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Original Article

EFFECT OF APPLYING NONLINEAR PEDAGOGY IN INVASION GAMES ON THE COGNITIVE, PHYSICAL AND AFFECTIVE DEVELOPMENT OF ELEMENTARY SCHOOL STUDENTS

EFEITO DA APLICAÇÃO DA PEDAGOGIA NÃO LINEAR EM JOGOS DE INVASÃO NO DESENVOLVIMENTO COGNITIVO, FÍSICO E AFETIVO DE ALUNOS DO ENSINO FUNDAMENTAL

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RESUMO

Objetivo: Este estudo investigou o impacto dos modelos pedagógicos não-lineares híbridos na educação física (PE) no aprimoramento da tomada de decisões, aquisição de habilidades e comunicação.**Materiais e métodos**. Durante um período de 12 semanas, o grupo de intervenção recebeu educação física utilizando métodos pedagógicos híbridos, enquanto os grupos de controlo seguiram o currículo de educação física já em vigor nas suas respectivas escolas. As escalas de tomada de decisão e desenvolvimento de habilidades, originalmente concebidas para uso estudantil, foram administradas tanto antes como após o programa. Os dois grupos foram comparados usando a análise de variação de duas e uma direções, testes t de amostras em pares e uma análise de correlação de Pearson.**Os resultados**. Os resultados da pesquisa revelaram uma melhoria substancial na tomada de decisões, desenvolvimento de habilidades e comunicação dentro do grupo de intervenção em comparação com o grupo de controlo. O tratamento com o aprendizado de jogos de invasão baseado em pedagogia não-linear leva a uma melhoria na capacidade de tomada de decisão. Isto é demonstrado pelos resultados de ANOVA bidirecional, ANOVA unidirecional e testes t de amostra em pares, onde o valor F é menor que 0.05 ($F = 0.000 < 0.05$) e o valor ρ é menor do que 0,05 ($\rho = 0,000 < 0.05$). A habilidade de aquisição de habilidades mostrou um aumento significativo após receber o tratamento de aprendizagem de jogo de invasão baseado em pedagogia não-linear, com um valor de $F < 0.05$ ($F = 0.000 < 0.05$) e $\rho < 0,05$ ($\rho = 0,000 < 0,05$). Adicionalmente, houve também um aumento observado na comunicação, com um valor de $F < 0.05$ ($F = 0.000 < 0.05$) e $\rho < 0,05$ ($\rho = 0,000 < 0.05$).**Conclusões.** A aplicação de modelos pedagógicos não-lineares híbridos em jogos de invasão durante a educação física pode melhorar significativamente as habilidades de tomada de decisão dos alunos, aquisição de habilidades e habilidades de comunicação. Estes resultados sugerem que os professores de educação física devem utilizar metodologias de aprendizagem eficazes. Além disso, estão a ser examinados os impactos da pedagogia não linear.
Palavras-chave: Tomada de decisão, aquisição de habilidades, comunicação, pedagogia não linear.

ABSTRACT

Purpose: This study investigated the impact of hybrid nonlinear pedagogical models in physical education (PE) on enhancing decision-making, skill acquisition, and communication.**Material and methods.** During a span of 12 weeks, the intervention group was provided with physical education using hybrid pedagogical methods, whilst the control groups followed the physical education curriculum already in place at their respective schools. The decision-making and skill development scales, originally designed for student usage, were administered both prior to and following the program. The two groups were compared using two- and one-way analysis of variance, paired sample t-tests, and a Pearson correlation analysis.**The results.** The research findings revealed a substantial enhancement in decision-making, skill development, and communication within the intervention group compared to the control group. Treatment with invasion game learning based on nonlinear pedagogy leads to an improvement in decision-making ability. This is demonstrated by the outcomes of two-way ANOVA, one-way ANOVA, and paired sample t-tests, where the F value is less than 0.05 ($F = 0.000 < 0.05$) and the ρ value is less than 0.05 ($\rho = 0.000 < 0.05$). The Skill Acquisition ability showed a significant increase after receiving the nonlinear pedagogy-based invasion game learning treatment, with a value of $F < 0.05$ ($F = 0.000 < 0.05$) and $\rho < 0.05$ ($\rho = 0.000 < 0.05$). Additionally, there was also an increase observed in communication, with a value of $F < 0.05$ ($F = 0.000 < 0.05$) and $\rho < 0.05$ ($\rho = 0.000 < 0.05$).**Conclusions.** Applying hybrid nonlinear pedagogical models in invasion games during physical education can significantly enhance students' decision-making abilities, skill acquisition, and communication skills. These findings suggest that physical education teachers should utilize effective learning methodologies. Furthermore, the impacts of nonlinear pedagogy are being examined.
Keywords: Decision making, skill acquisition, communication, nonlinear pedagogy.

Introduction

Divergent approaches might be a challenge in the field of physical education[1]. The conventional approach to physical education instruction has been substituted with a student-centered paradigm. Teachers prioritize instruction that focuses on required technical skills while neglecting the surroundings and students' choices. The student-centered approach involves the teacher assuming the role of a facilitator, while students are motivated to approach topics critically through independent inquiry[2,3]. Differences in approach can present a significant challenge to the implementation of physical education[4]. The conventional teacher-centric approach to physical education instruction has transitioned to a student-centric paradigm. Students are afforded the chance to exercise independence in the learning process through the use of a student-centered technique. The teacher plays multiple roles, both individually and in groups, including that of a conceptualizer, director, and facilitator for the exchange of critical viewpoints among students[5].

Although a large proportion of students (usually 80% or more) had a positive view towards traditional or teacher-centered physical education courses, there was a demand for a fresh approach[6,7]. Physical education places a high importance on engaging in physical exercise through a variety of sports, both individual and team-based. This sets physical education apart from most other courses taught in schools. Conversely, there are kids who develop a distate for physical education in school, so impeding the implementation of physical education instruction. Furthermore, there is compelling data indicating that a growing proportion of students perceive physical education to be of diminished significance, lacking in interest, and lacking in enjoyment[8]. The non-linear pedagogical approach, a component of student-centered learning, emphasizes a learning experience that fosters collaborative interaction and enhances multiple student competencies. This approach aims to boost students' motivation levels and facilitate an enjoyable learning process[9].

When it comes to how well someone learns, physical education programs should focus on enhancing individual abilities in areas such as physical coordination, mental processing, sensory perception, and emotional response[10]. Physical education is a subject included in the 2013 Curriculum of Indonesia, which raises emancipation to foster a student-centered learning method. Physical education is a crucial component of the National Education System as it enhances a wide range of complex learning outcomes. These outcomes include the development of movement skills, emotional intelligence, attitude values, social skills, critical thinking abilities, physical fitness, reasoning intelligence, healthy environmental management, and healthy lifestyles. Physical Education places a high importance on developing organized educational opportunities that are built on cognitive, affective, psychomotor[11].

The outcomes of skills are of primary interest to individuals and professionals in the field of sports, such as physical education teacher and sports coaches. These individuals are responsible for studying and understanding human movement and interaction on a regular basis. Developing effective strategies to increase skill acquisition and development of Physical Literacy has wide-ranging benefits that go beyond sports or physical activities in societies or schools. These techniques play a crucial role in helping individuals acquire functional movement[12]. Physical literacy encompasses the cognitive processes, perception, fitness, effectiveness, and social connection involved in learning activities that are integrated into a person's everyday life[13].

Nonlinear Pedagogy is a student-centered learning technique that has a notable impact on physical education in curricular studies study[12]. This work's pedagogically oriented approach enhances the value of all aspects and serves as a foundation for curriculum development[13]. Subject or disciplinary mastery is a highly important value orientation in the field of physical education. Practitioners in this field strive to provide verbal explanations for teaching perceptual motor abilities, demonstrate exercises, and simulate game scenarios[14]. Additional important value orientations in educational and curriculum research encompass the learning

process approach, which highlights the significance of how learning takes place, and the ecological integration of learners with specific learning contexts[15]. Students have a crucial role in achieving the best learning outcomes, such as gaming skills. Teachers also support students by demonstrating exemplary behavior and values during the learning process.

Teaching Games for Understanding renowned as nonlinear learning model used in physical education to teach games[16,17]. It focuses on a student-centered approach that encourages exploratory learning in circumstances that resemble games. The given text is a list containing the numbers[16]. a) The Constraints-Led Approach learning paradigm has the ability to offer a structure for physical education, enabling students to understand how to engage in exploration of tasks based on the environment. The purpose of this is to foster individuals who are more innovative in solving difficulties presented by the instructor. Furthermore, the Constraints-Led Approach necessitates an understanding of the fundamental neurobiological mechanisms in order to facilitate the development of skills. Utilizing games as a teaching method helps enhance students' understanding of movement exploration, enabling teachers to identify and assess their progress based on motor learning theory. Teaching is considered a dynamic discipline that combines scientific principles with artistic elements[17]. b) Physical Education The main goal of Sports Education is to develop students' proficiency in an enjoyable activity and enhance their confidence in performing activities throughout the season. This, in turn, motivates them to pursue further learning and improvement, thereby expanding their opportunities for leisure participation. Nevertheless, it is improbable that this goal will be achieved through the conventional structure of school physical education, which consists of brief periods focused on certain activities, while parents are responsible for organizing competitive events such as 5v5 basketball and 6v6 volleyball[18].

The experimental group in this study implemented a nonlinear pedagogic learning model in their physical education and sports programs to improve students' decision-making, skill acquisition, and communication abilities. The main objective of nonlinear pedagogic model is to comprehensively improve students' ability to acquire acquisition skill, decision making, and communicate effectively, while also enhancing their overall enjoyment of physical education. Students participated in a 12-week physical activity program that followed a nonlinear approach. The objective of this investigation is hence this study investigated the impact of hybrid nonlinear pedagogical models in physical education on decision-making, skill learning, and communication.

Methods

The current investigation utilizes a quasi-experimental research approach, specifically utilizing a control group pre-post test design. This research was carried out at an elementary school located in Yogyakarta, Indonesia. The experimental group in this study implemented a nonlinear pedagogic learning model in their physical education and sports programs to improve students' decision-making, skill acquisition, and communication abilities.

Sample

A representative group of 82 students from a singular elementary school was included in the present investigation. This study employed a random sample technique to choose the participants, which divided into group randomly. Primary school students often fall within the age range of 10 to 12 years. This study was carried out in the province of Yogyakarta, located in Indonesia. The aforementioned province is situated within the western area of Indonesia. It was conducted between August and October 2023.

Table 1. Subject characteristics intervention group

Elucidation	Frequency	%
Gender		
Male	41	50
Female	41	50
Age		
11	26	35
12	56	65
Class		
5	26	35
6	56	65
School		
Elementary School A	27	32
Elementary School B	29	37
Elementary School C	26	31

Source: The authors.

Procedures

At the beginning of the study, we developed an innovative physical education program utilizing nonlinear pedagogy, incorporating invasion activities for children in the first intervention group, others group are transform as control group without treatment. Additionally, we devised a scale to assess children's skill acquisition and decision-making abilities. In the second intervention group, a distinct linear pedagogy was employed, incorporating invasion games for children. A scale was also developed to evaluate children's skill acquisition and decision-making abilities. Each school implemented physical education and sports programs based on a control group, incorporating invasion games. Special training sessions were conducted for physical education and sports instructors assigned to the first and second intervention groups, who received supplementary training. Conversely, the control group did not receive any additional training. The duration of each program spans one semester, constituting a total of 12 weeks. Skill acquisition and decision-making scales are administered to all pupils both prior to and following physical education and sports programs.

Table 2. Interventions for nonlinear learning in experimental tests

Nonlinear-Linear-Control			
Session	**Variable**	**Physical Education Scope**	**Material**
1	Pre Test		
2	Nonlinear-linear-control	Invasion Game	Soccer
3	Nonlinear-linear-control	Invasion Game	Basketball
4	Nonlinear-linear-control	Invasion Game	Handball
5	Nonlinear-linear-control	Invasion Game	Futsal
6	Nonlinear-linear-control	Invasion Game	Basketball
7	Nonlinear-linear-control	Invasion Game	Handball
8	Nonlinear-linear-control	Invasion Game	Soccer
9	Nonlinear-linear-control	Invasion Game	Futsal
10	Nonlinear-linear-control	Invasion Game	Handball
11	Nonlinear-linear-control	Invasion Game	Soccer
12	Posttest		

Source: The authors.

Statistical analysis

The data analysis was conducted using SPSS Version 27.0 for Windows computing platform. The study employed a repeated measures analysis of variance (ANOVA) to assess the differences between the intervention 1 and 2 groups, as well as the control group, both prior to and during the implementation of physical education and sports programs. A one-way analysis of variance (ANOVA) was subsequently employed to assess the disparities in decision-making and skill acquisition among the groups prior to and after to the introduction of the physical education and sports program. Particularly, paired sample t-tests are employed to evaluate disparities between groups.

Results

According to applying parametric methods of statistical analysis, it is important to do a normality test on the given data:

Table 3. The result of normality test decision making, skill acquisition and communication

Kolmogorov-Smirnov							
		Decision Making		Skill Acqusition		Communication	
	Class	df	Sig	Df	Sig	df	Sig
Pre-test	Control	26	0.099	26	0.083	26	0.122
	Nonlinear	27	0.075	27	0.052	27	0.200
	Linear	29	0.056	29	0.056	29	0.129
Post-test	Control	26	0.123	26	0.088	26	0.052
	Nonlinear	27	0.133	27	0.051	27	0.087
	Linear	29	0.200	29	0.131	29	0.151

Source: The authors.

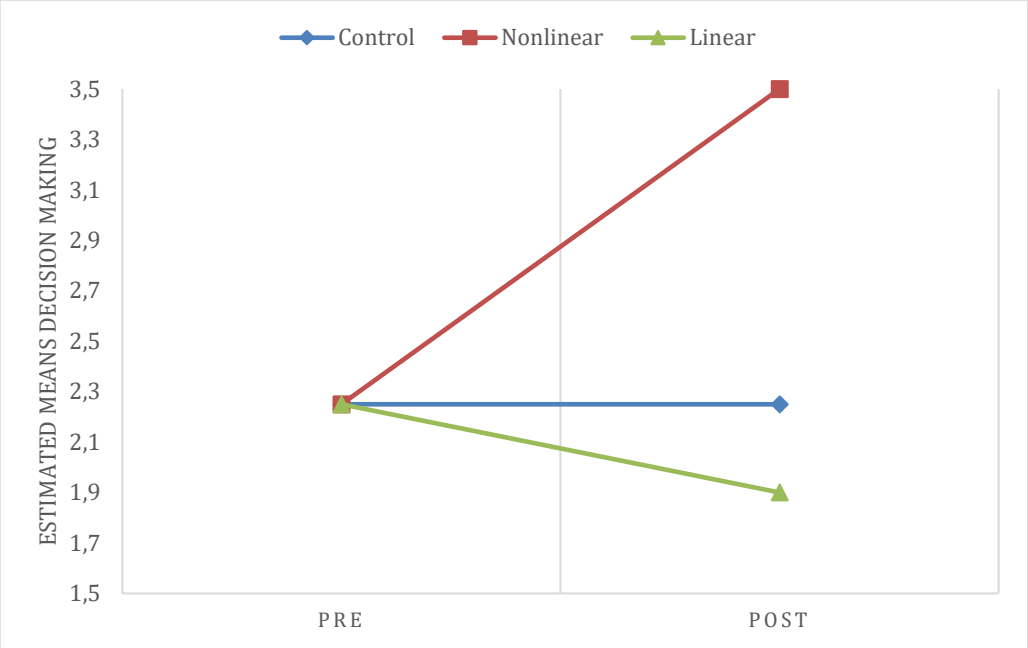

Figure 1. Comparative decision-making indicator testing students in the experimental and control group (or intervention group) before and after the experiment

- Control group – Nonlinear pedagogy group - Linear pedagogy group

Source: The Authors.

According to the data presented in Figure 1, a statistically significant interaction was observed between the mean ratings of the intervention and control groups ($F(2.430) = 30.771$, $p = 0.000$). This finding suggests that there was a significant difference between the groups in terms of the rate at which their decision-making skills changed across the pre-intervention and post-intervention periods. A one-way analysis of variance (ANOVA) additionally reveals statistically significant variations in group decision making. There are significant incremental changes observed in decision-making processes within the intervention nonlinear group, as evidenced by the increase in mean score from 2.43 to 3.31 after the testing phase. The cohort in the linear intervention group shown significant decreases in decision-making abilities from the pre-testing stage ($M=2.33$) to the post-testing stage ($M=2.08$). No additional statistically significant differences were seen between the pre- and post-test results of the first control group ($M=2.26$) and the second control group ($M=2.26$). This finding is supported by the results of the paired sample t-test, which indicated a statistically significant disparity in decision-making among participants in the intervention nonlinear group ($t(27)$; $p = 0.000$). The results of the paired sample t-test conducted on the intervention linear group revealed statistically significant differences in decision making ($t(29)$; $p = 0.000$). In contrast, there were no statistically significant differences observed in decision making within the control group ($t(26)$; $p = 0.961$).

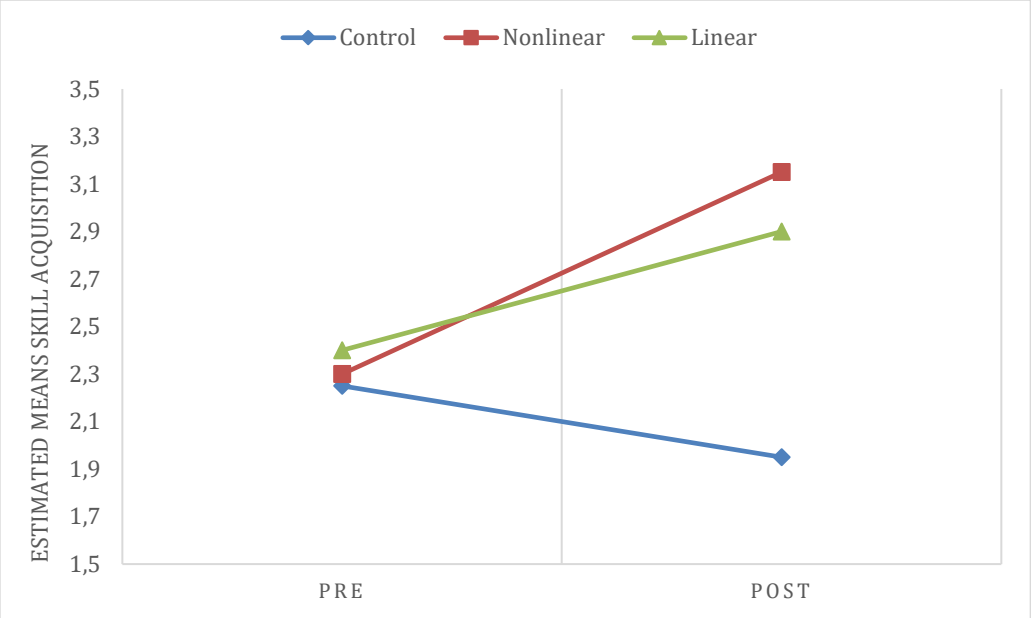

Figure 2. comparative assessment of skill acquisition was conducted on students in both the experimental and control groups (or intervention group) both before to and following the experiment.

- Control group – Nonlinear pedagogy group - Linear pedagogy group

Source: The authors.

Data shown in Figure 2 demonstrates a statistically significant interaction between the mean scores of the intervention and control groups. The results of the analysis ($F(2.333) = 12.402$, $p = 0.000$) suggest that there were statistically significant differences seen between the groups in terms of the rate of change in skill acquisition from the pre-intervention to the post-intervention period. One-way analysis of variance (ANOVA) also demonstrates statistically significant variations in skill growth among groups. There are significant incremental changes observed in skill acquisition between the pre-testing (M=2.33) and post-testing (M=3.16) sessions within the intervention nonlinear group. The intervention linear group shown a significant increase in skill acquisition from the pre-testing stage (M=2.41) to the post-testing stage (M=2.69). Furthermore, a notable alteration is observed, albeit with a diminishing magnitude, between the pre-test and post-test assessments. Specifically, the mean score of the initial control group was M=2.25, while for the subsequent group, it decreased to M=2.17. This assertion is further supported by the results of the paired sample t-test, which revealed a statistically significant difference in skill acquisition among the participants in the nonlinear intervention group ($t(27)$; $p < 0.0001$). The results of the paired sample t-test conducted on the intervention linear group revealed statistically significant differences in skill gain ($t(29)$; $p = 0.012$). There were no statistically significant differences observed in skill acquisition within the control group ($t(26)$; $p = 0.570$).

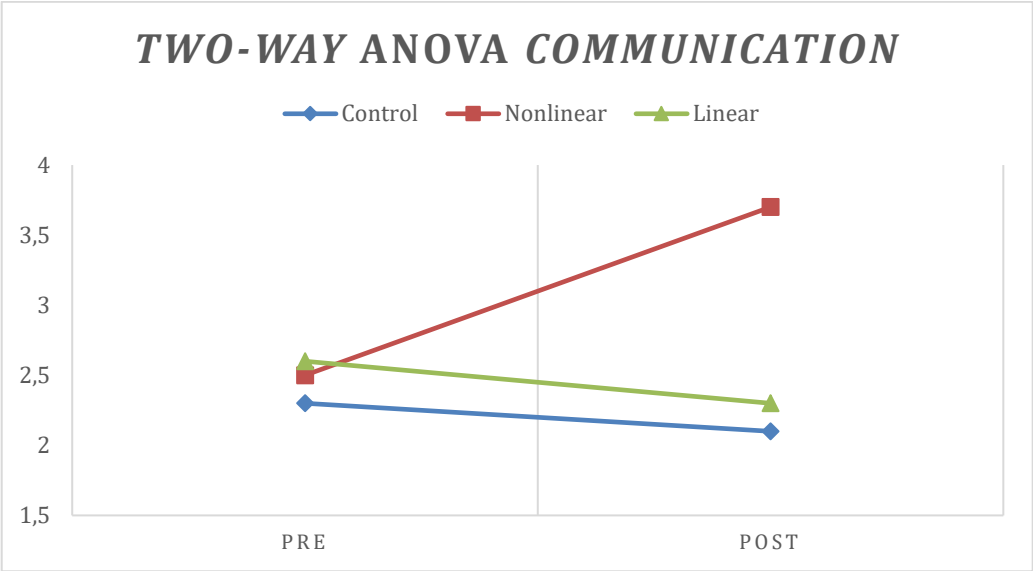

Figure 3. comparative assessment of communication was conducted on students in both the experimental and control groups (or intervention group) both before to and following the experiment.

- Control group – Nonlinear pedagogy group - Linear pedagogy group

Source: The authors.

The statistical analysis in Figure 3 revealed a significant interaction between the mean assessment of the intervention and control groups ($F(2.386) = 129.435$; $p = 0.000$). This finding indicates that the groups displayed a notable disparity in the pace at which their communication abilities developed prior to and following the course of the intervention. Furthermore, a one-way analysis of variance (ANOVA) uncovers notable inequalities in group communication. The nonlinear intervention group exhibited notable incremental improvements in decision-making abilities, as seen by the mean score of 2.38 before the intervention and 3.66 after the testing phase. The linear intervention group exhibited statistically significant decreases in communication levels from the pre-testing phase (M=2.55) to the post-testing phase (M=2.33). Further analysis revealed a decline in the pre-test and post-test scores of the initial control group (M=2.28) and the subsequent control group (M=2.19), but this decrease did not reach statistical significance. The identification of a statistically significant difference by the paired sample t-test offers more substantiation for this assertion.

Differential communication patterns were noted among participants in the nonlinear intervention group ($t (27)$; $p = 0.000$). The results of the paired sample t-test indicated statistically significant differences in communication among the intervention linear group ($t (29)$; $p = 0.001$). In contrast, the control group did not demonstrate any significant differences in communication rates ($t (26)$; $p = 0.266$).

Discussion

The hybrid learning paradigm, which is grounded on nonlinear pedagogy, places emphasis on the decision-making variable as a means to enhance efficacy among learners. The decision-making process in this context encompasses tactical elements, such as the execution of passing, dribbling, and kicking actions aimed at achieving the objective[19]. In this context, the utilization of diverse game modifications that manipulate task conditions enables players to effectively adjust to the unpredictability inherent in the learning process. This scenario closely resembles a game characterized by substantial ambiguity regarding the opponent's actions. In this context,

the manipulation of diverse task conditions in adaptive games allows students to effectively adjust to the inherent diversity of their practice. The acquisition of knowledge that closely resembles real-world game scenarios characterized by uncertainty regarding the behaviors of the adversary[20]. Furthermore, it facilitates the cultivation of enhanced decision-making skills among students in the context of learning[21]. Students do not acquire knowledge autonomously from practical learning environments alone. The development of students' learning and motor control can be characterized by the definition of learning as enduring changes in an individual's internal cognitive state resulting from the outcomes of movement[22]. This variable also enhances the efficacy of the linear learning model as the usage of drills contributes to the improvement of individual skill acquisition capabilities. Drill practice is commonly employed to enhance the automation of skill acquisition movements[23]. Skills acquisition refers to the process by which pupils establish their relationships with the functional environment[24].

Improvement of communication has been demonstrated to increase the efficacy of the nonlinear pedagogy learning paradigm[19]. The acquisition of movement abilities by students is not independent of the surrounding learning environment. As an illustration, when students in the NP group were prompted to specify numerous aspects of communication with friends and teachers that they appreciated about this class, a youngster expressed, "I really like this because I am able to articulate my viewpoint." "I really enjoy this ability as it allows me to articulate my viewpoint, and my typically unresponsive friends now actively listen to my words," elucidated the youngster[25]. An important aspect of the nonlinear approach is the affective component. With the hybrid model, students can enhance their communication skills by assuming roles such as coach, manager, player, audience, etc. Engaging in these roles trains children to communicate effectively not only with friends but also with teammates, opponents, coaches, etc[26].

In the nonlinear pedagogy intervention group, students exhibited substantial improvement in their decision-making, communication abilities and acquisition of skills. These findings indicate that the implementation of nonlinear pedagogical intervention in sports learning has notable advantages for the development of children's decision-making, communication abilities and skill acquisition. Accordingly, physical education learning enhances students' ability to make decisions, communication and acquire knowledge, as well as their technical skills and creative abilities[19,27]. Specialized sports education enables students to effectively solve problems independently. This program utilizes group learning principles by using invasion games. Students cultivate the capacity to apply their decision-making abilities in order to resolve a wide range of problem situations associated to games[27]. Through the integration of hybrid games that incorporate teaching games of understanding, physical education, and cooperative learning, students can derive pleasure from engaging in physical education classes[28], so greatly enhancing their decision-making, communication abilities and acquisition of skills. Physical education exerts a beneficial influence on the decision-making and learning capacities of elementary school students. Sports competition, as an illustration of real-life scenarios, fosters a feeling of accountability in the development of practical abilities, effective communication, and sound decision-making.

Linear pedagogy can be characterized by a teacher-centered approach in physical education, because (a) children must learn the optimal movement patterns for each motor skill and all children must conform to these idealized movement patterns; (b) motor skills must be broken down into basic and simpler movements to facilitate learning; (c) variability in movement within tasks is viewed as detrimental to learning and therefore must be reduced; (d) teachers at the beginning of learning should encourage an internal focus of attention for children with developing skills to reduce cognitive load, while, as children become proficient in skills, teachers will encourage an external focus of attention[13]. Whereas the characteristics of linear pedagogy are comparable to traditional learning in physical education that follows sports as a

technical approach, linear pedagogy is based on motor learning theory and therefore should lead to more favorable outcomes than the theoretical approaches currently used. With a teacher-led linear approach, optimal motor skill development can result in rapid learning, leading to an early sense of success that should enhance the perception of competence, contributing to higher levels of motivation in the lesson[13,29].

The proficiency in literacy is predominantly shaped by the interplay of physical, cognitive, emotional, and perceptual factors. Several influencing elements, including assignments, personnel, and the surrounding environment, contribute to the fulfilment of the four components[29]. The findings of linear and non-linear education, such as physical literacy may be broadly described as the combination of drive, self-confidence, physical skill, knowledge, and understanding that enable individuals to value and take responsibility for their participation in physical activity or life.

Nevertheless, when comparing non-linear and linear approaches, it is crucial to give priority to the requirements of the student-centered process. This ensures that the needs of the children who are the centre of attention are consistently addressed[30]. This message can be assisted by the teacher's capacity to support and guide children's creativity and critical thinking patterns during physical education learning[30]. Subsequently, once the acquisition of knowledge has been completed, the teacher conducts an assessment and further investigation that is easy to understand to the child's cognitive and motoric abilities, therefore avoiding any further strain on motor learning.

Conclusion

An improvement in decision-making abilities was observed in the intervention class after they were given nonlinear pedagogy-based invasion game learning treatment. Additionally, there was an improvement in communication abilities during the nonlinear pedagogy-based invasion game learning intervention that was carried out in the classroom. Furthermore, the implementation of nonlinear pedagogy-based invasion game learning led to an improvement in the capabilities of skill acquisition. For a greater understanding of gross-motor abilities, future studies should include linear and non-linear controls to evaluate hitting, fielding, net, and target games in PE.

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