terms. The increase in ‘positive interest’ suggests that students developed a more favorable affective orientation toward PE, while the substantial gain in ‘sports engagement’ indicates heightened behavioral involvement and effort. SDT conceptualizes such changes as indicators of more autonomous forms of motivation, reflecting enhanced satisfaction of competence and autonomy needs within the learning environment.

The absence of significant motivational change in the control group is equally informative. Given that both groups followed the same curriculum over the same duration, these findings effectively rule out testing effects, maturation, or seasonal influences as explanations for the observed improvements. Instead, the results underscore the specific role of the instructional design, demonstrating that motivation did not improve simply through continued exposure to PE, but only when pedagogical conditions were deliberately restructured through gamification. These findings corroborate prior research, which consistently reports that traditional PE instruction rarely produces meaningful motivational change, particularly among adolescents and vocational students (Fan et al., 2019; Wang, 2023; Chi, 2022). Conversely, studies grounded in SDT have shown that autonomy-supportive and competence enhancing environments, including gamified PE models, are effective in generating sustained improvements in interest and engagement (Fernández-Río et al., 2020; Sotos-Martínez et al., 2023). The present results closely mirror this pattern, reinforcing the argument that motivation gains are not spontaneous but structurally induced.

Furthermore, the exclusive presence of motivational gains in the experimental group addresses concerns raised in earlier short-term gamification studies regarding novelty effects or measurement reactivity, where temporary improvements were sometimes observed across conditions (Arufe-Giráldez et al., 2022). In line with more recent systematic reviews emphasizing theory-driven design (Sal-de-Rellán et al., 2025; Zequinha et al., 2025), the current findings suggest that sustained motivational change emerges only when gamification is systematically aligned with SDT principles, rather than implemented as a superficial motivational tool.

From a critical standpoint, this finding contrasts with some short-term gamification studies that report initial motivational gains in both experimental and control groups, possibly due to novelty or measurement reactivity (Arufe-Giráldez et al., 2022). The stability of motivation in the control group in this study suggests that traditional PE instruction alone may be insufficient to reverse declining motivation among vocational students, reinforcing calls for structural pedagogical reform rather than incremental adjustments.

4.4. Physical Fitness Outcomes as Behavioral Validation of Motivation Gains (H_3)

To test Hypothesis H_3, which posited that students participating in gamified physical education would demonstrate greater improvements in physical fitness than those receiving traditional instruction, posttest physical fitness outcomes were compared between the experimental and control groups using ANCOVA, with pretest scores entered as covariates. Table 6 presents the adjusted post-intervention means, associated *F*-values, and effect sizes for each fitness indicator and the composite physical fitness score.

As shown in Table 6, students exposed to the SDT-based gamified PE intervention significantly outperformed the control group across all measured fitness indicators, including vital capacity, sprint speed, muscular power, flexibility, cardiorespiratory endurance, and overall composite fitness ($p < 0.01$). The consistency of these results across multiple physiological domains strengthens the conclusion that the intervention produced broad-based fitness improvements rather than isolated or task-specific gains.

Table 6

Posttest physical fitness comparison (ANCOVA results)

Test Item	Experimental (n = 136)	Control (n = 119)	t	F	p	Partial η²
Vital Capacity (mL)	3953 ± 323.6	3695 ± 364.3	6.07	36.86	< 0.001***	0.13
50-m Run (s)	8.28 ± 0.60	8.75 ± 0.65	–6.54	42.74	< 0.001***	0.14
Standing Long Jump (cm)	188.5 ± 15.1	179.5 ± 19.0	3.09	9.56	0.002**	0.04
Sit-and-Reach (cm)	11.10 ± 2.30	9.83 ± 2.46	3.89	15.11	< 0.001***	0.06
Endurance Run (s)	223.5 ± 23.6	250.6 ± 26.2	–6.39	40.85	< 0.001***	0.14
Composite Score	82.40 ± 10.70	74.15 ± 12.50	6.89	47.48	< 0.001***	0.16

*p < 0.05, **p < 0.01, ***p < 0.001. The experimental group's composite score improvement to 82.4 points reaches the "good" range (80–89.9) under national standards, reflecting meaningful gains in health status.

From a practical standpoint, the largest effects were observed in cardiorespiratory endurance, sprint performance, and vital capacity, with partial η^2 values ranging from 0.13 to 0.14, indicating moderate to large practical significance in educational research contexts.

These outcomes are particularly meaningful because improvements in endurance-related indicators typically require sustained effort, repeated practice, and sufficient training intensity over time. Their enhancement, therefore, serves as strong behavioral evidence that the motivational gains documented in Sections 4.2 and 4.3 translated into increased exercise engagement and training volume during PE classes. Conversely, it is important to distinguish between statistical and practical significance for fitness items that yielded smaller effect sizes. For instance, although the improvement in the standing long jump demonstrated a small effect size (partial $\eta^2 = 0.04$), it remained statistically significant. In the context of school-based intervention research, even these smaller effect sizes hold meaningful educational relevance, as they indicate genuine neuromuscular adaptations within a constrained 12-week PE curriculum.

The improvement in the composite physical fitness score further underscores the intervention's effectiveness. The experimental group's adjusted mean of 82.40 places students within the national "good" fitness category, whereas the control group remained in the "pass" range. This shift is not only statistically significant but also educationally and health-relevant, particularly for vocational high school students, who are often identified as physically vulnerable due to lower baseline activity levels and limited access to structured exercise opportunities (Mercier et al., 2023).

These findings extend prior gamification research that has predominantly emphasized psychological and motivational outcomes while reporting inconsistent or limited effects on physical performance (Arufe-Giráldez et al., 2022; Sotos-Martínez et al., 2023). In contrast to studies suggesting weak transfer from motivation to performance (Hanus & Fox, 2015), the present results indicate that when motivation is sustained and behaviorally expressed, particularly through heightened sports engagement, meaningful physiological adaptations can occur. This distinction reinforces the importance of intervention duration and engagement intensity, both of which were explicitly addressed in the 12-week design of the current study.

From a theoretical perspective, the fitness gains observed here provide empirical support for SDT-based models proposing that autonomous motivation facilitates sustained behavioral engagement, which in turn leads to improved health outcomes (Johnson et al., 2016; Mazeas et al., 2022). The alignment between motivational improvements and objective fitness gains strengthens the argument that motivation functions not merely as an affective outcome but as a mechanism linking instructional design to physical health benefits.

4.5. Motivation as Partial Mediator Between Gamification and Physical Fitness (H_4)

To test Hypothesis H_4, which proposed that improvements in PE learning motivation would mediate the relationship between the gamified intervention and physical fitness outcomes, an SEM was specified. The model examined both direct effects of the intervention on posttest physical fitness and indirect effects operating through multiple motivational dimensions, while controlling for pretest motivation and fitness levels.

As illustrated in Figure 1, the gamified intervention exerted both direct and indirect effects on physical fitness through multiple motivational pathways. Table 7 presents the standardized path coefficients and bootstrapped mediation effects. The SEM results demonstrated that the gamified intervention exerted significant positive effects on all motivational dimensions, increasing ‘positive interest’, ‘sports engagement’, and ‘autonomous learning’, while significantly reducing ‘negative interest’. These paths provide strong confirmation that the intervention functioned as an SDT-consistent motivational environment supporting autonomy, competence, and relatedness.

Figure 1

SEM path model of gamified intervention → motivation → physical fitness

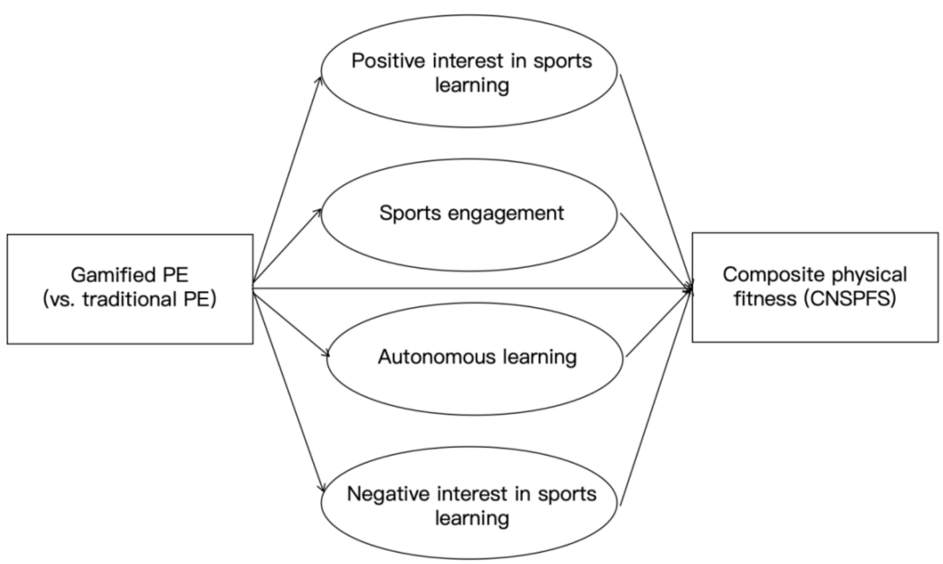

Table 7

SEM path coefficients and mediation effects (bootstrap 5000 samples)

Path	β	SE	p	95% CI Lower	95% CI Upper
Intervention → Positive Interest	0.45	0.08	< 0.001	0.29	0.61
Intervention → Sports Engagement	0.38	0.07	< 0.001	0.24	0.52
Intervention → Autonomous Learning	0.41	0.06	< 0.001	0.29	0.53
Intervention → Negative Interest	–0.52	0.07	< 0.001	–0.66	–0.38
Sports Engagement → Fitness	0.28	0.05	< 0.001	0.18	0.38
Positive Interest → Fitness	0.19	0.06	< 0.01	0.07	0.31
Autonomous Learning → Fitness	0.07	0.05	0.15	–0.03	0.17
Negative Interest → Fitness	–0.15	0.06	< 0.05	–0.27	–0.03
Intervention → Fitness (Direct)	0.21	0.07	< 0.01	0.07	0.35
Indirect (Int → Engagement → Fitness)	0.11	—	< 0.001	0.06	0.17
Indirect (Int → PosInterest → Fitness)	0.09	—	< 0.01	0.03	0.15
Indirect (Int → NegInterest → Fitness)	0.08	—	< 0.05	0.01	0.14
Total Indirect Effect	≈0.28	—	< 0.001	—	—

***Note*:** Significant mediation is indicated when the 95% Confidence Interval (CI) does not include zero. Bootstrapping with 5,000 resamples was utilized to ensure the robustness of the indirect effect estimates. Abbreviations: Int = Intervention; PosInterest = Positive Interest; NegInterest = Negative Interest; Fitness = Composite Physical Fitness.

Among the motivational mediators, ‘sports engagement’ emerged as the strongest and most consistent predictor of posttest physical fitness, followed by ‘positive interest’, while ‘negative interest’ showed a significant negative association with fitness outcomes. In contrast, ‘autonomous learning’ did not directly predict physical fitness gains once other motivational dimensions were accounted for. This differentiated pattern refines SDT-based assumptions by indicating that behaviorally expressed motivation, rather than cognitive or informational autonomy alone, is the most proximal driver of physiological adaptation.

The bootstrapped indirect effects confirmed that motivation partially mediated the relationship between the intervention and physical fitness. The largest indirect effect operated through ‘sports engagement’, followed by ‘positive interest’ and reduced ‘negative interest’. These findings support SDT-based models positing that instructional environments influence health outcomes primarily by fostering autonomous motivation that translates into sustained behavioral engagement (Johnson et al., 2016; Mazeas et al., 2022).

The persistence of a significant direct path from the intervention to physical fitness indicates partial rather than full mediation. This suggests that, in addition to motivational processes, other mechanisms, such as improved instructional structure, increased time-on-task, enhanced feedback quality, or more efficient skill acquisition, may have contributed directly to fitness gains. This addresses reviewer concerns that gamification effects may be purely psychological or short-lived and supports more integrative, multi-path explanatory models of PE intervention effectiveness (Lozano-Lozano et al., 2021).

From a theoretical perspective, the SEM results strengthen the study's conceptual framework by empirically validating the proposed SDT-based pathway: Gamification → Motivation → Behavioral Engagement → Physical Fitness. At the same time, the differentiated roles of motivational dimensions caution against treating motivation as a unitary construct and highlight the central importance of engagement-driven mechanisms in translating motivation into health outcomes.

4.6. Engagement Intensity as a Multi-Level Mechanism of Motivation Change (H_5)

To test Hypothesis H_5, which posited that individual engagement with the gamified intervention would positively predict motivational improvement, a two-level hierarchical linear model (HLM) was employed. This approach was selected to account for the nested structure of the data, with students (Level 1) nested within classes (Level 2), and to distinguish between individual-level engagement effects and class-level intervention effects.

The HLM results indicated that, after controlling for pretest motivation scores, individual-level Sports Engagement significantly predicted posttest 'positive interest' ($p < 0.01$). This finding confirms that students who engaged more actively with the gamified elements, such as participating consistently in challenges, striving for personal bests, and contributing to team-based tasks, experienced greater motivational gains. Importantly, this effect remained significant even after accounting for class-level variance, underscoring the role of learner agency within the gamified environment.

At the class level, participation in the gamified intervention also exerted a significant positive effect on motivation, indicating that the instructional design itself created a supportive motivational climate. However, the presence of a significant cross-level interaction revealed that the motivational benefits of individual engagement were amplified in the gamified classes. In other words, engagement mattered more when the learning environment was autonomy-supportive and competence-enhancing, as opposed to traditional PE settings.

From a theoretical standpoint, these findings provide strong support for SDT's core proposition that motivation emerges from the interaction between environmental affordances and individual behavior. Gamification did not function as a deterministic stimulus that uniformly increased motivation across all students. Instead, it created a context that enabled motivated action, with individual engagement serving as the proximal driver of motivational change. This interpretation aligns with recent critiques cautioning against overly mechanistic views of gamification and emphasizing the importance of learner responsiveness and differential uptake (Mercier et al., 2023).

The relatively modest intraclass correlation coefficient further suggests that while class-level design was important, motivational change was primarily driven at the individual level. This has important pedagogical implications, indicating that future gamified PE models may benefit from incorporating adaptive or personalized features that respond to individual engagement patterns.

5. Conclusion and Recommendations

5.1. Conclusion

This study demonstrates that an SDT-based gamified PE intervention can significantly enhance vocational high school students' motivation and objectively measured physical fitness in the Chinese context. Critically, sports engagement emerged as the key behavioral mechanism linking SDT-aligned gamification to fitness gains, showing the strongest association with post-intervention outcomes and accounting for a substantial portion of the motivation-to-fitness pathway. Over the 12-week program, students showed improvements in positive interest and autonomous learning alongside tangible gains in vital capacity, sprint performance, and composite fitness scores. Collectively, these findings provide robust empirical support for theory-driven gamification in vocational PE and offer evidence-based directions for future pedagogical reform.

5.2. Theoretical Implications

This study offers four theoretical implications for SDT-informed gamification in physical education.

First, the findings refine SDT-based explanations by demonstrating that engagement functions as the most proximal behavioral manifestation of need-supportive motivation in gamified PE. While autonomy- and competence-supportive features are foundational, the decisive theoretical hinge lies in whether these experiences translate into sustained, effortful participation capable of driving physiological adaptation.

Second, the results substantiate a multi-path explanatory structure rather than a single causal chain. Motivation partially mediated the effect of gamification on physical fitness, indicating that both motivational and structural design mechanisms (e.g., structured progression, feedback loops, increased practice exposure) may operate concurrently. This advances SDT‑gamification scholarship by positioning motivation not merely as an outcome, but as an empirically testable explanatory pathway.

Third, the use of multilevel modeling and structural equation modeling contributes methodological rigor to SDT-based gamification research. By accounting for nested data structures and explicitly modeling indirect effects, this study strengthens causal inference and demonstrates how advanced statistical modeling can clarify psychological‑behavioral‑physiological linkages in school-based interventions.

Fourth, by focusing on vocational high school students, this study extends SDT-based gamification theory to a relatively underexplored educational context. Demonstrating a robust engagement-driven pathway within this population highlights contextual boundary conditions and underscores the necessity of theory application tailored to vocational educational environments.

5.3. Recommendations for Practice

To translate the current empirical findings into educational practice, this study recommends the strategic implementation of SDT-oriented gamified physical education in vocational schools. First, regarding curriculum design, PE instructors should consciously integrate gamified elements that satisfy students' basic psychological needs for autonomy, competence, and relatedness, thereby transitioning passive compliance into active sports engagement. Second, educational institutions must prioritize teacher professional development to equip instructors with the pedagogical and technological competencies required to design, execute, and manage gamified instructional frameworks effectively. Lastly, at the institutional level, evaluation cycles should be adjusted to incorporate the tracking of behavioral engagement data and the integration of formative feedback. Establishing these robust evaluation and continuous improvement mechanisms is vital for mitigating novelty decay and sustaining the long-term effectiveness of gamified interventions.

5.4. Limitations

Despite its theoretical and practical contributions, this study explicitly acknowledges several methodological constraints. First, the single-site, regional design constrains the external validity and generalizability of the findings across diverse educational contexts. Second, the assessment of motivation and engagement relied primarily on self-reported measures, which are inherently susceptible to response bias. Third, the "package effect" of the comprehensive gamified intervention prevents the isolation and independent evaluation of individual gamification elements, making it difficult to determine which specific components drove the observed outcomes. Finally, the 12-week duration of the experiment precludes the assessment of long-term impacts, including the potential decay of novelty effects over an extended period. Other noted limitations include potential uncontrolled variations in teacher implementation fidelity and the reliance on standardized national frameworks for fitness scoring.

5.5. Future Research Directions

To address these constraints and advance the field, future research should proceed in several strategic directions. To enhance generalizability and evaluate the long-term impact on lifelong exercise habits, subsequent studies must adopt multi-center, longitudinal designs across diverse regions and vocational school types. Furthermore, deeper mechanistic exploration utilizing mixed-methods approaches is necessary to provide richer qualitative insights into the psychological need satisfaction process and to effectively disentangle the effects of individual versus combined gamified elements. The integration of gamification with emerging technologies, such as virtual and augmented reality (VR/AR) or wearable devices, also presents a promising avenue for pioneering personalized, data-driven, and immersive physical education models. Ultimately, facilitating the successful implementation and theoretical refinement of these instructional designs will require a dedicated research focus on teacher training models and pedagogical beliefs.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was not supported by any funding

Institutional Review Board Statement

The conduct of this study was approved by the University of Baguio Research Ethics Committee. The manuscript does not contain any individual person's data in any form (including identifiable images), and all results are reported in aggregate.

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