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PEDAGOGY

The Impact of Integrating Mathematics into Elementary Physical Education

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Abstract

The purpose of this study was to examine the effects of integrating mathematics into physical education. Participants included 132 fourth-grade students from four physical education classes at two schools. In-tact physical education classes were assigned to intervention and control groups. Mathematics activities were integrated into the intervention group's physical education classes for seven weeks. Data collection included three assessments of mathematics performance: mathematics grades, standardized mathematics assessment scores, and mathematics unit assessment scores. Data were collected pre- and post-intervention from the intervention and control groups and analyzed using mixed nested ANOVA. Results showed that across all measures of mathematics performance, students in both groups significantly improved from pre- to post-intervention. Significant differences based on the interaction of time (pre- and post-test) and group (intervention/control) were evident in mathematics unit assessment scores. These findings add to the growing body of literature on integrated curriculum in physical education.

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Introduction

The National Physical Education Standards state that physical education is a site for knowledge and skill development (SHAPE America, 2013). While the focus of physical education is movement education, physical education has the potential to be a site for learning other academic content through an integrated curriculum. Curriculum integration theorists use several terms in the literature to describe similar curriculum designs. Despite their terminology disagreements, these experts agree on the limitations of the separate-subject approach traditionally adopted in schools. Teaching subjects independently of one another does not allow students to make connections between content areas (Beane, 1995, 1997; Drake, 1997; Fogarty, 1991, 2002, 2009; Jacobs, 1989). Therefore, physical education offers the potential of movement-based cross-curricular learning.

In the classroom setting, previous research found that students who participated in integrated curricula performed just as well, if not better, than students who did not participate in integrated curricula (Chen & Yang, 2019; Kurt & Pehlivan, 2013; Vars, 1996). Furthermore, previous educational research has shown a link between movement and academic performance in the classroom (Donnelly et al., 2009; Duncan et al., 2012; Jensen, 2000; Mahar et al., 2006; Reed et al., 2010), where time-on-task improved (Mahar et al., 2006) and fluid intelligence increased (Reed et al., 2010). This connection between learning and movement in the classroom could be replicated in a naturally movement-based setting, such as physical education.

Although combining movement and classroom content in the classroom setting has shown favorable findings, empirical data regarding integrated curriculum in physical education are scarce (Marttinen, McLoughlin, Fredrick, & Novak, 2017). From the teachers' perspectives, integrated curriculum in physical education excited students (Hastie, 2011), allowed teachers to cover more material (Hastie, 2011), and encouraged students to make meaningful cross-curricular connections (Chen et al., 2011). Further, despite the addition of classroom content, physical activity was not sacrificed during physical education class (Cecchini & Carriedo, 2020; Chen et al., 2010).

Of this small body of literature examining integrated curriculum in physical education, two studies objectively measured academic performance (Cecchini & Carriedo, 2020; Derri et al., 2010). Derri et al. (2010) evaluated the effect of a five-week integrated physical education and language program on 67 kindergarten students. The experimental group used physical education to teach the oral and written speech program, while the control group taught the program in a traditional, non-movement-based classroom setting. Results showed the experimental group scored significantly better than the control group in all categories of analysis: written speech scores, oral speech scores, and total language scores. These findings suggest that oral and written speech are taught best in movement-based settings, such as physical education.

Similarly, Cecchini and Carriedo (2020) explored the impact of a three-week integrated unit connecting physical education and mathematics with 46 first-grade students. The control group participated in mathematics and physical education separately, and the intervention group participated in a shared (Fogarty, 1991) physical education and mathematics curriculum design. Results indicated both groups significantly improved subtraction knowledge from pre- to post-test. Further, the subtraction knowledge of students in the intervention group was significantly greater than that of the control group. These findings suggest that integrated curriculum designs in physical education can improve mathematics achievement.

Despite the overwhelming bodies of literature regarding integrated curriculum in the classroom setting and incorporating movement in the classroom setting, the similar area of inquiry of integrating classroom content into physical education is relatively small and predominantly non-empirical. The seven data-based articles demonstrate a foundational and promising qualitative account of the perspectives of teachers and students (Chen et al., 2007; Chen et al, 2011; Hastie, 2010; Rovegno & Gregg, 2007). More quantitative data are needed to explore the topic in greater detail. Although only two physical education empirical studies objectively measured academic achievement (Cecchini & Carriedo, 2020; Derri et al., 2010), findings from the classroom literature show integrated curriculum and incorporating movement into the classroom setting improved academic performance (Chen & Yang, 2019; Donnelly, et al., 2009;

Kurt & Pehlivan, 2013; Reed et al., 2010; Vars, 1996). Therefore, the purpose of this study was to examine the effects of integrating mathematics into physical education on multiple measures of mathematics performance. Specifically, does integrating mathematics in physical education influence mathematics grades, standardized mathematics assessment scores, and mathematics unit assessment scores?

Methodology

Participants and Setting

Fourth-grade students were recruited from two urban elementary schools in the same school district in the Southeastern United States. All 233 fourth-grade students in the two schools at the start of the study were eligible to participate. The potential participant pool comprised students from 11 different fourth-grade classrooms: five from Miller Elementary School and six from Woods Elementary School. A total of 132 participants, 57% of the population (57 boys, 75 girls), returned the parental consent and minor assent forms to participate in the study, as approved by the Institutional Review Board for Research Involving Human Subjects. Two physical education classes (one class from each school) made up the intervention group (n=59), and two physical education classes (one class from each school) served as the control group (n=73), participating in regularly planned physical education. Intact classes were assigned to intervention and control groups for integrated curriculum delivery. Figure 1 illustrates the schools' fourth-grade populations and the participant sample.

Design

The purpose of this intervention was to integrate mathematics into physical education using a connected integration design (Cone et al., 2009). The intervention utilized four templates to integrate classroom content, including *If – Then*, *Knowledge Tag*, *Out and Back*, and *Dice Roll and Solve* (Cosgrove & Richards, 2019). Before the study, the primary investigator communicated extensively via email and in person with the fourth-grade classroom teachers. During the intervention, weekly emails and meetings were held with

Figure 1

Study Participants

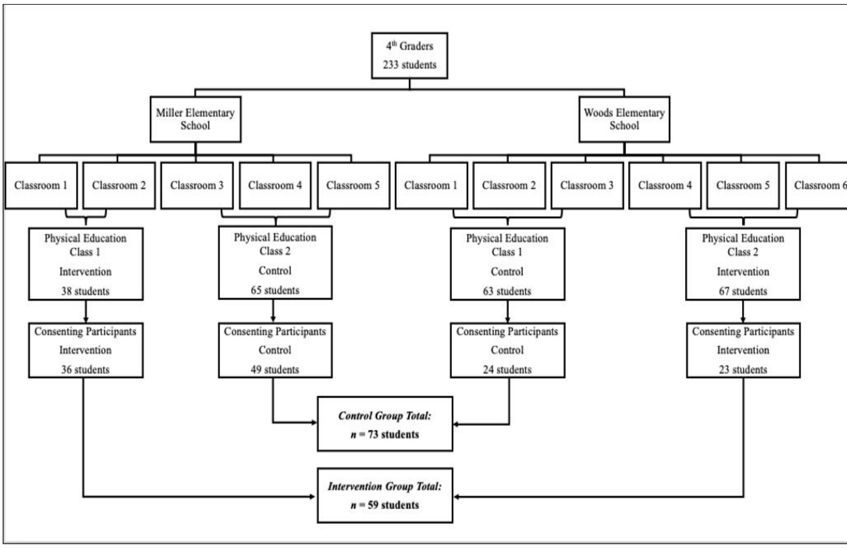


Table 1

Integrated Activity Template Examples, Adapted from Cosgrove & Richards (2019)

If – Then	
If	**Then**
The angle is an acute angle	Do 5 crunches
The angle is an obtuse angle	Do 5 mountain climbers
The angle is a right angle	Do 5 burpees
Knowledge Tag	
Math Task	
Identify which type of angle is pictured on the card to return to the game	
Out and Back	
Physical Education Movement Task	**Math Task**
Dribble the soccer ball	Convert the metric system measurements and order the cards from least to greatest
Dice Roll and Solve	
Physical Education Movement Task	**Math Challenge**
Frisbee passing with a partner	Solve for the perimeter and pass that many times

the intervention teachers to ensure the content covered in the physical education intervention reinforced what was being taught in the mathematics lessons. Throughout the study, topics covered in the mathematics unit were equivalence, symmetry, angles, area, perimeter, and properties of quadrilaterals, and the units taught in physical education were soccer and fitness at Miller Elementary School and frisbee and fitness at Woods Elementary School. The procedures of collaborating with classroom teachers and implementing the four integrated activities templates were piloted before this study. Table 1 provides an example of each activity template used in the study. The physical education teachers implemented one activity per day for 10 minutes for seven weeks. The researcher collaborated with the physical educators to create and deliver all the instructional materials needed for the ten-minute intervention activities, and the physical education teachers decided when the activities fit best in their lessons.

Data Collection

Data collection included three assessments of mathematics performance: mathematics grades, standardized mathematics assessment scores, and mathematics unit assessment scores. These data were collected pre- and post-intervention from the intervention and control groups. Student demographic data (age, sex, and race) were collected from school records.

Mathematics Grades

Participants' first quarter (nine weeks) and second quarter (nine weeks) mathematics grades were collected. First quarter grades served as the pre-intervention measure, and second quarter grades served as the post-intervention measure. Mathematics grades were obtained from school administration.

Standardized Mathematics Assessment

Standardized mathematics assessment scores were measured with the Scantron *Performance Series* assessment. "Scantron *Performance Series* is a computer-adaptive, online assessment that offers educators an efficient, standards-based method to immediately diagnose student needs and inform placement and instructional strategy decisions" (Alabama State Department of Education, 2018).

Students completed the assessment twice: in the fall (August) as a baseline and winter (December) to measure growth. This assessment was compulsory and administered by the classroom teachers. All students in the schools completed the Scantron *Performance Series* assessment; however, only consenting participants scores were collected. *Performance Series* assessment scores were obtained from the school administration.

Mathematics Unit Assessment

A mathematics unit assessment was completed pre- and post-intervention. All fourth-grade students completed these assessments; however, only the study participants' scores were obtained and analyzed. Topics covered in this unit were equivalence, symmetry, angles, area, perimeter, and properties of quadrilaterals. The textbook's unit assessment was used because all 11 fourth-grade teachers at both schools used the same book and sequenced their instruction identically. "A" and "B" forms of the assessment were created by the primary investigator; test items were pulled directly from the unit assessment and reviewed by the fourth-grade teachers. All unit topics were evaluated on both forms of the assessment, and both the "A" and "B" forms consisted of 12 questions. Those who completed the "A" assessment at pre-intervention took the "B" assessment at post-intervention, and vice versa.

Data Analysis

Data were entered into a Microsoft Excel document by the lead researcher and two trained research assistants and transferred into IBM SPSS Version 26 for analyses. Data were analyzed using a mixed nested analysis of variance (ANOVA), with time (pre-/post-intervention) as the within variable, group (intervention/control) as the between variable, and school (Miller Elementary School and Woods Elementary School) as the nested variable. All analyses included the Bonferroni adjustment to reduce the risk of Type I error.

Results

Participant Demographics

One hundred thirty-two students (n = 132) participated in the study. Participant age, sex as assigned at birth, and race data were gathered from school records. Participants ranged in age from nine to eleven years old at the time of the study. Table 2 displays the demographic information for the total sample.

Table 2
Total Sample Participant Demographics

	Female		Male	
Number of Participants	75		57	
Percentage of Sample	56.8		43.2	
	Asian	**Black**	**Hispanic**	**White**
Number of Participants	2	77	18	32
Percentage of Sample	1.6	59.7	14.0	24.8

Mathematics Grades

A mixed nested ANOVA was used to determine whether mathematics quarter grades differed based on group and time. There was a significant difference in mathematics grades between the two schools ($F_{2, 120}$ = 13.531, $p < .001$), where about 18% of the variance can be attributed to the school ($\eta^2 = .184$). There was no significant difference in mathematics grades based on the interaction of group and time ($F_{1, 120}$ = 0.406, $p = .525$, $\eta^2 = .003$). Because there was no significant interaction, the main effects were examined. There was a significant difference in mathematics grades based on the group ($F_{1, 120}$ = 5.225, $p = .024$), where the intervention group's mathematics grades were higher than the control group's. The interaction explains about 4% of the variance in mathematics grades ($\eta^2 = .042$). Additionally, there was a significant difference in mathematics grades in the first and second quarters ($F_{1, 120}$ = 41.728, $p < .001$), where mathematics grades were higher for the second quarter than the first. About 26% of the variance was explained by the time (first and second quarter) (η^2 = .258).

Standardized Mathematics Assessment

A mixed nested ANOVA was used to determine whether standardized mathematics assessment scores differed based on group and time. The standardized mathematics assessment used was the Scantron *Performance Series*. There was no significant difference in the Scantron *Performance Series* scores based on the school ($F_{2, 124} = .459$, $p = .633$, $\eta^2 = .007$). There was no significant difference in Scantron *Performance Series* scores based on the interaction of group and time ($F_{1, 124} = .975$, $p = .325$, $\eta^2 = .008$). Because there was no significant interaction, the main effects were examined. There was no significant difference in Scantron *Performance Series* scores based on the group ($F_{1, 124} = .001$, $p = 0.973$, $\eta^2 < .001$). However, there was a significant difference in Scantron *Performance Series* scores pre- and post-test ($F_{1, 124} = 91.828$, $p < .001$), where Scantron *Performance Series* scores were higher post-test than pre-test. About 43% of the variance was explained by the time of the assessment ($\eta^2 = .425$).

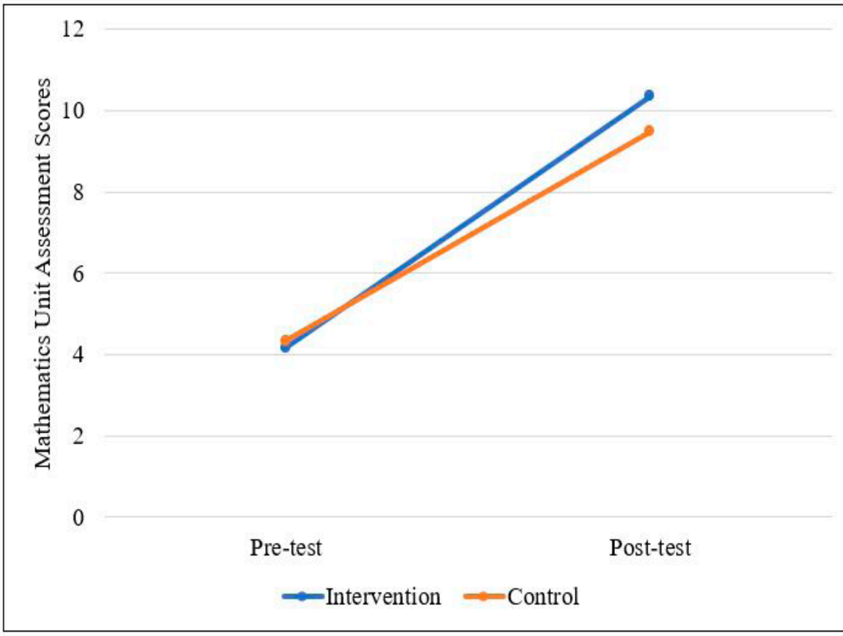
Mathematics Unit Assessment

A mixed nested ANOVA was used to determine whether mathematics unit assessment scores differed based on group and time. There was no significant difference in the mathematics unit assessment scores based on the school ($F_{2, 118} = 2.836$, $p = .063$, $\eta^2 = .046$). There was a significant difference in mathematics unit assessment scores based on the interaction of group and time ($F_{1, 118} = 4.164$, $p = .044$). The interaction explains about 3% of the variance in mathematics unit assessment scores ($\eta^2 = .027$). To follow up on this significant interaction, simple effects analyses were completed. There was no significant difference in mathematics unit assessment scores at pre-test based on the group ($t_{122} = -.404$, $p = .687$). However, there was a significant difference in mathematics unit assessment at post-test based on the group ($t_{128} = 2.105$, $p = .037$). See Figure 2 for a visual depiction of mean unit assessment scores.

Discussion

Objective measures of academic performance regarding integration in physical education have been widely excluded from the literature. To address this gap, the purpose of this study was to examine the effects of integrating mathematics into physical education

Figure 2
Mean Scores of the Mathematics Unit Assessments



on academic performance. Multiple measurements of mathematics performance were included: mathematics grades, standardized mathematics assessment, and mathematics unit assessment. It was hypothesized that mathematics performance would improve after integrating mathematics into physical education, as there appears to be a link between movement and academic performance in both the classroom setting (Donnelly et al., 2009; Reed et al., 2010) and physical education (Cecchini & Carriedo, 2020; Derri et al., 2010).

Across all measures of mathematics performance, students in both groups significantly improved from pre- to post-intervention. Mathematics grades significantly increased from the first quarter to the second quarter, Scantron *Performance Series* assessment scores significantly increased from pre-test to post-test, and mathematics unit assessment scores increased from pre-test to post-test. These findings confirmed those of previous physical education integration studies (Cecchini & Carriedo, 2020; Derri et al., 2010), where all students improved over time, showing no detrimental effects of the intervention.

When considering the interaction of group (intervention and control) and time (pre- and post-intervention), significant differences were only observed in the mathematics unit assessment, where the intervention group saw significantly greater improvements from pre- to post-test compared to the control group. This significant difference supported previous findings (Cecchini & Carriedo, 2020; Derri et al., 2010). Derri et al. (2010) found that kindergartners who participated in a written and oral speech program in physical education outperformed their peers taught the same content in a traditional classroom setting. Cecchini and Carriedo (2020) found that first graders who participated in an intervention that integrated mathematics into physical education performed better on a subtraction assessment than students in the control group.

To explain why mathematics performance significantly differed based on the interaction of group and time on only the mathematics unit assessment, the objective measures of academic performance of previous physical education integration studies were explored (Cecchini & Carriedo, 2020; Derri et al., 2010). Previous studies only employed one objective measurement of academic performance. Derri et al. (2010) created an assessment to measure written and oral speech, and Cecchini and Carriedo (2020) used a timed subtraction assessment to measure subtraction skills. In both studies, the content of the interventions aligned with the assessments. In the present study, mathematics grades and the Scantron *Performance Series* assessment represented global measures of mathematics performance, where the intervention covered some, but not all, of the content related to those assessments. However, the mathematics content covered in the intervention was informed by the content taught in fourth-grade mathematics during the study. Therefore, the entirety of the mathematics content integrated into physical education during the intervention was evaluated on the mathematics unit assessment. While this seven-week intervention had no impact on global measures of mathematics performance, integrating mathematics into physical education improved scores on a short-term mathematics unit assessment.

Limitations

As with any study, this one was not without limitations. School differences were a limitation of this study. While recruiting participants from multiple schools was a strength because it increased the sample size and added diversity, there was a nesting effect of school, where scores from Miller Elementary School were significantly greater than from Woods Elementary School. This limitation was accounted for by analyzing the data with a mixed nested ANOVA. A potential cause for the nesting effect could be the demographic differences between the two schools. Although in the same school district, students at Woods Elementary School represent a lower-income demographic. Additionally, more students at Woods Elementary School were English language learners, making language differences a potential barrier for students and their parents. This language barrier could explain the variance in the return rate of informed consents between the two schools. At Miller Elementary School, approximately 83% of the fourth-grade students consented to participating in the study. However, only approximately 36% of the fourth-grade students at Woods Elementary School consented to participate. Thirteen students between the two schools requested that all information and assessments to be translated into Spanish. One of these students was from Miller Elementary School, and 12 were from Woods Elementary School. Another potential cause of the differences in consent form return rate could have been a lack of trust in the university and the researchers.

Future Directions

Future studies are needed to continue to add to the body of literature surrounding integration in physical education. As Derri et al. (2010) suggested, future work should integrate other subjects into physical education after integrating language arts into physical education. Hastie (2011) connected science and physical education, and Rovegno and Gregg (2007) combined physical education with social studies; however, neither of these studies collected measurements of academic performance. Before the current study, Cecchini and Carriedo (2020) was the only study to objectively measure mathematics performance when mathematics was integrated into physical education.

In addition to further exploring integration across school subjects, future studies are suggested to examine integrating classroom content into secondary physical education. All previous studies (Cecchini & Carriedo, 2020; Chen et al., 2007, 2011; Derri et al., 2010; Hastie, 2011; Rovegno & Gregg, 2007), including the current study, examined integration in physical education at the elementary level. Secondary students represent a novel population regarding the effects of classroom content integration in physical education.

Lastly, future research should explore the manipulation of study timelines. Although the current study was the longest intervention integrating classroom content into physical education with quantitative measurements to date at seven weeks, longer interventions could see greater improvements across all measures, especially global measures of academic performance. This study used mathematics grades and a standardized mathematics assessment to evaluate mathematics performance globally. The seven-week timeframe of this intervention was potentially a limiting factor in impacting those measures.

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