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EFFECTS OF A MATH-INTEGRATED AFTERSCHOOL PHYSICAL ACTIVITY PROGRAM: A CASE STUDY

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Abstract

This case study aims to evaluate the impact of an afterschool physical activity (PA) program integrated with mathematics on elementary school students' Body Mass Index (BMI), fitness levels, and comprehension of geometry concepts–a recommended strategy for preventing child obesity. Utilizing descriptive statistics and t-tests, the study analyzes pre- and post-geometry assessments and FITNESSGRAM® assessments. Despite no significant weight change, the findings reveal improved cognitive understanding of geometry concepts and enhanced fitness levels. This research contributes valuable evidence supporting the positive effects of integrating PA into math learning environments, particularly benefiting low socioeconomic status (SES) and underrepresented children, addressing the decline in both physical activity and math performance during childhood.

Keywords

Afterschool Physical Activity Program, Math-Integrated PA, Cross-Curricular Integration, Mathematics Integration, Child Obesity Prevention, Fitness Levels, Comprehension of Geometry Concepts, Geo-Baloo

Introduction

The education system in the United States places a strong emphasis on core subjects such as math and reading, often overlooking the importance of physical activity (PA). An exclusive focus on core academic subjects, at the expense of PA, could have negative consequences on children's cognitive functions, attention spans, and social interactions because neglecting the need for movement could deprive children of the natural chemicals that enhance focus and memory (Elkin, 2012; Kempermann, 2002; Malm, 2008). It also might potentially contribute to an increased reliance on electronic devices and diminished attention in class, as well as a decline in social interaction.

The benefits of PA are also associated with several positive aspects of health, including a reduced risk of developing type 2 diabetes, cardiovascular disease, and obesity. Additionally, regular PA contributes to improved bone health and muscle strength (Centers for Disease Control and Prevention [CDC], 2015). However, children are not engaging in PAs on a regular basis in school, spending a significant amount of the school day seated (Mooses et al., 2017). This trend contributes to factors that lead to excess weight in childhood, which is associated with immediate and long-term health concerns (de Rezende, Rodrigues Lopes, Rey-López, Matsudo, & Luiz Odo, 2014).

The childhood obesity rate has been increasing for decades in the United States. According to the most recent data from the CDC, the prevalence of obesity is 18.5%, affecting about 13.7 million children and adolescents (Hales, Carroll, Fryar, & Ogden, 2017). One recommended strategy to prevent child obesity is to help children become more active by providing opportunities to participate in PAs regularly. One of the goals of physical education (PE) is to ensure that children meet the daily PA recommendations. Daily PA can be facilitated through various school settings, including PE classes, recess, classroom activities, and after-school programs. In this study, our focus was on exploring the integration of PA with the math curriculum, envisioning its potential application in classrooms for daily PA in the future. The primary aim of this study is to evaluate the impact of a math-integrated PA program for elementary school students on Body Mass Index (BMI), fitness levels, and their comprehension of geometry concepts.

Literature Review

Whenever learning is connected to a child's life, making it more relevant and personally meaningful, the impact becomes more profound and contributes to the development of long-term memory (Roberts & Kellough, 2008). Some children, particularly those identified as kinesthetic learners (Gardner, 2006), find that connections are most effectively established through movement. Physical activity also releases brain-derived neurotrophic factor (BDNF), which promotes a state of readiness for brain cells to grow and retain information for an extended period. Thus, incorporating movement into educational settings can be a strategy for math educators to support students' mastery of math competencies, and this is consistent with the known benefits of physical activity on cognitive function (Elkin, 2012; Kempermann, 2002; Malm, 2008).

Interdisciplinary Learning

Interdisciplinary learning involves integrating two or more subject areas in the educational process, aiming to enhance learning within each subject area (Cone, Werner, Cone, & Woods, 1998). The concept of integrating subjects is referred to as cross-curricular integration (Jacobs, 1989). Numerous research studies have demonstrated the success of cross-curricular integration across various disciplines. The findings suggest that integration is not only achievable but also enhances students' knowledge and inquiry skills (Finn & McInnis, 2014; Kokko, Eronen, & Sormunen, 2015; Lynch, 2016; Phillips & Marttinen, 2013; Usnick, Johnson, & White, 2003).

To increase the level of PA among children, physically active lessons have emerged, combining PA with academic concepts (Beck et al., 2016; Kibbe et al., 2011; Norris, Shelton, Dunsmuir, Duke-Williams, & Stamatakis, 2015). A recent movement is to integrate PA into the instruction of academic subjects (Bartholomew & Jowers, 2011; Vazou, Saint-Maurice, Skrade, & Welk, 2018). One of the most frequently implemented academic concepts in PA is mathematics (Cecchini & Carriedo, 2020; Elkin, 2012; Vazou et al., 2018).

Math-Integrated Physical Activity (PA) Activities

Over the past decade, mathematics educators have also emphasized the importance of interdisciplinary collaboration with other subjects in order to engage students in mathematical learning activities (English, 2009; Nakakoji & Wilson, 2020; Roth, 2020; Williams et al., 2016). Particularly, the utilization of PA in the instruction of mathematics has been considered as an innovative approach for elementary school students to improve mathematical learning and PA levels (Beck et al., 2016; Cecchini & Carriedo, 2020; Chen, 2007; Chen, Cone, & Cone, 2011; Snyder, Dinkel, Schaffer, Hiveley, & Colpitts, 2017).

Researchers have employed intentional body movements and positions as a strategy to enhance mathematical learning experience. Their findings indicate that the meaningful integration of movement and PA into the mathematical learning process has yielded positive academic outcomes in mathematics (Bartholomew & Jowers, 2011; Chen, 2007; Cecchini & Carriedo, 2020; Donnelly et al., 2016; Elkin, 2012; Snyder et al., 2017; Vazou et al., 2018; Wade, 2016).

As a result, integrating PA into the mathematics learning environments is certainly a promising teaching and learning approach, especially given the ease of embedding math and math literacy concepts with minor modifications. This method also holds potential to address both the apparent decline in PA across childhood and poor performance in mathematics during the school day, especially among low socioeconomic status (SES) and underrepresented young children (Brodersen, Steptoe, Boniface, & Wardle, 2007; Brodersen, Steptoe, Williamson, & Wardle, 2005; Heard, 2007). For successful integration, collaboration between math educators advocating for more active learning and PE teachers seeking a more central and integral role in schools could be highly beneficial for both parties. However, there are few empirical studies available to examine the potential of this collaboration (Cecchini & Carriedo, 2020; Marttinen, McLoughlin, Frederick, & Novak, 2017).

To fill this research gap, in this intervention study, one PE expert and two math educators collaborated to develop and design a math-integrated PA program using a thematic unit approach. This instructional method involves organizing and integrating curriculum content across different subjects around a central theme (Roberts & Kellough, 2008). The goal is to provide a more holistic and meaningful learning experience by emphasizing relationships between different subjects using a unified theme. The chosen central theme in this math-integrated PA program focuses on geometry concepts, particularly 2-dimensional (2D) shapes, various types of angles (including right angles and obtuse angles), and lines. These concepts were selected because of their extensive real-world applications, including in PA, such as determining the best angles for squatting or throwing a football. The purpose of this study is to examine the effects of this math-integrated PA invention program for elementary school students on BMI, fitness levels, and their comprehension of geometry concepts.

Methodology

Our research methodology consisted of three steps. First, we developed math-integrated activities and designed an afterschool physical activity (PA) program based on these activities. Next, we implemented the afterschool PA program at a local elementary school. Finally, we conducted a statistical examination to assess the effectiveness of the intervention on the participants' levels of both fitness and cognitive understanding of geometry concepts.

Development of Curriculum for a Math-Integrated Physical Activity (PA) Program

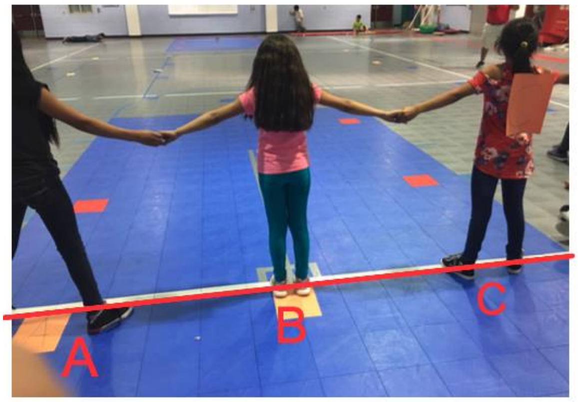
Building on the thematic unit approach described above, the program was designed by one expert in exercise science and two math educators, taking into consideration national standards for both PE and math education. The program's theme revolved around geometry concepts related to PE movements and PA. It applied geometric concepts, such as 2D shapes, types of angles, and lines, to various PE activities, including jumping and landing, balancing, overhand throw, and free-weight exercise. Developed across four areas, the program aimed to enhance flexibility, muscle strength, cardiorespiratory fitness, and understanding of geometry concepts. The program encompasses the five math-integrated physical activity (PA) activities as follows.

Activity 1. Warm-up: Making together

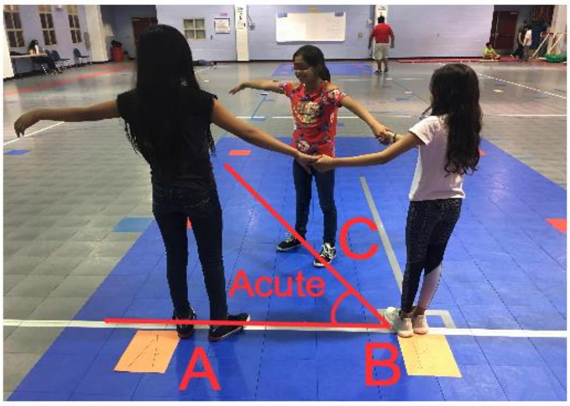
In this collaborative activity, teachers activate students' existing knowledge of closed shapes, right angles, parallel lines, and congruent segments. During this engaging exercise, students not only revisit these geometric concepts but also reinforce their understanding by physically embodying the shapes with their peers. By creating tangible examples using their bodies, students find it easier to comprehend and recall the associated vocabulary. Participants have the flexibility to work individually, in pairs, or within a group, depending on the specific shapes they aim to represent.

To initiate the activity, students are arranged in a circle, with a teacher positioned at the center. The teacher directs the students to form each shape using their bodies, either individually, in pairs, or as a group. For example, when prompted to demonstrate parallel lines, two students stand at a distance and extend their arms straight, ensuring the lines do not intersect. In a brief discussion, teachers can reinforce the concept that parallel lines do not intersect and consistently maintain an equal distance from each other. For crafting a closed shape, two students connect their arms without leaving any gaps. To portray a straight line (180 degrees) and an acute angle (less than 90 degrees), three students can collaboratively demonstrate. For the straight line, they can stand in a line to represent the concept visually (see Figure 1a). For the acute angle, they can form a vertex with two rays, illustrating the geometric concept (see Figure 1b). This pattern continues for other shapes in a similar fashion.

(a)



(b)



Note. (a) Making a straight line, & (b) Making an acute angle

Figure 1. Making together activity

Activity 2. Geo-Baloo: "Geometry + Hullabaloo"

We created the Geo-Baloo activity drawing inspiration from Hullabaloo, a high-energy game where kids engage in quick thinking and close listening, bouncing, twisting, spinning, high-fiving, and dancing to the upbeat music, fun sounds, and friendly voice of Hullabaloo (Park, Kim, & Kwon, 2019). In Geo-Baloo, mats featuring various quadrilaterals–trapezoids, parallelograms, rectangles, rhombuses, and squares–are positioned on the floor. An announcer, equipped with definitions and properties of the shapes, as well as commands for PE movements like jumping jacks, curl-ups, push-ups, and squats, guides participants. The announcer's instructions are accompanied by lively dance music, creating an engaging audio experience. The shapes are scattered randomly across the floor, adding an element of unpredictability to the activity (see Figure 2).

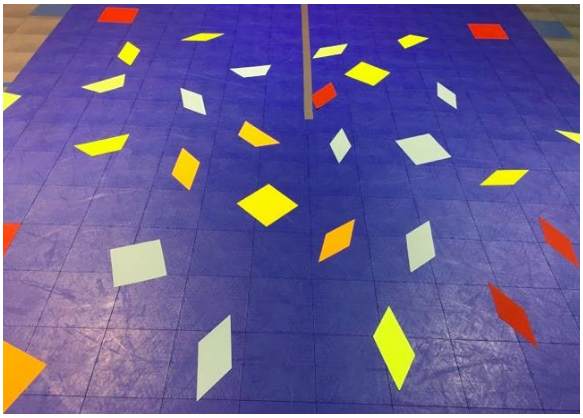


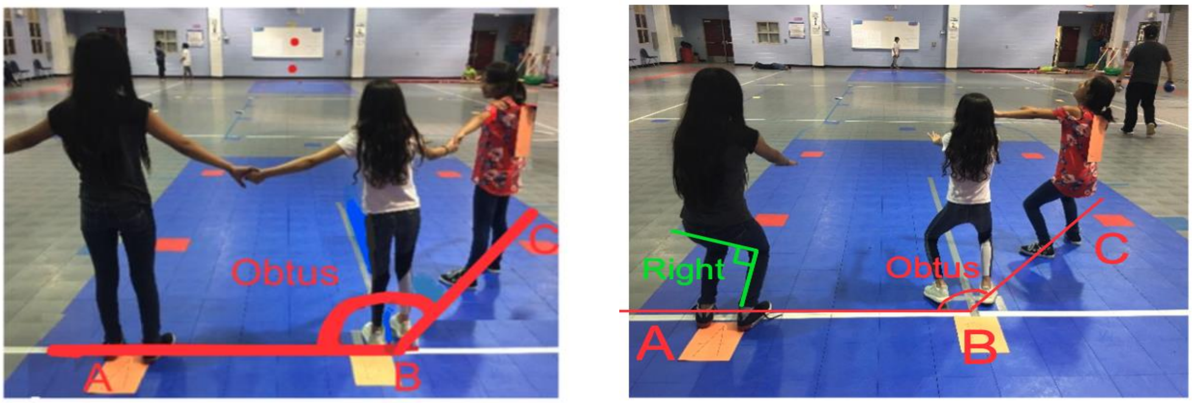
Figure 2. The Geo-Baloo activity

During the activity, students listen carefully to the definitions, properties, or names of different quadrilaterals and commands for PE movements. They must think quickly and complete missions announced by the instructor. For example, they might be instructed to *"Run to a shape with 4 right angles and do "Sit and reach" for 5 second, one, two, three, four, five"*; *"Fly to a rhombus and do 6 push-ups"*; *"Walk to a parallelogram and do as many curl-ups as can"*; and so on. A round of the activity concludes with the announcement, *"Freeze. Stay on that pad. If anyone is touching the square, you are the winner. Winner! Do a funky dance."*

Activity 3: Hands on hands

A group of three students, labeled A, B, and C, stand on a designated spot with their hands forming a parallel line (see Figure 1a). Each student has a specific role. Student A will call out an angle type, such as acute, right, or obtuse. Based on Student A's comment, Student C will adjust their position to demonstrate the angle. Once Student C has positioned themselves correctly, Student B will suggest a type of free-weight activity and specify the number of repetitions for the exercise. After Student B's recommendation, Students A, B, and C will proceed to complete the exercise. For example, Student C positions themselves to demonstrate an obtuse angle–an angle greater than 90 degrees but less than 180 degrees (see Figure 3a), and students perform squats based on the command given by Student B (see Figure 3b). Throughout the activity, students are instructed to analyze skill components and provide feedback to each other. For instance, they are asked to observe whether their partners' legs formed a right angle during a squat.

(a) (b)



Note. (a) Student C has positioned themselves to demonstrate an obtuse angle, & (b) Students are performing squats based on the command given by Student B.

Figure 3. Hands-on-hands activity.

Activity 4: Throwing

There are four skill components in the overhand throw. Stand sideways to the target, with the hand and arm positioned way back. Take one step toward the target with the opposite foot. Initiate the throw with the shoulder first, followed by the elbow, forearm, and hand moving forward. Direct the bellybutton towards the target during the throw. During a partnered activity, this station provides students with an idea of how to achieve a right angle by bending their arm, offering an opportunity to analyze the skill for others. One student should demonstrate each skill component of the overhand throw slowly, step by step, while facing the wall (see Figure 4). Meanwhile, their partner observes to ensure the proper formation of the right angle.

Figure 4. Throwing

Activity 5. Hope and angle

This activity involves a team relay race with groups of three to four students. Each team lines up behind the starting line. Once a teacher calls out a type of angle, such as acute, obtuse, or a right angle, along with an exercise like five push-ups or seven squats, a student at the front line will find and jump to the specified angle, then complete the exercise while holding the baton. Students then proceed to jump to other angles that are not the same as the one before, making their way through a finish line (see Figure 5). For example, if a teacher calls 'a right angle' with five push-ups, the student should first jump to 'a right angle,' and then, after completing the exercise, jump to 'an acute' or 'obtuse angle.' While playing the game, the student says 'acute,' 'right,' or 'obtuse' based on the angle they are on. If a player finishes, they should return to the starting line and then pass the baton to the next player. If everyone on a team finishes the race, the team will win.

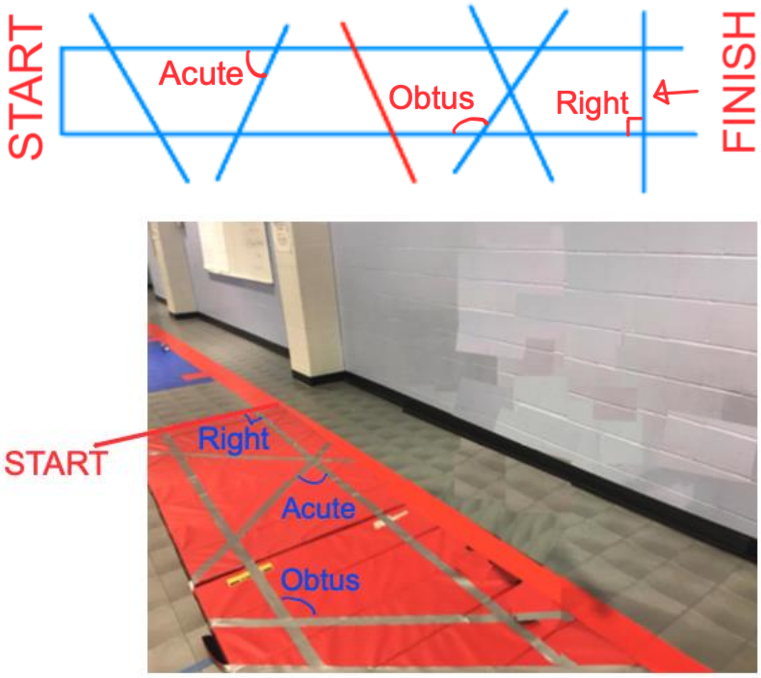


Figure 5. Hope and angle activity

Participants

The participants were recruited from third and fourth-grade students who had registered for the afterschool program at the local elementary school, which enrolls 94% economically disadvantaged students and has a 99% minority student enrollment. A total of 14 students, comprising six males and eight females (12 third graders and 2 fourth graders), voluntarily participated in the study. Informed consent was obtained from both the participants and their parents before the study, which was approved by the University Institutional Review Board. The average height and weight of the participants were 146.09 centimeters and 43.6 kilograms, respectively. During the study, participants engaged in a 4-week math-integrated PA program, lasting 45 minutes twice a week. The program aimed to promote abdominal strength and endurance, trunk extensor strength and flexibility, and upper body strength and endurance, with an emphasis on the concepts of geometry.

Staff Training

Two math educators and one specialist in physical education trained four preservice teachers: two majoring in elementary education and two majoring in physical education teacher education. The preservice teachers supported the implementation of the math-integrated PA program. The staff training was designed to provide an understanding of working with minorities and teaching strategies for a math-integrated physical activity program. The staff participated in a training session for a total of five hours: two hours for child protection training and three hours for teaching strategies conducted by the researchers.

Instruments

Two assessments were done before and after the intervention. To measure subjects' level of fitness, FITNESSGRAM® was implemented as an assessment instrument twice (pre- and post-test). The measured tested items were height, weight, curl-ups, shoulder stretch, Trunk Lift, Pushups, and the Pacer test. Height and weight were measured using a Seca S-214 portable height rod (Hanover, MD), and a Detector DR400C digital body weight scale (Webb City, MO), respectively. Pre- and post-geometry tests were also conducted. The geometry test consisted of 25 items to measure the level of knowledge on 2D shapes and different types of angles, including right angles and obtuse angles. The total score was 25 points. T-tests were employed to examine the effectiveness of the intervention on the participants' levels of both fitness and cognitive understanding of geometry concepts.

Results and Discussion

Upon implementing the math-integrated PA program, we observed that the participants effectively enhanced their grasp of geometric definitions and properties through active participation in body movement exercises. Students demonstrated a solid comprehension of the definitions and properties of 2D geometric shapes and types of angles by integrating mathematics into the PE setting. Notably, the Geo-Baloo activity facilitated an enjoyable and engaging learning process for the participants, transforming geometric concepts into a fun game. Through their active involvement in the activity, the participants had numerous opportunities to deepen their conceptual understanding of quadrilaterals, including their definitions and properties. This understanding enabled them to classify quadrilaterals hierarchically based on their properties. Remarkably, the participants not only gained knowledge but also thoroughly enjoyed the learning process. As indicated in Table 1, the statistical results from the pre- and post-geometry assessments support our observations regarding the participants' understanding of geometry concepts.

Pre-test		**Post-test**		*t*	*Sig*
Mean	Standard Deviation (SD)	Mean	Standard Deviation (SD)		
6.54	3.699	15.24	6.27	3.124	<.000

Table 1. Results of Pre- and Post-Geometry Tests

There was a significant difference observed in the pre- and post-geometry tests. The *t*-value for the test items is 3.124 ($p < 0.001$). This value is statistically significant and indicates an improvement in the participants' understanding of the geometry concepts after the intervention.

On the other hand, there was no significant difference observed in weight after the participants took the PA program. However, as shown in Table 2, there was a significant difference in all the measured fitness-related test items. The *t*-values for all the measured fitness-related test items (Curl-ups, Shoulder stretch right, Shoulder stretch left, Trunk lift, Push-ups, and Pacer test) are statistically significant ($p < 0.001$) and indicate significant improvements in participants' fitness levels.

Item	Pre		Post		*t*	*Sig*
	Mean	SD	Mean	SD		
Curl-ups	26.43	11.25	44.62	13.24	7.31	<.000
Shoulder stretch right	12.14	3.133	13.61	4.091	12.4	<.000
Shoulder stretch left	12.04	2.381	14.33	6.521	8.28	<.000
Trunk lift	9.642	1.292	13.41	7.749	6.5	<.000
Push-ups	16.43	6.699	21.43	11.27	7.11	<.000
Pacer test	12.93	10.82	23.79	11.24	7.72	<.000

Table 2. Results of Pre- and Post- FITNESSGRAM® Assessments

Considering the short 4-week intervention, lasting 45 minutes twice a week, it might not be surprising that there was no significant difference in the participants' weight change. However, the significant improvements in their level of fitness could lead us to expect a positive effect of the intervention to prevent child obesity if they engage in a year-long math-integrated PA program.

The participants increased their understanding of geometric concepts, including 2D shapes, types of angles, and lines, and improved their level of fitness during the math-integrated PA program. These observed enhancements in participants' fitness levels and cognitive understanding of geometry concepts following the intervention align with the findings from previous research studies that integrated PA with academic concepts (Beck et al., 2016; Cecchini & Carriedo, 2020; Chen, 2007; Chen et al., 2011; Snyder et al., 2017). This finding might lead to a discussion about the importance of a balanced and holistic approach to education that includes both academic and physical well-being.

Conclusion

Although there was no significant difference observed in weight after the participants had taken the 4-week math-integrated PA program, positive increases were observed in both geometry concept understanding and all the measured items in FITNESSGRAM®. This suggests that the 4-week math-integrated PA intervention has a significant effect on students' cognitive understanding of geometry concepts and fitness levels. We also noticed that the students effectively developed their understanding of the definitions and properties of 2D geometric shapes and different types of angles through engaging in the activities that integrate mathematics into the PE setting. In particular, the Geo-Baloo activity helped students enjoy the learning process of geometric concepts in a fun way.

Addressing the apparent decline in PA and math performance throughout childhood, especially among low SES and underrepresented young children, is crucial for promoting academic equity and ensuring the overall health and well-being of children. This study contributes to addressing these concerns by providing empirical evidence demonstrating the positive effects of integrating PA into mathematics learning environments, showing improvements in both cognitive understanding of geometry concepts and fitness levels.

Limitations and Future Research

While this study highlights the enhancements in both cognitive understanding of some geometry concepts and fitness levels resulting from the math-integrated PA program, it is important to note that the intervention had a limited duration. The short 4-week intervention period is insufficient to assess the impact on preventing child obesity. Moreover, this case study employed a small sample size and lacked a control group, focusing solely on the learning of specific geometry concepts. For future research, it is recommended that studies involving treatment and control groups consider implementing a year-long math-integrated PA program. This extended duration could encompass various activities integrating different mathematical concepts, including numbers, operations, and algebra. Such an approach would allow for a more in-depth exploration of the effects of the math-integrated PA intervention program on elementary school students' BMI, fitness levels, and comprehension of various mathematical concepts.

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