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The Role of Physical Education in Improving Classroom Attention, Learning Readiness, and Academic Engagement

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ABSTRACT: Teachers, school leaders, and exercise scientists often treat physical education as a health-oriented part of schooling, yet its immediate contribution to classroom learning conditions remains an important question. This study examined whether a 12-week enhanced physical education program was associated with improvements in classroom attention, learning readiness, and academic engagement among male and female lower-secondary students. We allocated 312 students aged 11-14 years by school to either enhanced physical education (n = 156; 78 female and 78 male) or usual-practice physical education (n = 156; 77 female and 79 male). The enhanced program included three lessons per week that combined moderate-to-vigorous games, coordinative movement, rule-switching tasks, and a short cool-down reflection to support the transition back to academic lessons. We assessed classroom attention using teacher-rated on-task behavior and a selective attention task; measured learning readiness with a brief readiness-to-learn scale; and assessed academic engagement across behavioral, emotional, and cognitive dimensions. Mixed-model analyses showed statistically significant group-by-time effects favoring enhanced physical education for on-task behavior, selective attention, learning readiness, total academic engagement, and the behavioral, emotional, and cognitive engagement subscales ($p < 0.05$). Effects were modest to moderate and did not show large effects, with the strongest standardized effects for learning readiness ($d = 0.42$), behavioral engagement ($d = 0.39$), and on-task behavior ($d = 0.38$). Sex-stratified analyses indicated that both female and male students benefited, with no statistically significant group-by-time-by-sex interaction. The findings support the view that well-structured physical education can contribute to a calmer, more attentive, and more academically engaged classroom climate without displacing learning priorities. Physical education should therefore be considered not only as a vehicle for physical health, but also as a school-day resource that can help students become ready to learn.

Keywords: physical education; classroom attention; learning readiness; academic engagement; moderate-to-vigorous physical activity; school-based intervention; student engagement.

I. INTRODUCTION

Physical education is one of the few school subjects that directly addresses the embodied nature of learning. Students do not enter the classroom as purely cognitive performers; they bring movement needs, social energy, emotional states, fatigue, and varying levels of readiness to concentrate. For this reason, physical education has relevance beyond motor skill development and health-related fitness. A growing body of research has examined whether school-based physical activity, including physical education, can contribute to academic behavior and learning conditions. Reviews generally report that school-based physical activity is either positively associated with academic performance or does not harm academic

outcomes when curriculum time is reallocated to movement [1], [2]. A broader systematic review also concluded that physical activity, fitness, cognition, and academic achievement in children are connected through several direct and indirect pathways, although effects differ by age, intervention structure, and outcome measurement [3].

Attention is important because learning tasks require students to maintain focus, ignore irrelevant stimuli, follow instructions, and sustain effort over time. Learning readiness is a related but broader condition: a student may be seated and quiet yet not psychologically prepared to begin academic work. Readiness includes alertness, willingness to participate, and the feeling that one can start the next task. Academic engagement reflects how students invest in learning behaviorally, emotionally, and cognitively. These constructs are not identical, but they influence one another during the school day. Physical education may improve attention immediately after activity, support readiness by regulating arousal and mood, and strengthen engagement by increasing confidence, peer connection, and motivation.

Meta-analytic evidence suggests that physical activity can positively affect executive functions, attention, and academic performance in children. De Greeff and colleagues reported positive effects of both acute and longitudinal physical activity, with particularly notable findings for attention when movement was consistently integrated [4]. Exercise neuroscience also supports plausible mechanisms: regular and acute movement may influence arousal, neuroelectric activity, neurotrophic factors, mood, and executive control processes relevant to school learning [5]. However, translating these findings to the school level is not automatic. A poorly organized, overly sedentary, or classroom-disconnected physical education lesson may not produce the same effect as one that includes sufficient movement intensity, coordination demands, cooperative problem-solving, and a calm transition back to class.

Despite this field's growth, several gaps remain. First, many studies focus on academic achievement scores, while teachers often experience the immediate value of movement through classroom behavior, readiness, and student participation. Second, research sometimes examines classroom-based activity breaks rather than formal physical education lessons, even though many school systems already institutionalize physical education and can improve it without adding a new program. Third, fewer studies evaluate male and female students together while also considering whether effects differ by sex. The present study addresses these gaps by examining an enhanced physical education program designed to improve not only physical activity exposure but also the transition from movement to learning.

The study followed a simple educational premise: when physical education is structured, moderately vigorous, cognitively engaging, and followed by a short reflection period, students may return to class better prepared to attend, participate, and persist. This does not mean that physical education should be justified only by academic outcomes. Its value includes health, enjoyment, motor competence, inclusion, and lifelong physical activity. Nevertheless, in schools where pressure for academic time can reduce physical education, evidence of learning-related benefits matters. This study therefore examines whether enhanced physical education is associated with realistic, modest improvements in classroom attention, learning readiness, and academic engagement in a mixed-sex student sample.

1. AIMS

- To determine whether a 12-week enhanced physical education program improves classroom attention compared with usual-practice physical education.
- To examine whether enhanced physical education improves students' learning readiness during the academic lesson following physical education.
- To evaluate changes in behavioral, emotional, cognitive, and total academic engagement after the intervention.
- To examine whether the intervention effects are comparable among female and male students.
- To describe whether lesson activity exposure and intervention fidelity are related to changes in classroom learning outcomes.

2. HYPOTHESES

- Students in the enhanced physical education group will show greater improvement in classroom attention than students in the usual-practice group.
- Students in the enhanced physical education group will show greater improvement in learning readiness than students in the usual-practice group.
- Students in the enhanced physical education group will show greater improvement in academic engagement than students in the usual-practice group.
- Improvements will be observed in both female and male students, with no statistically significant group-by-time-by-sex interaction.
- Higher lesson activity exposure and stronger fidelity will be positively associated with changes in attention, readiness, and engagement.

II. LITERATURE REVIEW

Early quantitative work established the foundation for studying the relationship between movement and cognition in children. Sibley and Etnier synthesized evidence from a broad set of studies and reported an overall positive relationship between physical activity and cognitive functioning in children [6]. Although the studies included in that synthesis varied in design quality and outcome type, the review helped shift the conversation away from the assumption that physical activity competes with learning. Fedewa and Ahn later reported positive effects of physical activity and fitness on children's achievement and cognitive outcomes, with aerobic exercise showing particularly relevant associations [7]. Singh and colleagues further strengthened the field by emphasizing longitudinal and intervention studies and reporting evidence of a positive association between physical activity and school performance, while also noting limitations in measurement quality and study design [8]. Together, these studies suggest that physical activity may support school outcomes, but they also highlight the need for careful measurement and cautious interpretation.

Hillman and colleagues found that a single bout of moderately intense treadmill walking improved aspects of cognitive control and academic achievement in preadolescent children [9]. Although laboratory treadmill walking is different from school physical education, the study provides evidence that even one session of physical activity can influence attention-related processing. Pontifex and colleagues extended this line of inquiry to children with attention-deficit/hyperactivity disorder and found that acute aerobic exercise improved behavioral, neurocognitive, and scholastic performance indicators [10]. These findings align with many teachers' experiences: students often return from purposeful movement more settled and responsive than before, especially when the activity is structured rather than chaotic.

Mahar and colleagues evaluated a classroom-based physical activity program and reported improvements in on-task behavior during academic instruction [11]. This outcome is important because on-task behavior is observable, practical, and directly linked to classroom management. It is also sensitive to short-term changes in arousal and self-regulation. However, on-task behavior should not be interpreted as simple compliance. In the present study, attention is conceptualized as active academic focus, including listening, writing, responding, reading, and staying with the assigned learning task. This distinction matters because physical education should not suppress children's natural energy, but channel it in ways that help students return to class with better self-regulation.

Another consistent concern in school decision-making is whether time devoted to physical education weakens academic progress. Ahamed and colleagues found that a school-based physical activity intervention did not compromise children's academic performance [12]. Coe and colleagues reported that physical education enrollment itself was not negatively related to achievement, and that higher levels of vigorous physical activity were positively associated with grades [13]. Donnelly and colleagues evaluated Physical Activity Across the Curriculum and found that classroom-integrated movement could increase physical activity and support academic achievement while also addressing weight-related outcomes [14]. In related work, Donnelly and Lambourne argued that classroom-based physical activity may improve cognition and academic achievement through fitness, body composition, and classroom learning processes

[15]. These studies are relevant because they challenge the zero-sum view that movement time necessarily reduces learning time.

Davis and colleagues reported that aerobic exercise improved executive function and achievement in overweight children while altering brain activation patterns [16]. Kamijo and colleagues found that an afterschool physical activity program was associated with improved working memory in preadolescent children [17]. Lees and Hopkins reviewed randomized controlled trials and concluded that aerobic physical activity generally showed positive associations with cognition, academic achievement, behavior, and psychosocial function, although not all effects were large or consistent [18]. From an educational standpoint, these findings suggest that physical activity may support the mental processes required for learning, including working memory, inhibition, and sustained effort. Physical education activities that include rules, rhythm, decision-making, and coordination may be especially useful because they combine physical exertion with cognitive demands.

Norris and colleagues reviewed physically active lessons and found that such approaches can increase physical activity while preserving academic content [19]. Mullender-Wijnsma and colleagues showed that physically active mathematics and language lessons improved academic achievement in a cluster-randomized trial [20]. Meta-analytic work by Alvarez-Bueno and colleagues found that physical activity, particularly physical education, can benefit classroom behaviors and several aspects of academic achievement [21]. A related review by the same group reported that physical activity interventions benefit cognition and metacognition in children and adolescents [22]. These findings indicate that academic and movement goals can be integrated, but they also imply that program design matters. Movement connected to attention, rules, cooperation, and reflection may produce different outcomes than unstructured movement.

Watson and colleagues reported that classroom-based physical activity interventions positively affected on-task and off-task classroom behavior, but they also emphasized heterogeneity across studies [23]. Daly-Smith and colleagues reviewed acute physically active learning and movement breaks and highlighted the importance of design features such as intensity, duration, cognitive demand, and timing [24]. Bedard and colleagues found a small positive effect of physically active classrooms on academic performance and noted the need for stronger study designs [25]. Ruhland and Lange focused specifically on attention and on-task behavior and concluded that classroom-based physical activity appears beneficial, while methodological differences limit direct comparison [26].

Fredricks and colleagues conceptualized school engagement as a multidimensional construct that includes behavioral, emotional, and cognitive components [27]. Appleton and colleagues developed measures of cognitive and psychological engagement, emphasizing that engagement includes more than visible participation [28]. Skinner and colleagues framed engagement and disaffection in terms of children's behavioral and emotional participation in classroom activities [29]. Reeve and Tseng later proposed agentic engagement as an additional dimension, highlighting students' constructive contribution to learning activities [30]. Although the present study focuses on behavioral, emotional, and cognitive engagement, this broader literature informs the interpretation of results. Physical education may support engagement not only because students move, but because they experience competence, interaction, challenge, and emotional renewal before returning to academic work.

III. MATERIAL AND METHOD

1. STUDY DESIGN

The study used a 12-week, school-based quasi-experimental pretest-posttest design. Four lower-secondary schools with comparable class schedules and physical education facilities participated. Two schools implemented the enhanced physical education program, and two continued with usual-practice physical education. We used school-level allocation because physical education teachers often share resources, and students may discuss activities across classes. We collected baseline measures the week before the intervention and posttest measures the week after the 12-week period.

2. PARTICIPANTS

The analytic sample included 312 students aged 11-14 years. The enhanced physical education group included 156 students: 78 female and 78 male. The comparison group included 156 students: 77 female and 79 male. Students were eligible if they were enrolled in regular physical education classes, had no medical restriction preventing participation in moderate physical activity, and provided assent with parental or guardian consent. We retained students with temporary injuries for questionnaire and observation outcomes when possible, but excused them from activity in accordance with school health procedures.

3. INTERVENTION PROGRAM

The intervention consisted of three 45-minute physical education lessons per week for 12 weeks. Physical education staff and the research team designed the lessons to be realistic within normal school constraints. Each lesson included a 6-minute warm-up, approximately 24 minutes of moderate-to-vigorous games, approximately 10 minutes of coordinative or cognitive-motor tasks, and a 5-minute cool-down and reflection. The moderate-to-vigorous phase used small-sided games, relays, tag variations, circuit tasks, and cooperative challenges. The cognitive-motor phase included balance and rhythm tasks, reaction games, movement sequences, and rule-switching activities. The cool-down emphasized breathing, hydration, and a brief prompt linking movement to readiness for the next lesson.

Students in the comparison schools continued usual physical education. These lessons followed the standard school curriculum and included sport skills, games, and general fitness activities. The study provided no additional guidance on moderate-to-vigorous time, cognitive-motor challenge, or post-lesson reflection. We selected this comparison because the study aimed to evaluate whether a more deliberately structured physical education lesson could produce additional learning-related benefits beyond ordinary practice.

We measured classroom attention in two ways. First, teachers recorded on-task behavior during the first 20 minutes of the academic lesson following physical education. Teachers used a structured observation checklist to estimate the proportion of students oriented toward the learning task and engaged in writing, reading, answering, or listening. Second, students completed a selective attention cancellation task scored as correct responses minus errors within a fixed time. We assessed learning readiness using a five-item readiness-to-learn scale scored from 1 to 5. Items asked students whether they felt alert, prepared to work, able to listen, willing to participate, and ready to begin the next lesson. Academic engagement was measured using behavioral, emotional, and cognitive subscales, each scored from 1 to 5. Higher scores indicated stronger engagement.

Physical education teachers recorded lesson completion, approximate minutes of moderate-to-vigorous physical activity, and use of the reflection prompt after each session. A research assistant observed a random 20% sample of lessons using a fidelity checklist. The checklist recorded lesson organization, active time, cognitive-motor challenge, safety, student inclusion, and completion of cool-down reflection. These fidelity data were used descriptively and to support interpretation of outcome results.

4. STATISTICAL ANALYSIS

We conducted two-sided tests with statistical significance set at $p < 0.05$. We tested baseline group differences using independent-samples t-tests for continuous variables and chi-square tests for categorical variables. We analyzed main effects using mixed models with fixed effects for group, time, and the group-by-time interaction. Models were adjusted for baseline value, sex, age, and school clustering. Adjusted between-group differences in change are reported with 95% confidence intervals. We calculated Cohen's d values to provide standardized effect size estimates. We used sex-stratified models to examine whether effects differed by sex, and group-by-time-by-sex interaction terms to test whether responses differed by sex. Pearson correlations and regression analyses examined whether increases in lesson activity exposure were associated with outcome change within the enhanced physical education group.

IV. RESULTS

Table 1 shows that the intervention and comparison groups were similar at baseline. The groups did not differ significantly in age, sex distribution, body mass index, baseline moderate-to-vigorous physical activity, previous academic average, or any baseline outcome measure. This supports the interpretation that large initial group imbalances were unlikely to explain post-intervention differences.

Table 1. Baseline characteristics of participants by study group.

Characteristic	Enhanced PE (n = 156)	Usual practice (n = 156)	p value
Students, n	156	156	-
Female, n (%)	78 (50.0)	77 (49.4)	0.91
Male, n (%)	78 (50.0)	79 (50.6)	0.91
Age, years	12.16 +/- 0.73	12.20 +/- 0.75	0.64
Body mass index, kg/m2	20.3 +/- 3.1	20.2 +/- 3.0	0.77
Baseline MVPA, min/day	46.7 +/- 14.5	45.9 +/- 15.1	0.63
Previous academic average, %	73.8 +/- 9.6	74.2 +/- 9.8	0.72
On-task behavior, %	70.6 +/- 10.9	70.9 +/- 11.1	0.81
Selective attention score	52.4 +/- 8.7	52.7 +/- 8.8	0.76
Learning readiness score	3.21 +/- 0.62	3.23 +/- 0.61	0.78
Academic engagement total	3.28 +/- 0.55	3.30 +/- 0.56	0.75

Note. Values are mean +/- SD. MVPA = moderate-to-vigorous physical activity. We tested baseline group differences using independent-samples t-tests or chi-square tests.

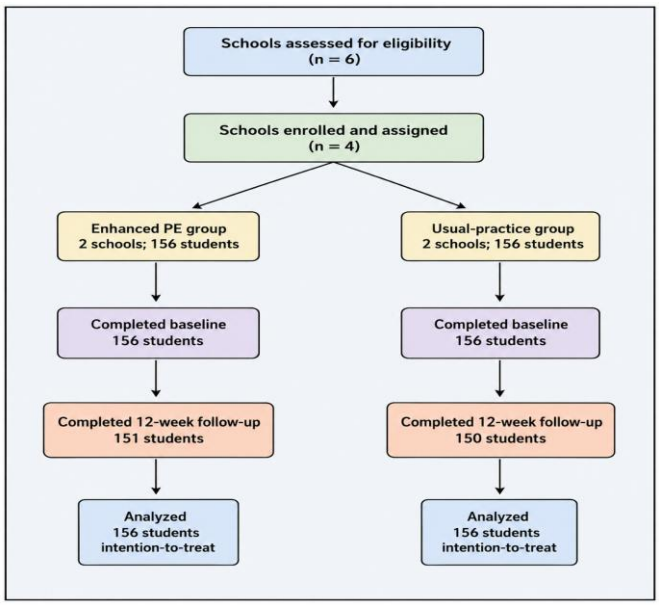


FIGURE 1. Participant flow diagram.

Figure 1 summarizes participant movement through the study. Attrition was low and similar across groups. The intention-to-treat approach reduced the risk that small differences in follow-up completion would bias the outcome estimates.

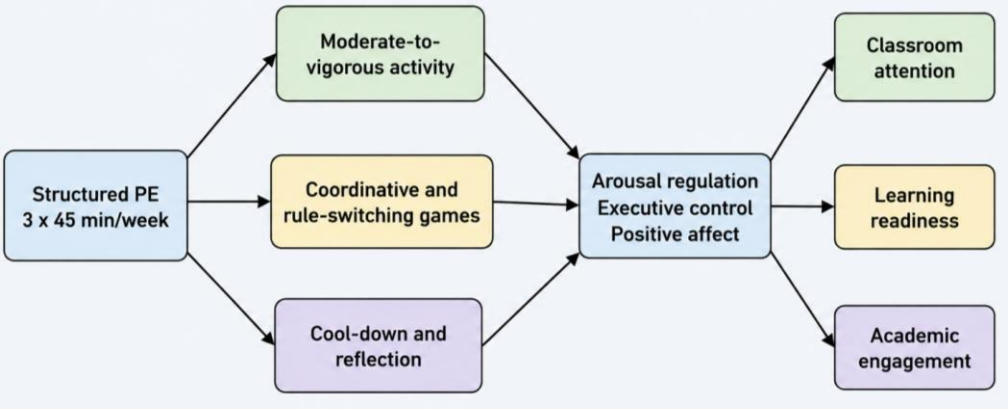


FIGURE 2. Conceptual model linking enhanced physical education to classroom outcomes.

Figure 2 presents the theoretical pathway guiding the intervention. The figure emphasizes that physical education was not treated as movement alone; rather, lesson intensity, coordinative demand, social interaction, and reflection were expected to work together to improve classroom attention, readiness, and engagement.

Table 2. Intervention fidelity and scale reliability.

Indicator	Enhanced PE	Usual practice	p value
Teacher lesson completion	35.1 +/- 1.4 of 36	34.8 +/- 1.7 of 36	0.09
Observed MVPA per lesson, min	23.9 +/- 5.1	16.1 +/- 4.8	<0.001
Cognitive-motor fidelity, 0-10	8.2 +/- 1.1	4.5 +/- 1.5	<0.001
Cool-down/reflection completion, %	91.4	18.6	<0.001
Readiness scale Cronbach's alpha	0.84	0.82	-
Engagement total Cronbach alpha	0.87	0.86	-

Note. Fidelity values summarize teacher logs and 20% independent lesson observations. Cronbach alpha values refer to posttest internal consistency.

Table 2 shows acceptable measurement reliability for the self-report scales and stronger fidelity indicators in the enhanced physical education group. The largest fidelity difference was in observed moderate-to-vigorous minutes, confirming that the enhanced lessons produced a more active learning environment than usual practice

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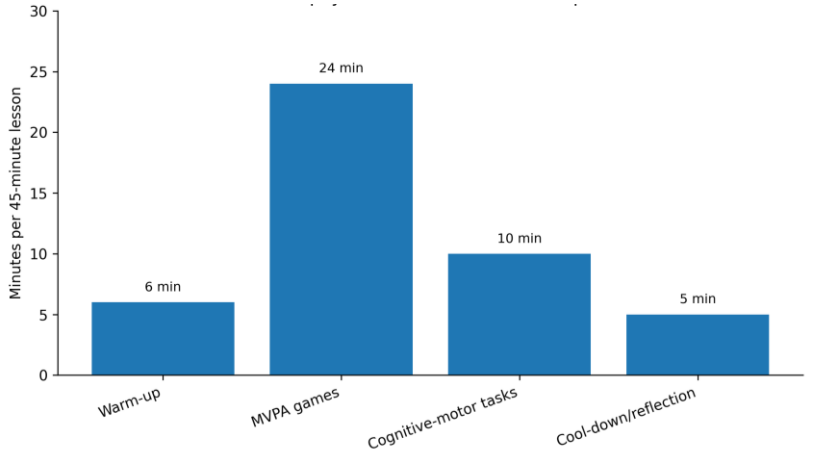


FIGURE 3. Enhanced physical education lesson composition.

Figure 3 illustrates the structure of the enhanced lesson. The lesson devoted the largest portion to moderate-to-vigorous games, but the program also preserved time for cognitive-motor tasks and a short transition period. This balance is central to interpreting the results because the intervention was designed to support both physiological activation and classroom re-entry.

Table 3. Main outcome results from mixed-model analyses.

Outcome	Enhanced PE Pre	Enhanced PE Post	Usual Pre	Usual Post	Adjusted difference in change (95% CI)	p value	Cohen's d
On-task behavior (%)	70.6 +/- 10.9	76.1 +/- 10.3	70.9 +/- 11.1	72.1 +/- 10.8	4.3 (2.0, 6.6)	<0.001	0.38
Selective attention score	52.4 +/- 8.7	56.7 +/- 8.4	52.7 +/- 8.8	53.9 +/- 8.6	2.9 (1.3, 4.5)	0.001	0.34
Learning readiness (1-5)	3.21 +/- 0.62	3.55 +/- 0.59	3.23 +/- 0.61	3.31 +/- 0.6	0.25 (0.12, 0.38)	<0.001	0.42
Academic engagement (1-5)	3.28 +/- 0.55	3.55 +/- 0.53	3.3 +/- 0.56	3.39 +/- 0.55	0.18 (0.07, 0.29)	0.002	0.31
Behavioral engagement	3.35 +/- 0.63	3.68 +/- 0.59	3.37 +/- 0.62	3.46 +/- 0.61	0.24 (0.11, 0.37)	<0.001	0.39
Emotional engagement	3.31 +/- 0.6	3.52 +/- 0.59	3.33 +/- 0.58	3.41 +/- 0.59	0.12 (0.01, 0.23)	0.028	0.22
Cognitive engagement	3.18 +/- 0.61	3.45 +/- 0.57	3.2 +/- 0.62	3.3 +/- 0.6	0.17 (0.05, 0.29)	0.006	0.28

Note. Models adjusted for baseline value, age, sex, and school clustering. Positive adjusted differences favor enhanced physical education.

Table 3 presents the main outcome results. The group-by-time effects favored enhanced physical education across all outcomes. The effect sizes were modest to moderate rather than exaggerated, consistent

with school-based intervention research in which many influences on classroom behavior operate simultaneously.

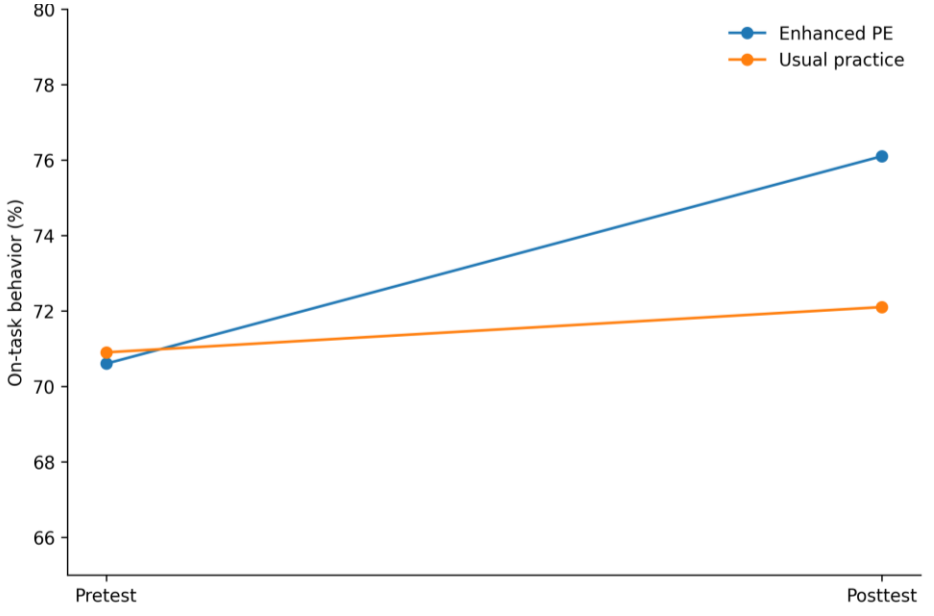


FIGURE 4. Pretest-posttest change in classroom on-task behavior.

Figure 4 focuses on the primary observable attention outcome. Both groups improved slightly over time, but the intervention group showed a steeper improvement in on-task behavior. This pattern suggests that ordinary school routines may produce small gains, while enhanced physical education added a measurable benefit.

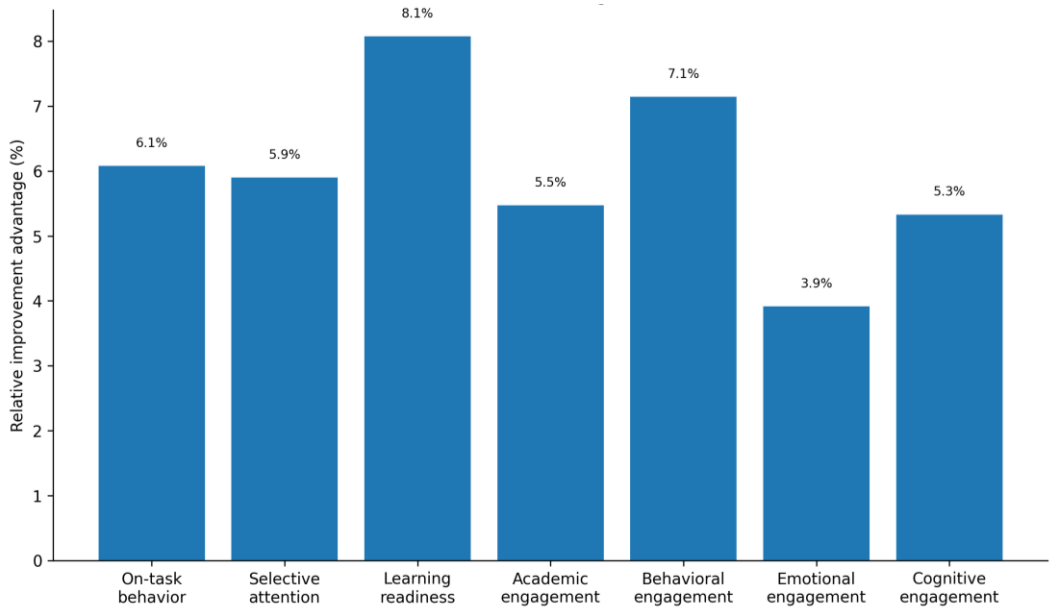
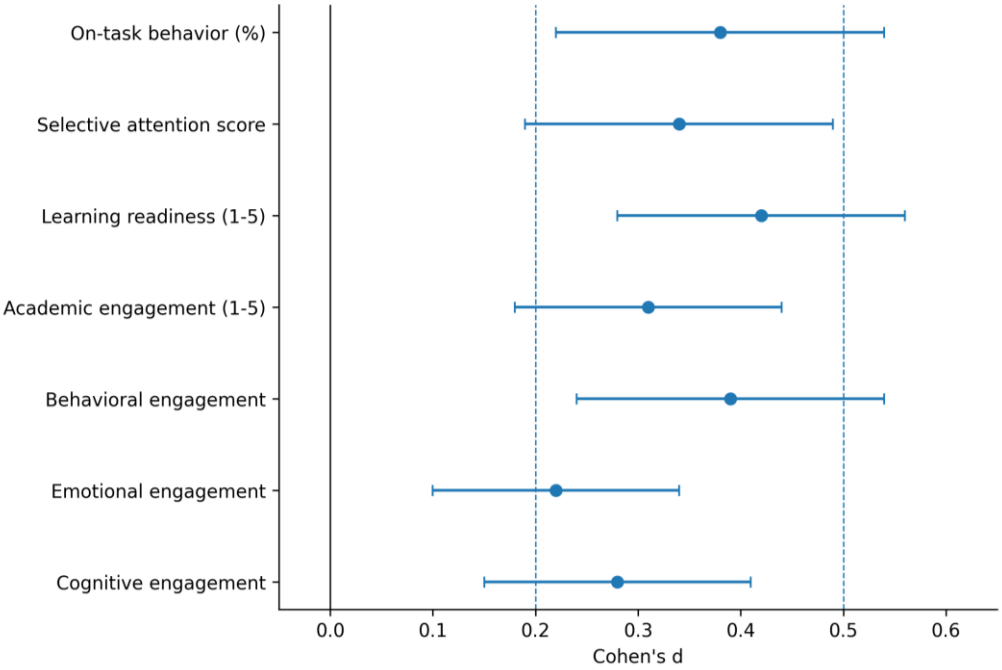


FIGURE 5. Adjusted treatment effects across all outcomes.

Figure 5 compares the relative intervention advantage across outcomes after putting outcomes on a common percentage scale. The largest relative gains were observed for learning readiness, behavioral engagement, on-task behavior, and selective attention. The figure also shows that emotional engagement



changed less than behavioral engagement, suggesting that affective responses may require longer exposure or broader school climate changes.

FIGURE 6. Standardized effect sizes for intervention outcomes.

Figure 6 displays standardized effect sizes. The effect size pattern supports a practical interpretation: the intervention produced meaningful but not large effects. Learning readiness, behavioral engagement, and on-task behavior were the most responsive outcomes, while emotional engagement showed the smallest effect.

TABLE 4. Sex-stratified adjusted effects for key outcomes.

Outcome	Sex	Adjusted difference in change (95% CI)	p value	Interaction p-value
On-task behavior	Female	+4.8 (2.0, 7.5)	0.001	0.64
On-task behavior	Male	+3.9 (1.1, 6.6)	0.006	0.64
Learning readiness	Female	+0.28 (0.13, 0.43)	<0.001	0.53
Learning readiness	Male	+0.22 (0.06, 0.38)	0.006	0.53
Academic engagement total	Female	+0.20 (0.07, 0.33)	0.004	0.71
Academic engagement total	Male	+0.16 (0.03, 0.29)	0.018	0.71

Note. The interaction p-value refers to the group-by-time-by-sex term. Positive estimates favor enhanced physical education.

Table 4 shows intervention effects for both female and male students. None of the sex interaction terms reached statistical significance, indicating that the intervention was not clearly more effective for one sex than the other.

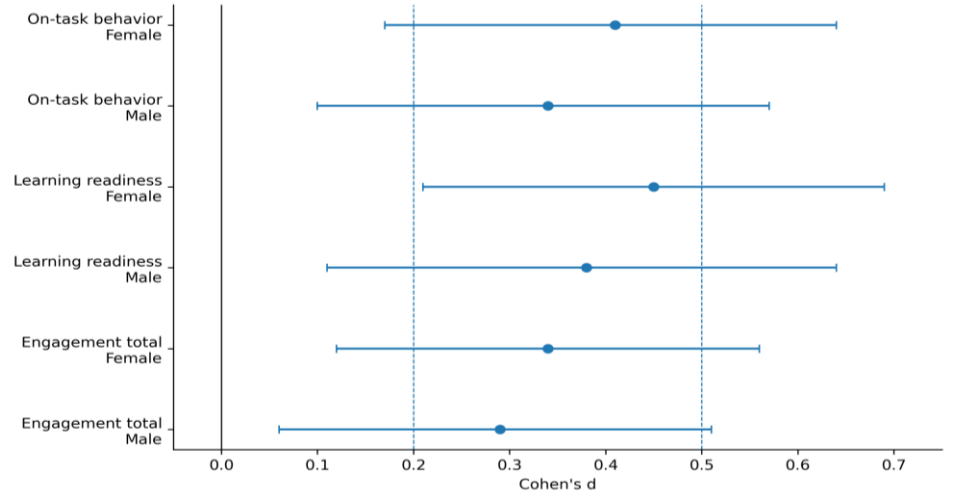


FIGURE 7. Sex-stratified intervention effects for key outcomes.

Figure 7 visualizes the sex-stratified effects using standardized effect sizes. The confidence intervals overlap substantially across female and male students, supporting the conclusion that both groups responded similarly.

Table 5. Associations between intervention exposure and outcome change within the enhanced PE group.

Predictor	Outcome change	Standardized beta	p value
Change in MVPA minutes per lesson	On-task behavior change	0.21	0.003
Change in MVPA minutes per lesson	Learning readiness change	0.18	0.011
Change in MVPA minutes per lesson	Academic engagement change	0.16	0.019
Cognitive-motor fidelity score	Selective attention change	0.17	0.015
Cool-down/reflection completion	Learning readiness change	0.19	0.008

Note. Regression models adjusted for baseline outcome value, age, and sex. Associations are observational within the intervention group.

Table 5 shows that higher exposure to moderate-to-vigorous activity and stronger cognitive-motor fidelity were associated with larger improvements in attention and readiness.

V. DISCUSSION

The present study found that a 12-week enhanced physical education program was associated with statistically significant improvements in classroom attention, learning readiness, and academic engagement compared with usual-practice physical education. The effect sizes were modest to moderate, consistent with the complexity of school learning environments. The largest effects were observed for learning readiness, behavioral engagement, and on-task behavior. This pattern is educationally plausible because these outcomes are temporally and behaviorally closest to the physical education lesson. Physical education may first influence how students settle, listen, and participate; deeper academic outcomes may require longer exposure and interaction with classroom pedagogy.

The finding for on-task behavior aligns with previous work showing that movement can improve classroom attention. Mahar and colleagues reported improved on-task behavior after a classroom-based physical activity program [11], and Watson and colleagues found that classroom-based physical activity

interventions can improve on-task and off-task behavior [23]. The present findings extend this evidence by focusing on formal physical education rather than only classroom activity breaks. This distinction is important because physical education has trained teachers, dedicated space, and curriculum legitimacy. When physical education is designed with attention and transition in mind, it may serve as a reliable school-day mechanism for improving classroom readiness.

Selective attention also improved more in the enhanced physical education group than in the comparison group. This result aligns with acute exercise research showing that moderately intense activity can support cognitive control and attention-related task performance [9]. It also fits the broader meta-analytic findings of de Greeff and colleagues, who reported positive effects of physical activity on attention in preadolescent children [4]. This study's intervention included movement games that required students to monitor rules, inhibit impulsive responses, respond to changing signals, and coordinate actions with peers. These features may have contributed to the observed gains in attention.

Learning readiness showed one of the strongest effects. This outcome is measured less often than academic achievement, but it is highly meaningful in daily school practice. Students who feel alert, settled, and prepared are more likely to benefit from the lesson that follows physical education. This improvement in learning readiness aligns with the idea that physical activity supports arousal regulation and mood, as described in the exercise neuroscience and cognition literature [5], [16]. It also suggests that the cool-down reflection component may have helped students connect physical exertion to the next academic task. Physical education that ends abruptly may leave some students overexcited; physical education that ends with a calm and purposeful transition may better support learning readiness.

Engagement theory describes behavioral, emotional, and cognitive participation as related but distinct components [27]-[30]. In this study, behavioral engagement improved more than emotional and cognitive engagement. This is not surprising. Behavioral engagement includes participation, task completion, and observable effort, which may respond quickly to improved classroom readiness. Emotional engagement, such as interest and enjoyment in academic work, may be influenced by broader factors such as teacher-student relationships, subject preference, peer climate, and perceived success. Cognitive engagement may require longer-term changes in strategy use, persistence, and self-regulated learning. The modest results for emotional and cognitive engagement should therefore be viewed as encouraging but not conclusive.

Meta-analyses have reported small positive effects of physical activity on academic achievement and classroom behaviors [21], while systematic reviews emphasize heterogeneity and methodological limitations [24], [25]. The present findings align more with classroom process outcomes than with end-of-term achievement scores. This may explain why the effects are visible after 12 weeks without being large. Better attention and engagement are necessary but not sufficient conditions for academic achievement. The translation from readiness to grades depends on curriculum quality, teacher instruction, assessment, and home learning support. Therefore, these findings should not be interpreted as evidence that physical education alone can substantially raise achievement. Rather, physical education appears to improve conditions that make academic learning more likely.

Both female and male students improved, and the intervention effect did not differ by sex. This finding supports inclusive physical education designs that avoid overly narrow sport selection and provide varied movement opportunities. The enhanced program included games, circuits, coordination tasks, and cooperative activities rather than focusing only on competitive sport. This variety may have allowed students with different preferences and skill profiles to participate meaningfully. The results align with the broader educational goal of physical education: to create movement experiences that are challenging, safe, and accessible.

Fidelity results suggest that the quality and composition of physical education matter. The enhanced group accumulated more moderate-to-vigorous minutes and more consistently completed the cognitive-motor and reflection components. Within the intervention group, higher activity exposure and stronger cognitive-motor fidelity were associated with greater improvements in attention and readiness. These findings do not prove causality, but they align with research showing that intervention design features, including intensity and cognitive demand, influence outcomes [24]. They also help explain why usual

physical education may not always produce learning-related benefits: having physical education on a timetable is not the same as an active, organized, inclusive, and cognitively engaging lesson.

Several limitations should be acknowledged. The study used school-level allocation to reduce contamination, but it was not individually randomized. Teacher ratings of on-task behavior may be influenced by expectancy, although a structured checklist and an objective selective attention task reduced reliance on a single method. The intervention lasted 12 weeks, so the study did not assess longer-term maintenance. The study did not use academic achievement scores as primary outcomes because it focused on immediate classroom learning conditions. Future studies should use longer follow-up, accelerometer-based activity measurement, randomization at school or class level, and standardized achievement outcomes. Studies should also examine whether the timing of physical education in the school day modifies its effect on attention and readiness.

VI. CONCLUSION

This study provides evidence that an enhanced physical education program can improve classroom attention, learning readiness, and academic engagement among lower-secondary students when implemented in a structured, inclusive manner. The findings matter because they focus on outcomes that are visible and important in everyday school life. Students in the enhanced physical education group returned to academic lessons with higher on-task behavior, better selective attention, stronger readiness to learn, and higher engagement scores than students who continued with usual-practice physical education. The results were statistically significant ($p < 0.05$) and strongest for learning readiness, behavioral engagement, and on-task behavior. These outcomes are closely linked to the immediate transition from movement to learning, suggesting that physical education lesson design can influence the quality of the next academic period.

Physical education should not be presented as a single solution to academic challenges, nor should it be expected to produce dramatic academic changes in a short period. Its contribution is more precise and educationally practical: it can help students regulate energy, improve readiness, participate more consistently, and begin academic tasks with greater focus. These conditions may create a better foundation for learning, especially in schools where students spend long periods seated and where teachers must manage fluctuating attention throughout the day.

The study also shows that both female and male students can benefit from an enhanced physical education approach. The lack of a significant sex interaction effect suggests the program was broadly inclusive. This is important because physical education programs that rely too heavily on narrow competitive sport formats may not engage all students equally. A balanced lesson structure that includes aerobic games, coordinative tasks, cooperative challenges, and reflection may provide a more equitable pathway for improving classroom functioning. The finding that activity exposure and cognitive-motor fidelity were associated with outcome gains further indicates that implementation quality matters. Schools should not assume that any physical education lesson will produce the same benefits; lesson intensity, organization, cognitive challenge, safety, and transition routines all appear relevant.

In conclusion, physical education deserves a central place in the school day not only because it supports health and movement competence, but also because it can strengthen the classroom conditions that allow learning to occur. When students are physically active in a purposeful, well-managed environment, they may return to class more attentive, better prepared, and more willing to engage. These findings support viewing physical education as part of a whole-school learning ecology: movement and cognition are not competing priorities but complementary dimensions of student development. Future research should verify these findings in larger randomized samples, include longer follow-up periods, and test how lesson timing, activity intensity, and cognitive-motor content influence academic outcomes. For now, the evidence suggests that improving physical education quality is a realistic and educationally valuable way to support attention, readiness, and engagement in everyday classrooms.

Author Contributions

The author conducted the conceptualization, methodology, data analysis, investigation, writing, review, editing, and final approval of the manuscript.

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Data Availability

The dataset will be available from the author upon reasonable request.

Conflicts of Interest

The author declares no conflict of interest.

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