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Original Article

BRIDGING THEORY AND PRACTICE: THE POWER OF CONTENT KNOWLEDGE AND NONLINEAR PEDAGOGY IN SKILL ACQUISITION

CONECTANDO TEORIA E PRÁTICA: O PODER DO CONHECIMENTO DO CONTEÚDO E DA PEDAGOGIA NÃO LINEAR NA AQUISIÇÃO DE HABILIDADES

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RESUMO

Apesar dos efeitos conhecidos das pedagogias lineares (LP) e não lineares (NLP) no desempenho esportivo, o papel do conhecimento pedagógico do conteúdo (PCK) dentro dessas abordagens permanece pouco explorado. Este estudo examina como os workshops de conhecimento do conteúdo (CK) influenciam o PCK dos professores e impactam o desempenho do forehand do tênis de mesa dos alunos sob duas metodologias de treinamento: linear (CK-LP) e não linear (CK-NLP). Cinquenta e quatro alunos de educação física (Mage = 21,78, DP = 2,03) foram designados para três grupos: controle (G1), LP (G2) e NLP (G3). Cada um recebeu 10 dias de treinamento de forehand do tênis de mesa. O G1 foi treinado antes do workshop CK-LP, enquanto o G2 foi treinado depois. O professor então compareceu ao workshop CK-NLP antes de treinar o G3. O PCK do professor foi avaliado com base na comunicação verbal, demonstração e adequação do treinamento, enquanto o desempenho do aluno foi medido usando um teste de precisão padronizado. Os resultados indicaram que os workshops de CK reduziram as intervenções do professor (G1 > G2 > G3), especialmente instruções verbais e feedback. O desempenho do aluno melhorou significativamente, com maiores ganhos em G2 e G3. Este estudo valida a eficácia dos workshops de CK em aprimorar as estratégias de ensino e a aquisição de habilidades do aluno. No entanto, o tipo de treinamento fornecido influencia a extensão dessas melhorias (G3>G2). Pesquisas futuras devem explorar efeitos de longo prazo e avaliações de habilidades mais amplas em condições de jogo real.

Palavras-chave: pedagogia linear, conhecimento de conteúdo especializado, conhecimento de conteúdo pedagógico, tênis de mesa, forehand

ABSTRACT

Despite the known effects of linear (LP) and non-linear (NLP) pedagogies on sports performance, the role of pedagogical content knowledge (PCK) within these approaches remains underexplored. This study examines how content knowledge (CK) workshops influence teachers' PCK and impact students' table tennis forehand performance under two coaching methodologies: linear (CK-LP) and non-linear (CK-NLP). Fifty-four physical education students (Mage = 21.78, SD = 2.03) were assigned to three groups: control (G1), LP (G2), and NLP (G3). Each received 10 days of table tennis forehand training. G1 was trained before the CK-LP workshop, while G2 was trained afterward. The teacher then attended the CK-NLP workshop before training G3. Teacher PCK was assessed based on verbal communication, demonstration, and training appropriateness, while student performance was measured using a standardized accuracy test. Results indicated that CK workshops reduced teacher interventions (G1 > G2 > G3), especially verbal instructions and feedback. Student performance improved significantly, with greater gains in G2 and G3. This study validates the effectiveness of CK workshops in enhancing teaching strategies and student skill acquisition. However, the type of training provided influences the extent of these improvements (G3>G2). Future research should explore long-term effects and broader skill assessments in real-game conditions.

Keywords: linear pedagogy, specialized content knowledge, pedagogical content knowledge, forehand table tennis

Introduction

Over the past two decades, researchers have focused on comparing linear (LP) and non-linear (NLP) training approaches in sports skill development [1]. Linear methods prioritize repetition, suggesting that optimal patterns are achieved through repetitive practice, with learning occurring via perceptual rejection after repeated attempts [2]. In contrast, NLP emphasizes the coupling of perception and action, where learners adapt to the environment by manipulating constraints based on their individual characteristics [3]. NLP encourages exploration and problem-solving, promoting flexibility in adapting to environmental and task

demands [4]. Recent studies have highlighted differences in goals, patterning, repetition, feedback, and instruction between LP and NLP [5]. It is believed that the flexibility of NLP enhances learners' ability to adapt, fostering improved performance compared to the more rigid, repetitive nature of LP [6].

Much of the literature comparing LP and NLP suggests that NLP is more effective in the sports environment [1, 5-7]. Flexible practice environments characteristic of NLP provides learners the opportunity to adapt and refine their skills in diverse and dynamic situations. This high adaptability stems from manipulating constraints, contributing to improved performance in varied conditions, facilitating rapid learning, and nurturing creativity [8].

Teacher knowledge is generally known in three levels: common content knowledge (CCK), specialized content knowledge (SCK) and pedagogical content knowledge (PCK) [9]. CCK is the knowledge a person needs to perform an activity successfully; including knowledge about rules, customs, techniques and tactics [10]. Conversely, SCK refers to the knowledge necessary for learning an activity, encompassing comprehension of training and demonstration tasks as well as awareness of learner errors. Essentially, SCK represents the knowledge a teacher requires to effectively impart CCK [11]. Furthermore, pedagogical content knowledge refers to the knowledge by which the teacher adapts their knowledge to suit the learners needs [12]. Experimental findings reveal that elevating SCK and CCK contributes to the enhancement of PCK, as well as improvements in students' performance. Kim, (2016) demonstrated improved volleyball skills in participants following a CK workshop, with teachers using a wider range of task progressions and verbal instructions [13]. Similarly, Iserbyt et al., (2017), found enhanced badminton performance post-CK workshop, emphasizing effective use of descriptions, analogies/metaphors, signs, and feedback by teachers [14]. Furthermore, Iserbyt et al., (2020) , revealed increased task adaptations and improved crawl performance for teacher's PCK and performance of students following a CK workshop [15]. Similarly Iserbyt et al., (2016), noted that participation in a sports education workshop was more effective than a traditional method workshop in enhancing both teacher behavior and student breaststroke performance [16]. Examining the literature reveals the significance of CK workshops in influencing teacher behavior and student performance, a relationship that can be influenced by the educational approach[16]. However, the comparative assessment of student performance and teacher behavior following CK workshops in LP and NLP remains unexplored. This is particularly relevant as some empirical studies suggest that NLP may be more effective in enhancing sports performance compared to LP [5]. Therefore, this study aims to assess and compare the impact of CK-LP and CK-NLP workshops on both teacher pedagogical content knowledge and students' performance in table tennis forehand.

Sports skill acquisition faces the challenge of balancing structured repetition with creative exploration. Research indicates that the impact of teachers' content knowledge varies depending on the instructional framework, but the interaction between this knowledge and the learning environment is not fully understood. This study compares CK-LP and CK-NLP workshops, with the following hypotheses: (1) participation in CK-NLP workshops will lead to a greater increase in teachers' content knowledge, (2) students taught by teachers who attended CK-NLP workshops will perform better in forehand table tennis, and (3) the effect of CK workshops on student performance will be mediated by changes in teachers' content knowledge. This research is crucial for optimizing teaching methods and designing more effective learning environments.

Methods

Participants

The participants of this study included one teacher who was purposefully selected and 48 physical education students who voluntarily participated in this study. Based on G-power ($\alpha = 0.05$,1-$\beta = 0.80$, $f = 0.40$) [5, 7], and considering the 2 (pre-post) x 3(groups) MANCOVA test, a total of 36 participants were needed for this study.

The selected teacher was a 45-year-old male with 23 years of teaching experience in (removed for reviewers) schools in the field of physical education. He also had a bachelor's degree in physical education and a third-level table tennis coaching degree from the Table Tennis Federation of Iran. The selected teacher was not professionally involved in table tennis either as a coach or a player. However, he has experience teaching table tennis in school settings. The selection criteria for this instructor were based on four key factors: 1) his willingness to participate in the research, 2) his interest in acquiring information about new training methods in physical education, 3) his proficiency in teaching table tennis, and 4) his unfamiliarity with NLP. To assess his knowledge of table tennis, the coach reported his knowledge in four areas and according to Ward et al., (2014) [17], with good knowledge in all areas.

The participants for this study were drawn from the pool of undergraduate male student teachers who expressed an interest in acquiring table tennis skills. The recruitment process was based on their availability and willingness to attend training sessions conducted in the table tennis hall of the (removed for reviewers) table tennis Federation. Initially, 58 individuals from (removed for reviewers) University indicated their readiness to participate. Upon the commencement of the study, three participants failed to attend the introductory meeting. Furthermore, one participant was excluded due to availability to attend designated training sessions. Consequently, the final cohort for the study comprised 54 individuals (Mage=21.78, SDage=2.03). This selection aimed to ensure a homogeneous group of participants with a shared interest in table tennis and the ability to commit to the training program. The demographic information of the students is given in Table 1. The results of the one-way ANOVA test reveal no difference between the groups in terms of demographic characteristics (Table 1). All participants provided written informed consent before completing the study. Therefore, the study received institutional approval and that the participants' informed consent was obtained.

Table 1. Demographic information of students

	(G1) *N=18* *mean±SD*	*(G2)* *N=18* *mean±SD*	*(G3)* *N=18* *mean±SD*	*All* *N=54* *mean±SD*	*F*	*P*
Age (years)	21.51±2.21	22.11±1.77	21.74±2.12	21.78±2.03	0.12	0.16
mass (kg)	74.91±3.74	75.11±4.01	73.47±5.47	74.49±4.4	0.36	0.12
Height (cm)	178.44±6.01	179.11±5.99	177.25±5.9	178.26±5.96	0.1	0.21

Note: **G1=control group, G2=LP group, and G3= NLP group*
Source: The authors.

Research Design

A quasi-experimental design was adopted for this study, featuring three distinct groups, each comprising 18 students. Following an initial familiarization session with the students, their table tennis performance was assessed before commencing any training. During the pre-test session, the accuracy of performance with valid test was evaluated by one of the authors, with recorded scores for each student. The students were then categorized into three performance-based groups: below average, average, and strong. Each group comprised 6 students falling within the below average, 6 within the strong, and 6 within the average performance categories. The purposeful grouping ensured a balanced representation of below average, average, and

strong performers within each of the three experimental groups. Pre-test, intervention and training were conducted in the table tennis hall of the (removed for reviewers) Table Tennis Federation. In this hall, there are 25 number of tennis tables with the 274cm*152.5 cm dimensions and the height of the net 15.25 cm .SPC yc-363 ball throwing machine was used for pre-test and post-test.

The training period for this study was 10 days, similar to that of Iserbyt et al., (2016) [16]. Each day, the students had an hour and a half of practice. Which included warm-up (about 20 minutes), training (about 50 minutes) and free practice (about 20 minutes). In the first and second week, G1 had training from Saturday to Wednesday from 8:00 PM to 9:30 PM. The teacher was instructed to strengthen the table tennis forehand of the students based on his own knowledge, no information was given. On the last day and immediately after practice, the post-test same to the pre-test was taken and the information was recorded. On Thursday and Friday of the second week, the teacher participated in the LP-CK workshop. The content of this workshop was designed and developed by the third author (holder of first-class international table tennis teaching and coaching certificate), the first and second author, who are experts and researchers of LP and NLP methods and holders of first-class table tennis coaching certificate of (removed for reviewers) Table Tennis Federation. The contents of the workshops were approved by 6 motor learning professors with LP expertise in (removed for reviewers) and 6 international table tennis instructors in (removed for reviewers). This workshop was taught by the first author, and was held for 6 hours, of which three hours were practical and three hours were theoretical. The theory class on Thursday lasted one and a half hours in two sessions, morning and evening. The practical class was also held on Friday with similar conditions. On Friday, with the presence of the first, second, and third author, the teacher taught different students from the study students in two shifts, morning and evening (one and a half hours each) and based on LP-CK. With this work, the level of alignment of the teacher's training with the workshop was checked and confirmed. From Saturday to Wednesday of the third and fourth week (8-9:30 PM), the teacher taught G2 according to LP-CK, and then the same test as the first group was taken. NLP-CK workshop was held on Thursday and Friday of the fourth week, designed by the first, second and third author and taught by the first author. Its content was also approved by 6 motor learning professors with NLP expertise (different from LP specialists) and 6 international table tennis instructors. In the fifth and sixth week, Saturday to Wednesday (8:00-9:30PM), the teacher taught G3 according to the NLP-CK workshop, and the post-test was taken.

Independent variables

In this study, two independent variables LP-CK and NLP-CK were considered, in both of which the teacher participated in the related workshop. The purpose of holding these workshops was to emphasize CCK and SCK. Considering that table tennis forehand was considered in this study. Therefore, the content of the workshops was focused on improving the accuracy of the table tennis forehand performance. These workshops could not be PCK because there was no shaping to meet the needs of the students [16]. To assess the teacher's understanding and mastery of workshop content, evaluations were conducted by first interviewing the teacher and then observing their performance in the practical workshop. During each training session, two independent observers coded the teacher's performance to ensure reliability. Inter-rater reliability, measured by Cohen's kappa, was high, with a kappa value of 0.85 ($p < 0.001$), indicating strong agreement between observers.

Both workshops shared certain core components. CCK workshops concentrated on teaching rules, techniques, and tactics. In the SCK workshop, the focus was on how to effectively teach the forehand in table tennis, structure the class to enhance learning, demonstrate skills, identify common student errors, and correct them. The workshop format

included an introduction, training sessions, Q&A, theoretical evaluation, practical training, hands-on participation with further Q&A, and practical assessment.

LP-CK workshop

The content of the LP-CK workshop focused on learning based on a cognitive perspective [18]. In this content, the feedback and pattern formed the main form of the practice, and the teacher was helped to use various feedback (such as normative positive feedback) as well as demonstration patterns in the form of beginner or advanced patterns. The application of each of these feedbacks based on the principles of motor learning should be appropriate to the level of the student that all these topics were told to the teacher. In general, the focus in this workshop was on seven important issues: goal, pattern, description, repetition, variability, feedback and instructions. In the goal section, the teacher was told that the ways to reach the goal should be clearly shown to the students and feedback should be given according to his performance. In the pattern section, the teacher was taught to introduce the ideal model to the student and show it that was done by him or another person. In the description section, the teacher learned that in order to improve the students' performance, it is better to describe the skill verbally and to describe the ways to achieve the goal during and after the performance. In the repetition section, the teacher was told that the skill should be repeated until the student reaches the ideal pattern. Variability in the LP-CK workshop referred to the change of training intervals, which the teacher was told should be used for the students to learn more. The instruction referred to the correct execution of the skill, compliance with the rules and the correct execution method, to achieve which verbal and video feedback was given. This LP method has been used in recent studies [1, 18], that they are cited in this research.

NLP-CK workshop

The content of the NLP-CK workshop focused on learning based on the perspective of ecological dynamics [19]. The primary emphasis of the workshop was on manipulating constraints to shape practice, guiding teachers to enhance student performance without relying on traditional feedback and patterns. In this workshop, the seven issues of goal, pattern, description, repetition, variability, feedback and instruction were focused. In the goal section, the teacher was told that he should not show the student the ways to reach the goal, but only specify the goal so that the student can find the way to reach it. In the pattern section, the teacher was taught not to consider an ideal model for the student, because each person has his own unique model and should help the learner find his own unique model. In the description section, the teacher was told to describe the goal and show the way to reach it by manipulating the constraints. In the repetition section, the teacher was told that the student should repeat different ways at his own will and not look for an ideal model. Variability in the NLP-CK workshop was achieved by repeating the skill regardless of the pattern. Instruction refers to the description of the purpose. This NLP method has been used in recent studies [5]which they are cited in this research. The general differences between LP and NLP, which were focused on in the two workshops of this study, are shown in table 1 in attachment file, which are from the studies [5, 7] is inferred.

Dependent variables

Teacher performance

Teacher performance, specifically PCK, was assessed across all classes during each 10-day training block. This evaluation encompassed three key domains: verbal communication (providing or withholding feedback, offering verbal instructions or instructions related to manipulating constraints, describing skills or outlining goals), demonstration (deciding whether to provide a pattern or refrain from doing so), and the appropriateness of training methods

(evaluating variability, repetition, and the presence or absence of a defined goal; figure 1), as adapted from Kim, (2011) [11]. The reliability of the PCK evaluations was assessed using Cronbach's alpha, yielding an alpha value of 0.90, indicating excellent internal consistency.

rbal Communication	*monstration*	*propriateness Of Training Methods*
Instructions 1. General = how to warm up and cool down, class rules 2. Educational = how to implement the skill 3. Determining the rules for the execution of the movement = limits and limits for skill discovery	Display 1. By teacher 2. by skilled person 3. By a beginner	ature and appropriate
Descriptive 1. Description of how to implement the skill 2. Description of how to achieve the goal 3. goal description	Partially correct display 1. By teacher 2. by skilled person 3. By a beginner	ature and inappropriate
Similes 1. Simile to an animal 2. Similarity to the hero 3. Comparison with the skills of other sports	wrong display	mature and appropriate
Sign 1. In line with perform 2. In line with the goal	Manipulate constraints 1. Manipulation of the environment (such as playing in the open environment) 2. Task manipulation (such as: removing the net) 3. Manipulation of the person (such as: using the non-dominant hand)	mature and inappropriate
Feedback 1. Confirmation of performance 2. Corrective feedback	physical assistance 1. teacher himself 2. Using a teammate	ature and appropriate

Figure 1. Characteristics considered for the teacher in this study

Student performance

Performance accuracy

To evaluate the performance accuracy in table tennis forehand, the performance accuracy score test was used. In this test, there are 6 squares of 50x50cm, inside each square there is a small square of 25x25cm. The scoring was such that the student's response to the shot without screwing the ball machine, according to Figure 2, if it was in zone 1, he would get a

score of 3. If it was placed in region 4, he would get 2 points, and for the rest of the regions, he would get 1 point (the highest and lowest score for each person could be 90 and 30, respectively). 30 balls were sent to each person, and the average score of response of student on 30 ball was considered. This scoring and performance evaluation method has also been used in previous studies [20, 21].

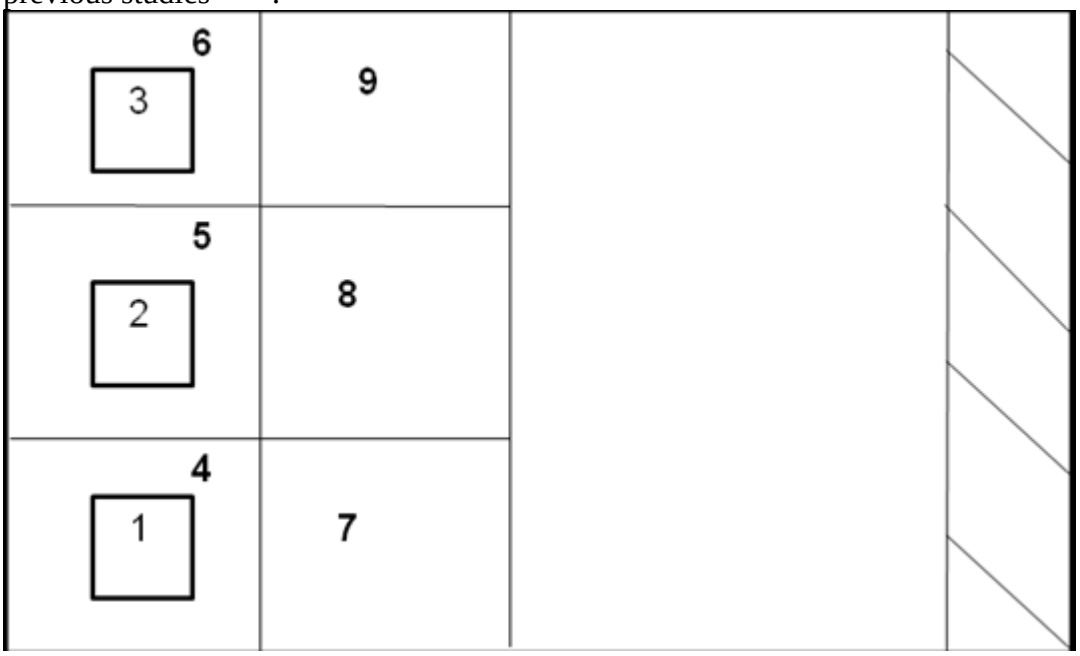

Figure 2: How to score the accuracy of table tennis performance
Source: The authors.

Data Collection

During the training, the teacher was equipped with a microphone to record his voice and also a camera recorded all his activities. Four cameras also monitored the students' performance during the test. The cameras were 25 Hz with a resolution of 2448 x 3264 megapixels [5]. In addition, two research assistants recorded the teacher's behavior (Cohen's= 0.86, p <.0.001, 95% CI 0.78 - 0.92), and the first author was present in all the sessions in the hall to ensure that the training is progressing in line with the purpose of the study. The reactivity of the students was reduced by introducing the assistants and the researcher to the students by the teacher, by filming a lesson before the start of the study and by not communicating with the students during all the interventions [16]. Filming started from the moment the teacher entered the class and ended when the last student left the pool.

Statistical analysis

Finally, G2 (2 students) and G3 (3 students) did not participate in the post-test, and the data of 18 students in G1, 16 students in G2, and 15 students in G3 were analyzed. The teacher's behavior was reported descriptively. Quantitative data related to learners were analyzed using SPSS-24 software. First, the Kolmogorov-Smirnov test was used to check the normality of the data. Inferential statistics were conducted with a 2 (pre-test vs. post-test) × 3 (Group) ANOVA. For effect sizes, partial eta squared (η^2) values were reported, with benchmarks of 0.01, 0.06, and 0.14 referring to small, medium, and large effects, respectively. Post-hoc comparisons were performed using LSD tests with Bonferroni adjustments for multiple comparisons. In addition to statistical significance, the effect sizes observed in this study indicate practically meaningful differences. Specifically, the large η^2 values found in the post-test comparisons highlight that

the improvements—particularly in the NLP group—are not only statistically reliable but also educationally relevant for teaching practice.

Results

Expected procedural fidelity was measured in both LP-CK and NLP-CK conditions. In both groups, fidelity was assessed on four levels: (1) actions that matched exactly what should be taught, (2) actions that were mostly correct, (3) actions that were different but still aligned with workshop goals, and (4) actions that were different and inconsistent with workshop goals. Fidelity score was calculated by dividing the number of tasks in each level by the total number of tasks in that lesson, multiplied by 100 [16]. Overall fidelity was 91% in LP-CK and 89% in NLP-CK, indicating high fidelity. To ensure reliability, two trained research assistants independently coded the tasks, and their consistency was measured using Cohen's kappa, resulting in a high agreement (kappa = 0.82, $p < 0.001$, 95% CI 0.78 - 0.92). According to the workshop's ideal fidelity standards, expected scores were 84% for LP-CK and 86% for NLP-CK, which were then reviewed by two independent evaluators. Their ratings also showed high agreement, with a Cohen's kappa of 0.88 ($p < 0.001$, 95% CI 0.78 - 0.92). This consistency in evaluations and high fidelity percentages indicate that both groups closely adhered to the workshop's intended guidelines.

A total of 963 actions (verbal communication, demonstration, and the appropriateness of training methods) of the teacher were observed during the 30 days of training (10 day for each group). Of these, approximately 37% were found in G1 (362), about 36% (348) in G2, and about 26% (253) in G3. The number of actions identified varied according to the type of training. For example, in G2 feedback is given 192 times (confirm and corrective feedback) but in G3 39 times (confirm feedback). Manipulation of constraints has been done 94 times in G3 and 9 times in G2. This shows the alignment of training with the principles of LP or NLP. Full information is given in table 2. See Figure 1 in the attached file for more details on the distribution of actions across groups.

Table 2. The results of the coach's behavior

		G1	*G2*	*G3*
Instructions	General	19	15	11
	Educational	20	17	0
	Determining the rules for the execution of the movement	0	0	16
Descriptive	Description of how to implement the skill	18	14	0
	Description of how to achieve the goal	9	6	0
	Goal description	9	4	19
Similes	Simile to an animal	0	0	12
	Similarity to the hero	4	6	4
	Comparison with the skills of other sports	0	2	5
Sign	In line with perform	6	8	0
	In line with the goal	0	1	16
Feedback	Confirmation of performance	79	50	39
	Corrective feedback	99	142	0
	By coach	41	12	0

		G1	*G2*	*G3*
Display	By skilled person	9	14	0
	By a beginner	4	16	8
Partially	By coach	0	0	0
correct	By skilled person	0	0	0
	By a beginner	19	9	2
*	Wrong display	0	0	0
Manipulate	Environment Manipulation	0	0	12
constraints	Task manipulation	0	6	48
	Individual Manipulation	0	3	34
physical	Coach himself	6	7	3
assistance	Using a teammate	1	4	8
*	Mature and appropriate	4	5	12
	Mature and inappropriate	6	3	1
	Immature and appropriate	9	4	3
	Immature and inappropriate	0	0	0

Source: The authors

The Kolmogorov-Smirnov test was employed to examine the normality of the data concerning students' performance, revealing normal distribution across all levels ($p>0.05$). According to the one-way ANOVA test between the groups for performance accuracy and in the pre-test ($F=0.06$, $p= 0.97$) the difference was not significant but for the post-test ($F=11.03$, $p<0.001$) the difference was significant. According to ANOVA test 2 (pre-test-post-test)*3 (group) the effect of test and test*group was significant. For more information see table 3. Also, the results of the LSD test for the difference between groups in the post-test showed that there is a significant difference between G1 and G2 ($p=0.04$, $d=-0.696$), between G1 and G3 ($p<0.001$, $d=-1.628$) and G2 and G3 ($p<0.001$, $d=-0.932$). In this regard, G3 has been better than G2 and even better than G1 (see figure 3).

Table 3. The results of the 3x2 ANOVA test for performance accuracy

variable	*Source*	*Mean Square*	*DF*	*F*	*P*	ηp^2
Record	test	6538.79	1	433.42	<0.001	0.90
	Test*group	717.87	2	47.58	<0.001	0.67
	error	15.08	46	*	*	*

Source: The authors.

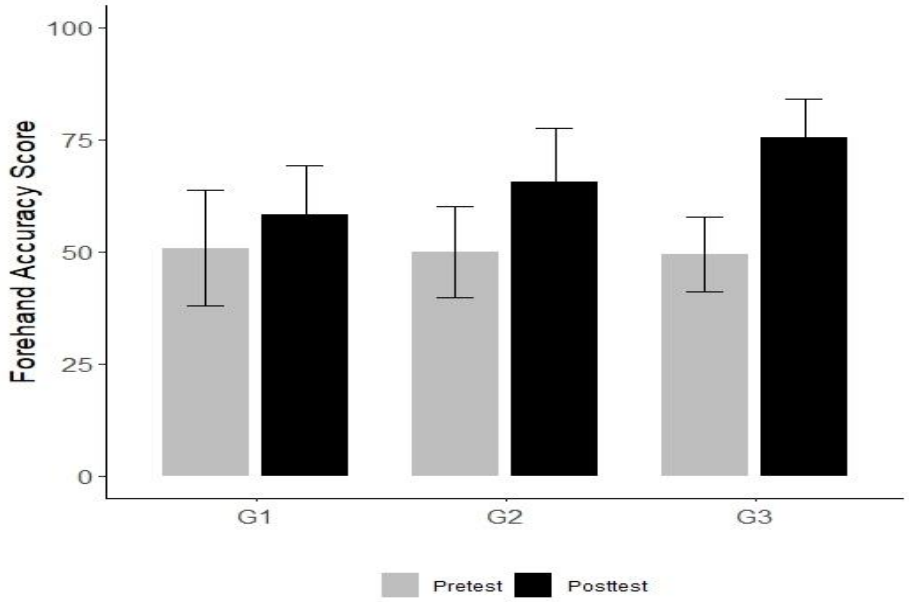

Figure 3. Mean and standard deviation of pre-test and post-test table tennis forehand performance in three training groups
Source: The authors.

Discussion

This study aimed to compare the impact of two coaching pedagogies, LP-CK and NLP-CK, on teachers' knowledge (including verbal communication, visual representation, and appropriateness of teaching) and students' performance (specifically forehand performance in table tennis). The main research questions were: (1) Do CCK and SCK workshops influence teacher behavior and student performance? (2) Is there a significant difference in the effectiveness of LP-CK and NLP-CK workshops? The results showed that the instructional method significantly affected teacher behavior. Group G3 (NLP-CK), taught by teachers trained in NLP-CK workshops, exhibited the greatest improvement in forehand performance accuracy, surpassing both G1 and G2. This finding highlights the greater effectiveness of the NLP approach, which emphasizes adaptability and exploration, helping students improve their skills in dynamic environments.

This study shows that by participating in the CK workshop, the objective knowledge of the teacher's work is improved in accordance with the teaching method. Similar results were found by Iserbyt et al., (2016) [16] , indicating that by participating in a CK workshop, some teachers may be able to aviod some unnesecary actions. It can be said that participating in CK workshops is helpful because it helps the teacher to improve his/her knowledge according to the conditions and characteristics of the students [11]. This improvement of knowledge helps the teacher to use the words appropriate to the students feature and move purposefully in this direction and avoid additional words and verbal feedback [14, 15]. Instead, use similes and symbols. As our results section also revealed, the use of feedback decreased for G2 and G3 compared to G1, and the use of similes increased. Improving the teacher's knowledge helps him to consider the unique characteristics of the students to improve their performance and design exercises for them that fit the characteristics of the class [11]. This helps the teacher to have a dynamic teaching style. In other words, CK workshops help the teacher avoid using the same method for all student and design his teaching according to the conditions of each student. This issue is also emphasized in the perspectives of ecological dynamics [22] , and since learning and growth in this perspective are proportional to the constraints of the individual, the environment

and the task [23]. It is emphasized that teachers should decide what to do according to the current situation.

For student's performance, the results showed that G1 improved performance accuracy score of forehand table tennis by 14%, G2 by 31%, and G3 by 50% . These results are in line with the effect of the CK workshop in line with the study of Iserbyt et al., (2016) [16], in their study, participation in the traditional training and sports education (sports education > traditional) on the teachers's behavior, the record and the reduction of the number of arm stock were effective in the 50m breaststroke. The effectiveness of knowledge-building workshops was confirmed in the study of Kim, (2016) [13] on volleyball skills and in the study of Iserbyt et al., (2017) [14]on badminton skills. The results of our study, in line with the results of previous studies, generally highlight the importance of improving teacher knowledge. Also, in our study and the study of Iserbyt et al., (2016) [16] in particular, the results show that knowledge-enhancing workshops have different effectiveness according to the type of teaching method, and here participation in the NLP-CK workshop was reported to be more effective than LP-CK.

Skill acquisition literature focusing on the use of non-linear pedagogy often criticize the use of more traditional linear methods that focus on breaking down the skill into smaller parts, linking information and movement in the real environment is prevented [24]. The main concern with LP is that this approach usually takes away the opportunity for exploration and problem solving from the student by introducing and repeating a dominant pattern and restricting the individual to practice that activity, and the student plays an almost passive role [19, 24, 25]. But in NLP students encouraged by the teacher to solve the challenges resulting from the constraint; in which there is no ideal model for all individuals, but the teacher guides student to learn and develop a specific skill by manipulating the constraints appropriate to his unique physical characteristics. In this approach, the teacher's attention is on the manipulation of the environment and the task, which makes the right decision appropriate to the current situation to be made at any moment. Also, the exploratory nature of this approach makes the student have an internal motivation to participate in physical activity [2]. These foundations are confirmed by comparing the performance of students in LP and NLP methods by the results of the present study and the behavior of the teacher (manipulation of constraints versus use of feedback or pattern).

One of the most important goals of improving the knowledge of the teacher is to help them adapt his behavior and teaching methods to the characteristics of the students [11]. In such a way that they have high flexibility to use the teaching method [15]. NLP also emphasizes the two principles of flexibility and adaptability in practice [8]. According to the principles of NLP, teachers are required to continuously assess students' conditions and tailor exercises accordingly, adapting teaching methods when conditions change (e.g., fatigue). By examining this issue, it is understood that the principles of NLP and PCK methods are in line with each other and this similarity in theoretical foundations helps the teachers who participate in the NLP-CK workshop to help the students more. A finding supported by the study's results where improved student performance correlated with teachers purposefully adjusting their approaches based on training conditions and student responses (utilizing feedback, instructions, manipulation of constraints, etc.).

limitations of the study

This study has several limitations that should be acknowledged and critically considered. First, the absence of a true randomized control group limits causal inference; although the quasi-experimental multi-group design partly mitigates this issue, sequencing effects cannot be ruled out because the same teacher trained G1 before attending the CK-LP workshop, then trained G2 after CK-LP, and finally trained G3 after CK-NLP. Potential maturation, novelty, and teacher learning effects across weeks may therefore have influenced

outcomes. Second, by nature the quasi-experimental design restricts control over confounders such as prior sport experience, informal practice outside sessions, or differences in motivation and fatigue; while baseline performance stratification was used, residual confounding is still possible. Third, the intervention period was short (10 days) and no follow-up or transfer tests were administered, which precludes conclusions about retention of learning or generalization to game-like contexts. Fourth, attrition occurred at post-test (2 non-completers in G2; 3 in G3), producing unequal group sizes and possible attrition bias; analyses were per-protocol and did not include an intention-to-treat approach. Fifth, the sample comprised male physical education students from a single university (and a single country) trained by one male teacher, which limits representativeness and external validity to other ages, females, different institutions, and practitioners with different backgrounds. Sixth, only two pedagogical approaches (LP and NLP) were compared; therefore, the relative standing of these approaches versus alternative or hybrid models remains uncertain. Seventh, measurement choices may constrain ecological validity: student performance was indexed by a single forehand accuracy test using a ball machine, without in-game decision-making or pressure; teacher PCK was coded by observers who, despite high inter-rater reliability, were not blinded to condition, which may introduce expectation bias. Finally, given modest and unequal group sizes, normality testing has limited power and parametric results (ANOVA, post-hoc tests) should be interpreted with appropriate caution. Future research should use randomized or counter-balanced designs with multiple instructors, longer interventions with retention/transfer assessments, blinded coders, larger and more diverse samples, and broader performance measures in authentic game settings, alongside comparisons with additional pedagogical models.

Conclusion

The findings of this study emphasize the critical role of teacher training workshops in improving pedagogical knowledge, which in turn enhances teaching behaviors and positively influences student learning and skill acquisition. The effectiveness of these improvements is closely tied to the type of training provided. Our results show that NLP aligns with Pedagogical Content Knowledge (PCK) principles by promoting adaptability and flexibility, making it particularly beneficial in practical teaching environments. This approach allows teachers to adjust their methods based on contextual demands and individual student needs, increasing engagement and cognitive involvement, thus improving learning outcomes. Beyond the theoretical contribution, the study provides clear practical applications for real educational settings. In schools, physical education teachers can apply NLP by designing tasks that encourage exploration and problem-solving rather than repetitive drills, which may improve student motivation and long-term participation in physical activity. In coaching contexts, NLP-based methods can help athletes transfer technical skills more effectively to dynamic game situations, enhancing both performance and creativity. In teacher education, integrating CK workshops with NLP principles can prepare future educators to individualize instruction, manage diverse classrooms, and promote inclusive learning environments. Practically, this study highlights the direct impact of NLP-based teacher training on instructional quality, leading to better student performance in both cognitive and motor skills. The benefits of NLP extend beyond physical education to other domains, such as professional training, teamwork, and social skills development. Additionally, incorporating objective assessment methods like behavioral coding can enhance the quality of teacher training and help design more effective instructional models. Scientifically, this research supports evidence-based teaching methods and calls for further experimental studies to assess the effectiveness of various teacher training approaches. Future research should adopt longer interventions and include follow-up tests to evaluate skill retention over time. Studies with larger and more diverse samples—including

both genders, younger learners, and athletes from different contexts—are needed to improve generalizability. It would also be valuable to compare LP and NLP with alternative or hybrid pedagogical models to provide a more comprehensive perspective. Finally, the integration of emerging technologies such as virtual reality and motion tracking could open new opportunities for enhancing teacher training workshops and examining their effects on student learning in authentic game situations.

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