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Enhancing physical fitness through gamification: Evidence from vocational high school students

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Abstract

Physical fitness is an essential component for vocational high school (SMK) students, as it directly relates to their productivity and readiness for future work demands. This study aimed to examine the effect of gamification-based Physical Education on the physical fitness of vocational high school students in Palu, South Sulawesi. A quasi-experimental non-equivalent control group design was employed with a sample of 30 students divided into two groups: an experimental group (physical education learning with gamification) and a control group (conventional physical education learning). Standardized physical fitness tests—including flexibility, muscular strength, endurance, and BMI—were administered before and after the intervention. Results showed that the experimental group's average score increased from 2.73 (pre-test) to 4.60 (post-test), while the control group improved from 2.67 to 4.20. Paired sample t-tests confirmed significant improvements within both groups ($p < 0.05$). However, the independent sample t-test indicated no significant difference between the experimental and control groups ($p = 0.077 > 0.05$). These findings suggest that gamification can effectively enhance students' physical fitness within a group, but its short-term implementation does not demonstrate superiority over conventional methods. This study contributes to the growing body of literature on innovative approaches in physical education, particularly in vocational schools, where physical readiness is closely linked to employability. Gamification shows potential as a complementary strategy to boost student motivation and engagement in physical education. Future research is recommended with longer intervention periods, larger samples, and consideration of external variables to optimize the impact of gamification on physical fitness.

Keywords: Gamification, physical fitness, physical education, vocational high school.

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INTRODUCTION

Physical fitness is widely recognized as one of the most important aspects supporting quality of life, productivity, and student readiness in facing both academic and non-academic demands (Corbin et al., 2013; Donnelly et al., 2016). In the context of vocational high schools (SMK),

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physical fitness takes on an even greater significance. Students at this level are directly prepared for the workforce, where physical endurance, stamina, and practical skills are essential for optimal performance in industrial activities. National guidelines from the Indonesian Ministry of Youth and Sports (Kemenpora, 2020) also emphasize that low physical fitness can hinder student performance and reduce overall productivity.

In Palu, South Sulawesi, several local observations and reports indicate that the physical fitness of SMK students tends to fall within the moderate to low categories. For instance, school-based assessments conducted by the Central Sulawesi Provincial Office of Education in 2021 reported that less than 40% of SMK students achieved the recommended fitness levels based on national standards (Mohammad Fadly Saputra et al., 2021). This condition illustrates a critical gap between the expected physical readiness of vocational students and the reality of their current fitness levels. Such evidence highlights the urgent need for innovative interventions that can effectively increase participation in physical activities and enhance physical fitness among SMK students.

Several factors contribute to the decline in student physical fitness. A sedentary lifestyle, increased use of digital devices, low motivation to participate in physical activities, and the lack of innovative approaches in Physical Education, Sports, and Health learning all play significant roles (Rideout et al., 2022; Tandiono et al., 2021; WHO, 2020). On the one hand, the development of digital technology facilitates learning and provides access to information. On the other hand, it promotes screen-based behaviors, which compete with students' opportunities to engage in active movement. This paradox underscores the challenge for educators: how to integrate students' digital lifestyles with the need for regular physical activity (Alnawwar et al., 2023).

Previous efforts to improve student participation in physical education have included game-based learning, technology integration, and collaborative approaches (Ginanjar et al., 2020; Widyalaksono et al., 2020). While these methods have shown promise, research findings

indicate that improvements in physical fitness are not always consistent, and sustaining student motivation remains a challenge (Baena-Extremera et al., 2021; Liu & Lipowski, 2021). This highlights a research gap: although gamification has been applied in primary and secondary schools, little is known about its effectiveness in vocational high schools, where students have distinct characteristics and higher demands for workplace readiness. Thus, the novelty of this study lies not only in adopting gamification as an instructional strategy but in testing its effectiveness within physical education learning for SMK students in Palu, South Sulawesi, a context rarely explored in prior research.

Gamification, defined as the application of game elements such as points, challenges, leaderboards, and rewards in non-game contexts, aims to enhance motivation and engagement (Deterding et al., 2011). Research has shown that gamification can increase student engagement, make learning more enjoyable, and foster intrinsic motivation to participate in activities (Sailer & Homner, 2020; Seaborn & Fels, 2015). In the context of physical education, gamification has the potential to transform repetitive or monotonous physical exercises into engaging, competitive, and meaningful experiences (Moya-Ramon et al., 2020). For example, level-based challenges or symbolic rewards can help maintain consistency in student participation in physical activity (Sillaots, 2015).

The theoretical basis of this study is supported by self-determination theory, which emphasizes the importance of autonomy, competence, and relatedness in fostering intrinsic motivation (Murphy et al., 2022). By using gamification elements such as rewards, challenges, and leaderboards, students' sense of competence and competition can be stimulated, which in turn may enhance engagement in physical activities even if the measurable fitness outcomes are not immediately distinct between experimental and control groups. Linking gamification to motivational theories strengthens its relevance and explains why gamification holds promise for improving not only engagement but also long-term behavioral change.

The practical implications of this research are equally important. For physical education teachers, gamification provides concrete strategies to make physical education more attractive to students who are otherwise disengaged. For example, teachers can integrate leaderboards to track class performance, use level-based physical challenges to encourage progression, or award symbolic rewards to sustain student motivation. For schools, gamification can be embedded into the broader physical education curriculum as part of efforts to modernize teaching approaches and align with the digital habits of Generation Z students. For policymakers, the findings of this study may serve as a reference for developing innovative and culturally relevant models of physical education in vocational contexts, thereby supporting the holistic readiness of SMK graduates for the workforce.

Based on these gaps, this study aims to analyze the effect of gamification-based physical education learning on the physical fitness of vocational high school students in Palu, South Sulawesi. Specifically, the study investigates whether gamification strategies can significantly improve students' fitness levels and provide both theoretical and practical contributions to the field of physical education.

METHOD

This study uses a quantitative approach with a quasi-experimental design of the non-equivalent control group type. This design was chosen because in the school context, it was not possible to fully randomize the research subjects; instead, existing classes were used as the experimental and control groups. This design allows the researcher to compare two different groups without randomization, ensuring that the results obtained can still measure the effect of the treatment empirically. The research design can be illustrated in the following table:

Table 1. Research design

Groups	Pre-Test	Treatment	Post-Test
Experiment	O1	X (Gamifications physical education)	O2
Control	O3	- (Conventional physical education)	O4

Explanation:

O1 and O3: pre-test of physical fitness.

O2 and O4: post-test of physical fitness

X: treatment in the form of gamification-based physical education learning.

The research population was all students of SMK Negeri 3 Palu, South Sulawesi who participated in physical education learning in the even semester of the 2024/2025 academic year, with a total of 260 students. From this population, 30 students were selected and divided into 15 students in the experimental group and 15 students in the control group. The sampling technique used purposive sampling with the criteria of students actively participating in physical education lessons, having no physical limitations or medical history that hinder physical activity, and obtaining permission from the school and parents.

The research instruments consisted of five physical fitness tests. The V-Sit and Reach test was used to measure lower back and hamstring flexibility. The 60-second Sit-Up test was used to measure abdominal muscle strength and endurance. The 30-second Squat Thrust test was used to assess lower limb muscle endurance and coordination. The PACER Test (Progressive Aerobic Cardiovascular Endurance Run) is used to measure cardiorespiratory fitness. Meanwhile, the Body Mass Index (BMI) is used to assess body composition using the formula:

$$BMI = \frac{Weight\ (kg)}{[Height\ (m)]^2}$$

Notes:

Body weight is measured in kilograms (kg).

Height is measured in meters (m).

BMI is used as a simple indicator to determine the proportion of body weight to height, which is an important component of physical fitness.

Data analysis was performed using SPSS 26.0. The analysis stages included normality testing with Kolmogorov-Smirnov and Shapiro-Wilk, homogeneity test with Levene's Test, paired sample t-test to analyze

significant differences between pre-test and post-test in groups, and independent sample t-test to analyze differences in post-test averages between the experimental and control groups. The significance level used was $\alpha = 0.05$.

The research procedure was carried out in three stages. The preparation stage included coordination with the school, socialization to students and parents, and the determination of experimental and control classes. The intervention implementation stage lasted for six meetings over three weeks, with a frequency of twice a week and a duration of 90 minutes per meeting. In the experimental group, physical education learning was conducted using a gamification approach in the form of level-based fitness challenges, a point system, a leaderboard, and symbolic rewards. The control group followed conventional physical education learning according to the curriculum without gamification elements. The final stage was evaluation, which was conducted by administering a pre-test before the intervention and a post-test after the intervention. The test results were then analyzed to determine the effect of gamification on students' physical fitness.

This study has limitations, including the absence of full randomization, which may introduce class bias, external factors such as physical activities outside school that cannot be controlled, and the relatively short intervention duration of three weeks, which may not be sufficient to demonstrate significant differences between groups.

RESULTS

This section presents the results of statistical analyses carried out in the study. The results include descriptive statistics, tests of normality, tests of homogeneity of variance, paired samples test, and independent samples test. Each table is followed by a detailed interpretation to clarify the meaning of the results in the context of gamification in Physical Education for vocational high school students in Palu City, South Sulawesi.

Table 2. Descriptive statistics

Grups	N	Min	Max	Mean
Pre-Experiment Test	15	2	3	2.73
Post-Experiment Test	15	4	5	4.60
Pre-Test Control	15	2	3	2.67
Post-Test Control	15	3	5	4.20

Table 2 shows the descriptive statistics of pre-test and post-test scores for both groups. The experimental group had a mean pre-test score of 2.73, which increased to 4.60 in the post-test. Meanwhile, the control group's mean score increased from 2.67 in the pre-test to 4.20 in the post-test.

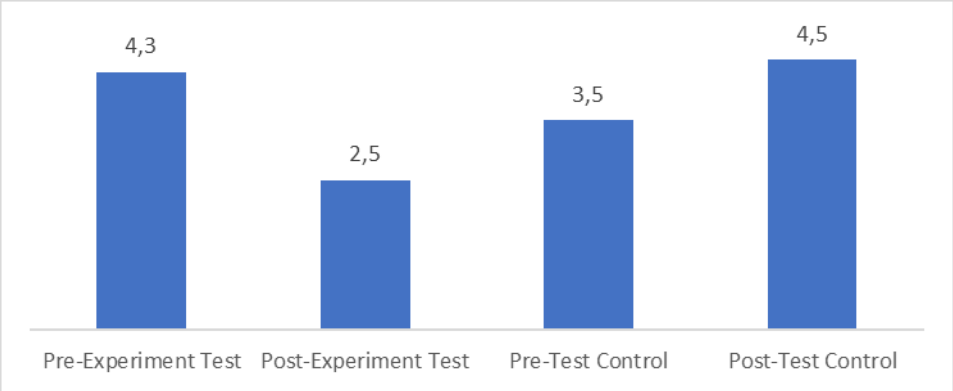

Figure 1. Comparison of Mean Pre-test and Post-test Results

Although both groups improved, the experimental group demonstrated a greater improvement, suggesting that gamification may contribute to a more substantial increase in students' physical fitness.

Table 3. Tests of normality

Grups	Kolmogorov-Smirnov Statistic	df	Sig.	Shapiro-Wilk Statistic	Sig.
Pre-test Experimental	0.141	15	0.200*	0.976	0.931
Post-test Experimental	0.070	15	0.200*	0.993	1.000
Pre-test Control	0.102	15	0.200*	0.969	0.850
Post-test Control	0.099	15	0.200*	0.968	0.833

Table 3 displays the results of the normality tests using Kolmogorov-Smirnov and Shapiro-Wilk. The significance values (Sig.) for all groups are greater than 0.05, which indicates that the data are normally distributed. This fulfills one of the assumptions required for conducting parametric tests such as t-tests.

Table 4. Test of homogeneity of variance (Levene's Test)

Levene Statistic	df1	df2	Sig.
0.262	1	28	0.613

Table 4 shows the homogeneity of variance test results using Levene's Test. The significance value is 0.613, which is greater than 0.05. This means that the data variances between the experimental and control groups are homogeneous, thus satisfying another assumption for conducting parametric statistical analyses.

Table 5. Paired samples test

Pair	Mean Difference	Std. Deviation	t	df	Sig. (2-tailed)
Experimental Pre-Post	-1.867	0.352	-20.546	14	0.000
Control Pre-Post	-1.533	0.516	-11.500	14	0.000

Table 5 presents the paired samples test results for both groups. The experimental group showed a mean difference of -1.867, with a significance value of 0.000, indicating a significant improvement from pre-test to post-test. The control group also showed a significant improvement with a mean difference of -1.533 and p-value of 0.000. Although both groups improved significantly, the experimental group had a larger mean difference, suggesting that gamification provided a greater impact on students' physical fitness compared to conventional methods.

Table 6. Independent Samples Test

F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	95% CI Lower-Upper
0.262	0.613	1.833	28	0.077	0.400	-0.047 – 0.847

Table 6 provides the independent samples test results. The significance value is 0.077, which is greater than 0.05, indicating that there is no statistically significant difference between the post-test results of the experimental and control groups. This means that although gamification improved physical fitness within the experimental group, it did not show a statistically significant advantage over conventional learning methods within the short intervention period.

DISCUSSION

The findings of this study indicate that gamification-based Physical Education improved students' physical fitness within the experimental

group, although no significant difference was observed between the experimental and control groups. This suggests that gamification was effective in fostering internal improvement but did not demonstrate clear superiority over conventional methods within the short intervention. This result is consistent with the argument of Donnelly et al., (2016), who emphasized that physical fitness improvement often requires long-term and structured activity to achieve meaningful physiological changes. Similarly, Benzing & Schmidt, (2018) noted that adaptations in cardiovascular endurance and muscular strength cannot be fully captured in interventions lasting only a few weeks, which may explain why gamification did not yield significant differences compared to traditional learning.

When linked to previous research, these findings highlight both similarities and contrasts. For example, Staiano et al., (2017) found that exergame interventions improved adolescents' physical health and psychosocial outcomes, demonstrating the positive impact of gamified approaches. Likewise, (Romero-Blanco et al., 2020) reported that gamification enhanced student engagement and academic performance in higher education contexts. However, unlike these studies, the present research did not show stronger outcomes compared to the control group. This difference may reflect the unique characteristics of vocational high school students, who, as noted by Corbin et al., (2013); and Kemenpora, (2020), face greater demands for stamina and productivity while preparing for industrial work, yet are often constrained by sedentary habits and digital lifestyles (Alnawwar et al., 2023; Rideout et al., 2022). These contextual factors may have limited the extent to which gamification translated into measurable gains in fitness.

The motivational effects of gamification can be further explained using self-determination theory. According to Wichmann, (2011), intrinsic motivation arises when individuals feel autonomous, competent, and connected. Gamification elements such as points, leaderboards, and challenges foster a sense of competence and competition, which can

increase student engagement (Sailer & Homner, 2020; Seaborn & Fels, 2015). This theoretical perspective helps explain why the experimental group showed improvement in physical fitness scores, even though the differences between groups were not statistically significant. It also resonates with (Camacho-Sánchez et al., 2023), who emphasized that gamification promotes engagement in learning contexts but cautioned that such engagement does not always guarantee long-term behavioral or physiological outcomes.

From a practical perspective, the findings suggest that gamification has value in enhancing engagement and motivation in vocational high schools, even if short-term physical fitness outcomes are modest. Teachers of Physical Education can adopt gamification elements to transform repetitive exercises into more meaningful experiences, for example by creating level-based challenges or symbolic rewards to encourage persistence (Sillaots, 2015). Schools can also integrate gamification into broader physical education programs to modernize learning approaches and counteract sedentary behavior, which is increasingly prevalent among students due to high digital device use (Tandiono et al., 2021; WHO, 2020). Policymakers should view gamification as a pedagogical strategy aligned with the digital lifestyles of Generation Z, while also serving as a bridge to prepare vocational students for the physical demands of their future workplaces.

Nevertheless, the study has limitations that must be acknowledged. The absence of randomization reduces internal validity, as class-based differences may have influenced the results. The intervention's short duration limited its capacity to reveal long-term physiological changes, while external variables such as extracurricular physical activity, diet, and sleep were not controlled (Alnawwar et al., 2023; Tandiono et al., 2021). These limitations point to methodological recommendations for future research: employing randomized experimental designs, incorporating psychological measures of motivation, and conducting longitudinal studies to observe long-term effects. Such refinements will help determine

whether gamification can produce sustained improvements in both motivation and physical fitness in vocational education settings.

In essence, this study demonstrates that gamification can effectively increase engagement and foster internal improvements in vocational high school students' physical fitness, yet its comparative advantage over conventional methods remains dependent on longer, more rigorous, and context-sensitive interventions.

CONCLUSSION

This study concludes that gamification-based Physical Education improved students' physical fitness internally, even though it did not show significant differences compared to conventional learning. This indicates that gamification is effective in enhancing engagement and motivation, but its measurable superiority may require longer interventions and more structured designs to manifest. The novelty of this research lies in situating gamification within vocational high schools in Palu City South Sulawesi, a context rarely explored in previous studies that have largely focused on elementary or general secondary schools. By addressing this gap, the study expands the theoretical understanding of gamification in Physical Education and highlights the unique relevance of vocational students who face both workplace readiness demands and digital lifestyle influences.

Practically, the findings suggest that physical education teachers can adopt strategies such as level-based challenges, leaderboards, and symbolic rewards to sustain student participation. Schools can integrate gamification as part of digital pedagogy innovations, while policymakers may consider it as a model to modernize vocational curricula and align education with industrial demands. Future research should employ randomized designs, consider motivational variables, and conduct longitudinal studies to capture the long-term potential of gamification in vocational contexts.

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