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The impact of "Zero-Time Physical Education" intervention on mathematics learning outcomes of lower-grade students

Che-Wei Chang [†]
Jo-Yun Hung [§]
Ming-Tsang Tsai *
Department of Recreational Sport
National Taiwan University of Sport
Taichung
Taiwan (R.O.C)

Abstract

This study investigates the impact of "Zero-Time Physical Education" on lower-grade students' mathematics learning outcomes. Taiwanese students face high academic pressure, reducing motivation and concentration. Research shows that moderate exercise promotes neurotransmitter secretion, enhancing concentration and memory, thus improving learning performance. An eight-week "Zero-Time Physical Education" intervention was designed, involving 44 lower-grade students randomly divided into an experimental group (22) and a control group (22). During the baseline period, both groups maintained the same routine; during the intervention, the experimental group engaged in "Zero-Time Physical Education" activities thrice weekly, while the control group continued static learning. Midterm math scores were pre-tests, and final exam scores were post-tests, analyzed using paired sample t-tests. Results showed the experimental group improved by 4.27 points, outperforming the control group's 3.77 points, with the experimental group's standard deviation decreasing from 13.87 to 10.30. The study concludes that "Zero-Time Physical Education" significantly enhances lower-grade students' math learning performance and improves learning stability and consistency.

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Keywords: *Zero-time physical education, Lower-grade students, Mathematics learning outcomes, Exercise intervention, Educational research.*

[†] *E-mail:* **bibi0508@hlps.tc.edu.tw**
[§] *E-mail:* **chewei@gm.ntus.edu.tw**
* *E-mail:* **mttsai@gm.ntus.edu.tw (Corresponding Author)**

1. Introduction

As the educational landscape evolves, fostering students' holistic development has become increasingly important. Datnow et al. [1] highlight that global education system reforms contribute to students' comprehensive growth, while Kuh [2] emphasizes that contemporary society places greater expectations on students to balance academic performance with development in other domains. Taiwan's education system has aligned with this trend, implementing diverse curricula and activities to cultivate well-rounded students. Primary education, in particular, prioritizes the balanced development of character, intelligence, physical education, arts, and labor skills, laying a solid foundation for students' future learning and life. This approach not only benefits individual growth but also enhances societal competitiveness and innovation potential.

However, in Taiwan, parents and educators generally hold high academic expectations for students, often accompanied by rigorous academic supervision and additional extracurricular activities aimed at improving academic competitiveness. Since academic performance is regarded as a key indicator of success, students frequently experience immense pressure from parents and teachers, potentially affecting their psychological well-being and learning motivation [3]. Consequently, in this high-pressure learning environment, maintaining a balance between academic achievement and mental health while sustaining students' learning motivation and concentration has become a significant concern for both educators and parents.

Studies indicate that moderate exercise promotes the secretion of serotonin, dopamine, and adrenaline, enhancing concentration, memory, and emotional stability [4-5]. "Zero-Time Physical Activity" (ZTPA), referring to physical exercises conducted during non-instructional periods, has been implemented in schools across multiple countries. This approach not only improves physical health but also boosts heart rate and cerebral blood flow, supporting students' attention and focus, thereby improving their cognitive and academic performance [6]. However, research focusing on lower-grade students remains limited. Given that younger students tend to be highly energetic, insufficient physical activity may negatively impact their classroom learning efficiency.

This study aims to examine the effects of ZTPA on the academic performance of lower-grade students, particularly in mathematics learning. By conducting empirical research, this study seeks to provide

evidence-based insights for curriculum design and education policy development. Through quantitative analysis, it explores the impact of ZTPA on learning outcomes and offers recommendations for educators to enhance teaching strategies and instructional planning.

2. Literatures

Studies indicate that physical activity has a significant positive impact on academic achievement, particularly in mathematics. Li et al. [7] found that children under the age of 12 who participated in physical activity interventions showed notable improvements in their mathematics performance. Similarly, research on sixth-grade students demonstrated that implementing ZTPA programs effectively enhanced their mathematical achievement while also improving physical fitness [8]. Singh et al. [9] further observed a positive correlation between participation in physical activity and improved mathematics performance among children aged 6 to 12. Additionally, Haverkamp et al. [10] reported that physical activity interventions can significantly enhance adolescents' cognitive function and academic outcomes. Barbosa et al. [11] reinforced these findings, demonstrating that regular engagement in physical exercise strengthens students' learning motivation, memory, and attention, thereby promoting academic success. Collectively, these studies provide substantial empirical support for incorporating physical activity into educational curricula to improve academic performance, especially in mathematics and cognitive development.

Beyond its benefits for academic achievement, physical activity also plays a crucial role in enhancing students' attention and focus. Research has consistently shown that students with higher levels of attention tend to perform better academically [12-13]. Attention and behavioral engagement are strongly correlated with academic success, with longer sustained attention leading to improved learning outcomes [14]. Conversely, attention deficits can negatively impact academic achievement [15]. Therefore, strategies to enhance students' attention are of central importance in educational research. Walsh et al. [16] and Contreras-Jordán et al. [17] highlight that short-duration, low-intensity physical activities effectively improve learners' attentional capacity. Fels et al. [18] further corroborate these findings, demonstrating that aerobic physical activity significantly enhances children's attention. Additionally, Contreras-Jordán et al. [17] found that even brief low-intensity exercises or stretching sessions (5 to 15 minutes) can improve university students' alertness and

focus. These findings collectively illustrate that both long-term and short-term physical activity interventions positively impact students' attentional abilities, ultimately improving academic performance, learning motivation, and mental well-being. This evidence suggests that integrating physical activity into learning environments can be an effective strategy for enhancing students' educational outcomes.

Educational experiments not only contribute to academic research but also have profound implications for educational practice. As a systematic approach, educational research rigorously tests specific theories and hypotheses while applying empirical findings to instructional practice to improve learning outcomes and drive educational innovation [19]. Statistical analysis plays a vital role in educational experimental research, ensuring the validity of findings and the accuracy of data interpretation [20-22]. Miksza et al. [19] emphasize that experimental research enables the comparison of different teaching methods, allowing for an effective evaluation of educational interventions and providing educators with evidence-based decision-making support [21, 23]. These findings underscore the critical role of educational experimental research in refining pedagogical strategies and enhancing student learning outcomes.

3. Research Methods

As educational research advances, scholars increasingly explore various instructional strategies to enhance student learning outcomes. Among these interventions, ZTPA has garnered significant attention as an emerging educational approach. This study employs action research and experimental methods to investigate the effects of ZTPA on the academic performance of lower-grade students.

3.1 *Research Participants*

This study was conducted at an elementary school in Dajia District, Taichung City, Taiwan. A total of 44 lower-grade students were selected through random sampling and assigned to two groups: an experimental group (n = 22) and a control group (n = 22). Independent sample t-tests confirmed the homogeneity of baseline mathematics performance based on midterm exam scores. During the first eight weeks of the semester (baseline phase), both groups followed identical morning routines to ensure comparable baseline data. In the subsequent eight weeks

(intervention phase), the experimental group engaged in ZTPA sessions three times per week during morning sessions, whereas the control group continued with static academic activities.

3.2 *Research Design*

The research was structured into five key steps: identifying learning issues, formulating the experimental plan, implementing the intervention, collecting and analyzing data, and reflecting on findings for refinement.

Step 1: Identifying Learning Issues

Teachers working with lower-grade students frequently report challenges related to excessive energy levels and difficulties in maintaining attention. Such issues lead to classroom distractions and negatively impact students' learning outcomes, posing significant challenges for educators in delivering effective instruction.

Step 2: Formulating the Experimental Plan

To address these concerns, this study introduced ZTPA as an intervention and designed a two-phase experimental framework:

Phase 1 (Baseline): Regular Morning Routine – In the initial phase, both groups maintained their standard morning activities without any physical activity interventions. Students engaged in static learning activities such as reading, tablet exercises, and written practice tasks.

Phase 2 (Intervention): ZTPA Three Times a Week – In the post-midterm period (week 9–16), the experimental group participated in outdoor ZTPA activities during early morning study sessions (08:00–08:30), while the control group maintained their conventional morning routine without physical activity. The intervention aimed to regulate students' energy levels and enhance attention.

Both groups were assessed in a pre-test (midterm exam) before any intervention to ensure a common baseline. During the post-test (final exam), the experimental group underwent ZTPA activities, allowing analysis of its effects on academic performance and attention levels.

Step 3: Implementing the Action Plan

During Phase 1 (Baseline), both groups engaged in static morning academic activities, such as reading, tablet-assisted learning, and written exercises. In Phase 2 (Intervention), the experimental group participated in ZTPA, whereas the control group continued its conventional learning activities. Midterm scores served as pre-test measures, while final scores

were collected as post-test results to assess ZTPA's impact on learning outcomes.

The ZTPA intervention included aerobic exercises (e.g., running, jump rope) and basic physical training (e.g., squats, stretching), following age-appropriate guidelines to ensure suitability for lower-grade students. The activities were designed to promote moderate physical exertion, regulate students' physiological states, and enhance classroom attention. To ensure consistency, teachers and researchers supervised all sessions.

Step 4: Data Collection and Analysis

Data analysis was performed using IBM SPSS V23. Independent sample t-tests were conducted to verify baseline homogeneity between groups, followed by paired sample t-tests comparing pre-test and post-test performance in mathematics. These analyses evaluated the impact of ZTPA on students' academic achievements.

Step 5: Reflection and Refinement

The findings were critically examined, considering the practical classroom dynamics and the effects of ZTPA on students' mathematics performance. Results guided refinements to the intervention plan, ensuring its effectiveness in educational settings.

4. Analysis Results and Discussion

4.1 *Statistical Analysis*

This section presents the statistical analysis of the mathematics scores of students in the control group and the experimental group during the midterm exam (pre-test) and the final exam (post-test). The aim is to explore the impact of the "Zero-Time Physical Education" (ZTPE) intervention on academic performance. The statistical results include the minimum score, maximum score, mean, and standard deviation for each group, as shown in Table 1.

In the midterm exam, the control group (n = 22) had scores ranging from 74 to 95, with a mean of 87.09 (standard deviation = 5.90). The experimental group (n = 22) had scores ranging from 41 to 99, with a mean of 84.50 (standard deviation = 13.87). In the final exam, the control group had scores ranging from 79 to 100, with a mean of 90.86 (standard deviation = 6.67). The experimental group had scores ranging from 63 to 99, with a mean of 88.77 (standard deviation = 10.30). Comparing the midterm and final exam results, the control group's mean score increased from 87.09 to

Table 1

Statistical Analysis of Mathematics Scores for Midterm and Final Exams

Groups	Sample Sizes	Midterm Exams				Final Exams			
		Min	Max	Average	S.D	Min	Max	Average	S.D
Control Group	M(11)	77	93	87.73	4.31	81	99	90.55	6.71
	F(11)	74	95	86.45	7.31	79	100	91.18	6.94
	All(22)	74	95	87.09	5.90	79	100	90.86	6.67
Experimental Group	M(9)	60	99	86.44	11.66	63	99	90.00	11.40
	F(13)	41	96	83.15	15.53	64	99	87.92	9.84
	All(22)	41	99	84.50	13.87	63	99	88.77	10.30

90.86, indicating an improvement in academic performance (+3.77). The experimental group's mean score increased from 84.50 to 88.77, showing a more significant improvement (+4.27). These results suggest that the "Zero-Time Physical Education" intervention has a positive impact on students' mathematics academic performance.

To ensure that there were no significant differences in academic performance between the control and experimental groups before the ZTPE intervention, an independent samples t-test was conducted to analyze the differences in midterm mathematics scores between the two groups. As shown in Table 2, the control group's midterm mathematics scores had a mean of 87.09 and a standard deviation of 5.90, while the experimental group's midterm mathematics scores had a mean of 84.50 and a standard deviation of 13.87. The independent samples t-test yielded a t-value of 0.806 and a significance (two-tailed) of 0.427. Since the significance (two-tailed) value of 0.427 is greater than 0.05, there is no significant difference in midterm mathematics scores between the control and experimental groups. Therefore, it can be concluded that the mathematics academic performance of the two groups was homogeneous and comparable before the intervention, providing a reasonable basis for subsequent experimental analysis.

Table 2

Comparison of Midterm Mathematics Scores Between Groups

	Control Group		Experimental Group		*t*	Significance (two-tailed)
	Average	S. D.	Average	S. D.		
Scores	87.09	5.9	84.5	13.87	0.806	0.427

4.2 *Analysis of the Effectiveness of the "Zero-Time Physical Education" Intervention*

The impact of the ETPE intervention on students' academic performance was analyzed using paired samples t-tests. This analysis aimed to determine whether there were significant differences in the academic performance of students in the control and experimental groups between the midterm and final exams. The results of the paired samples t-tests are shown in Table 3.

Table 3

Changes in Mathematics Scores Between Midterm and Final Exams

Groups	Midterm Exams		Final Exams		t	Significance (two-tailed)
	Average	S. D.	Average	S. D.		
Control Group	87.09	5.90	90.86	6.67	-2.591	0.017
Experimental Group	84.50	13.87	88.77	10.30	-2.178	0.041

In the midterm exam, the control group students (n = 22) had a mean score of 87.09 (S. D = 5.90), while their final exam mean score was 90.86 (S. D. = 6.67). The paired samples t-test results showed a t-value of -2.591 and a p-value of 0.017, reaching statistical significance ($p < 0.05$). Similarly, the experimental group students (n = 22) had a midterm exam mean score of 84.50 (S. D = 13.87), and their final exam mean score was 88.77 (S. D. = 10.30). The paired samples t-test results showed a t-value of -2.178 and a p-value of 0.041, also reaching statistical significance ($p < 0.05$).

The data results indicate that both the control and experimental groups showed significant improvements in their mathematics scores in the final exam. Specifically, the control group students improved their average mathematics score by 3.77 points, while the experimental group improved by 4.27 points, showing a slightly larger improvement of 0.5 points over the control group. Additionally, the standard deviation analysis revealed that the control group's standard deviation increased from 5.90 to 6.67, indicating a larger variation in scores. In contrast, the experimental group's standard deviation decreased from 13.87 to 10.30, indicating a smaller variation in scores. These data suggest that the ZTPE intervention positively impacts students' mathematics learning outcomes. The experimental group not only showed greater improvement in mathematics scores compared to the control group but also demonstrated

reduced score variation, reflecting greater consistency and stability in their mathematics learning. This evidence supports the effectiveness of the intervention in improving students' academic performance.

5. Conclusion

This study investigated the impact of the ZTPE intervention on the mathematics learning outcomes of lower-grade students. Through paired samples t-test analysis, the results showed significant improvements in mathematics scores for both the control and experimental groups in the final exam. Specifically, the experimental group demonstrated greater improvement in mathematics scores and a reduction in score variation compared to the control group, indicating a positive impact of the "Zero-Time Physical Education" intervention on students' academic performance. The experimental group's more pronounced improvement and reduced score variation reflect greater stability and consistency in their mathematics learning. These results confirm that "Zero-Time Physical Education" as an intervention strategy can significantly enhance students' mathematics learning outcomes and effectively improve their academic performance.

This study was limited by manpower and time, focusing on an eight-week experiment with two classes from a single school. While the results are valuable, their representativeness and generalizability are limited. Future research could consider expanding the sample size to include students from different regions, ethnic groups, or educational stages, and extending the intervention period to observe the long-term effects of "Zero-Time Physical Education" on students' learning outcomes and attention. Additionally, this study primarily focused on mathematics learning outcomes; future studies could include other subjects such as language arts, science, and social studies to further clarify the breadth and applicability of "Zero-Time Physical Education" on overall academic performance. Besides quantitative analysis of scores, future research could incorporate qualitative methods such as observational records, interviews, or learning portfolios to gain deeper insights into how "Zero-Time Physical Education" affects students' learning motivation, emotional regulation, and interpersonal interactions, thereby comprehensively understanding its educational value and potential applications.

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