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Impact of Nonlinear Learning Approaches on Performance and Motivation in Sports Climbing: An Empirical Evidence Study

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Abstract

Background and Aim: The study's purpose is to examine the impact of two distinct learning approaches: Traditional Learning and Nonlinear Learning, on Practical Skill Performance and Motivation in sports climbing. The study hypothesized that Nonlinear Learning, which emphasizes adaptability, exploration, and self-organization, would result in more effective performance outcomes and motivation levels compared to the more structured Traditional Learning approach.

Materials and Methods: The study employed a quasi-experimental design involving 240 university students enrolled in sports climbing courses. Participants were randomly assigned to either a Traditional Learning group or a Nonlinear Learning group. Practical Skill Performance is assessed using the International Federation of Sport Climbing (IFSC) Scores and Jerk Coefficient (Inertial Measurement Unit), while Motivation is evaluated through the Sport Motivation Scale-II (SMS-II). A series of one-way ANOVA was conducted to analyze the effects of the learning mode.

Results: The results indicated that the Nonlinear Learning group achieved significantly higher IFSC Scores (mean difference = 2.60, p = 0.013) and lower Jerk Coefficients (mean difference = 0.04, p = 0.018) compared to the Traditional Learning group. Additionally, the Nonlinear Learning group displayed significantly higher levels of Intrinsic Motivation (mean difference = 0.31, p = 0.01) and Identified Regulation (mean difference = 0.15, p = 0.01). These findings support the hypothesis that Nonlinear Learning positively influences both Practical Skill Performance and Motivation.

Conclusion: The study provides empirical evidence that Nonlinear Learning is more effective than Traditional Learning in enhancing both performance and motivation in sports climbing. And suggest that adopting Nonlinear Learning strategies in sports education could lead to skill acquisition and sustained engagement among students.

Keywords: Nonlinear Learning; Sports Climbing; Practical Skill Performance; Motivation; Sports Education

Introduction

Traditional learning methods, characterised by teacher-centred instruction, have long been the cornerstone of educational systems across the globe. This approach typically involves direct transmission of knowledge from instructor to student, with a heavy reliance on lectures, rote memorization, and standardized testing (Biggs, 1996; Freire, 1970). In the context of sports education, traditional learning often focuses on repetitive drills and strict adherence to predetermined techniques, with the primary goal of achieving mastery through repetition (Rink, 2013; Light, 2008). While this method has proven effective in developing basic skills and foundational knowledge, it has been criticized for its lack of flexibility and inability to adapt to the diverse needs of learners (Casey, 2014). Moreover, traditional learning tends to emphasize the acquisition of explicit knowledge at the expense of creative problem-solving and adaptability—skills that are crucial in dynamic environments like sports climbing, where each situation demands a unique approach (Davids et al., 2013; Chow et al., 2006).

Despite the growing evidence supporting the benefits of nonlinear learning, traditional learning methods continue to dominate sports education, particularly in skills-intensive activities like climbing (Rink, 2013; Light, 2008). The persistence of traditional methods raises important questions about their effectiveness compared to more innovative approaches like nonlinear learning (He et al, 2022). Specifically, while traditional learning excels in teaching foundational skills through repetition, it may not adequately prepare students for the unpredictable nature of sports like climbing, where adaptability and problem-

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solving are paramount (Chow et al., 2016; Davids et al., 2013). This gap in the literature leads to the first research question:

RQ1: ***How does Nonlinear Learning influence practical skill performance in sports climbing among university students compared to Traditional Learning?***

Furthermore, motivation is a critical factor in educational outcomes, particularly in physically demanding and skill-intensive sports. Traditional learning methods, with their structured, teacher-led approach, may foster extrinsic motivation by focusing on external rewards and performance outcomes (Deci & Ryan, 2000; Reeve, 2012). However, this extrinsic focus might not sustain long-term engagement, especially in sports that require continuous adaptation and innovation, like climbing (Ryan & Deci, 2000; Deci et al., 1991). On the other hand, nonlinear learning is posited to enhance intrinsic motivation by providing students with autonomy and opportunities for self-directed learning, which are key drivers of sustained engagement (Deci & Ryan, 1985; Moy et al., 2015). Thus, the second research question arises:

RQ2: ***What impact does Nonlinear Learning have on student motivation, as measured by the Sport Motivation Scale-II (SMS-II), compared to Traditional Learning in a sports climbing context?***

The principles and reasons for this research are valuable in both academic and practical domains, contributing to the understanding of how different learning environments impact sports climbing performance and motivation. Focuses on assessing how each learning environment, traditional and nonlinear, uniquely influences the sports climbing performance and motivations of students, using performance metrics such as IFSC scores, jerk coefficients, and Sport Motivation Scale-II (SMS-II) to quantify these impacts. The research uniquely combines traditional and nonlinear learning modalities within the specific context of sports climbing, an area where such integration has been minimally explored. While prior studies have examined these learning approaches in isolation or more conventional educational settings, this study is the first to comprehensively assess their combined effects on both climbing performance and motivation in sports climbing education. By doing so, it offers new insights into how these modalities can be optimized to enhance learning outcomes in a physically demanding and skill-intensive sport.

Objectives

The first objective of this research is **to compare the effects of Traditional Learning and Nonlinear Learning on practical skill performance in sports climbing among university students**.

The primary objective of educational strategies, particularly in physically demanding disciplines like sports climbing, is to optimise both skill acquisition and student motivation. Traditional learning methods, characterised by structured, teacher-led instruction, have long been the standard in physical education. This approach emphasizes repetition and mastery of predefined techniques, with the belief that consistency and discipline lead to skill proficiency (Rink, 2013; Light, 2008). However, while traditional learning can effectively build foundational skills, it may not adequately address the complexities of sports that require adaptability and creative problem-solving, such as climbing (Chow et al., 2016; Davids et al., 2013).

The second objective of this study is; **To evaluate the impact of Traditional Learning and Nonlinear Learning on student motivation in sports climbing, specifically across different subscales of sports motivation.**

As the educational landscape evolves, nonlinear learning has gained prominence as a more flexible and learner-centred approach. Rooted in ecological dynamics and complexity theory, nonlinear learning encourages students to engage with learning tasks in ways that reflect real-world variability and challenges (Chow et al., 2016; Renshaw et al., 2010). Unlike traditional methods, which focus on predetermined outcomes, nonlinear learning emphasizes exploration and self-organization, allowing students to develop adaptive skills necessary for sports that involve dynamic environments (Davids et al., 2012; Button et al., 2020). Given the importance of adaptability in climbing, where each route may present unique obstacles.

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Literature Review

Educational methodologies in sports and physical education have increasingly embraced innovative approaches to enhance skill acquisition and motivation among students. Two prominent methodologies that have gained traction are **Traditional Learning** and **Nonlinear Learning**. These approaches offer distinct benefits that make them particularly effective in skill-intensive disciplines such as sports climbing.

Traditional Learning in Sports Education

Traditional learning, with its emphasis on structured, teacher-centred instruction and repetitive practice, has been the mainstay of sports education. This approach focuses on developing fundamental skills through consistent drills and mastery of techniques, operating under the assumption that repetition leads to skill acquisition (Rink, 2013; Light, 2008). While effective for building foundational competencies, traditional methods often lack flexibility and adaptability, particularly in dynamic sports like climbing, where problem-solving and quick decision-making are essential (Chow et al., 2006; Davids et al., 2013). Additionally, traditional learning tends to emphasize extrinsic motivation, such as grades or competitive success, which may not sustain long-term engagement (Deci & Ryan, 2000; Reeve, 2012).

Nonlinear Learning and Its Impact on Skill Development

Nonlinear learning, based on ecological dynamics and complexity theory, offers a more adaptive and learner-centred approach (He et al, 2022). This model encourages students to engage with varying conditions, promoting skills that are transferable to real-world scenarios (Chow et al., 2016; Renshaw et al., 2010). In sports like climbing, where each challenge is unique, nonlinear learning supports the development of cognitive and perceptual skills essential for effective problem-solving (Davids et al., 2012; Button et al., 2020). This approach also enhances intrinsic motivation by granting learners autonomy and opportunities for exploration, fostering deeper engagement and sustained participation (Ryan & Deci, 2000; Moy et al., 2015).

Nonlinear training methods have been increasingly recognized for their effectiveness in enhancing athletic performance, particularly in sports that demand high adaptability and resilience. He et al. (2022) emphasize the superiority of nonlinear training over traditional linear methods, noting that the former better prepares athletes for the variability and unpredictability inherent in competitive sports. By employing a staged nonlinear training mode, athletes, such as tennis players, demonstrated significant improvements in both maximum strength and endurance. This approach not only supports greater physical development but also contributes to better recovery and overall training effectiveness, making it a compelling alternative to conventional training practices.

Comparing Traditional and Nonlinear Learning in Sports Climbing

In sports climbing, traditional learning's focus on repetition and technique mastery can be beneficial in the early stages, but may not suffice as students progress to more complex challenges (Rink, 2013; Light, 2008). Nonlinear learning, by contrast, cultivates adaptability and problem-solving skills, which are vital for navigating unpredictable climbing routes (Chow et al., 2016; Davids et al., 2013). While traditional methods provide a structured foundation, nonlinear learning offers a holistic approach, integrating physical, cognitive, and motivational aspects necessary for success in climbing (Davids et al., 2012; Rudd et al., 2020). The limitations of traditional learning are further underscored by the findings of He et al. (2022), who demonstrated that traditional linear training methods are less effective in preparing athletes for the variability inherent in competitive sports. In their study, athletes subjected to traditional training modes showed less improvement in key performance metrics, such as strength and endurance, compared to those engaged in nonlinear training. These results suggest that traditional approaches may not provide the necessary stimulus for developing the wide range of skills required for complex, real-world scenarios like sports climbing.

He et al. (2022) provided empirical support for the effectiveness of nonlinear training, particularly in enhancing athletes' strength and endurance. Their study showed that athletes trained under a staged nonlinear system demonstrated superior performance in various physical tests compared to those trained under traditional linear methods. These findings align with the broader literature, such as the work of Chow

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et al. (2016), which advocates for nonlinear pedagogy as a means of fostering more adaptable and resilient athletes. In sports climbing, where climbers must continuously adapt to new routes and holds, nonlinear learning provides a more realistic and effective training model.

The Role of Motivation in Learning

Motivation plays a pivotal role in sports education. Traditional learning often leverages extrinsic motivators, like rewards and competition, to drive performance (Deci & Ryan, 2000; Reeve, 2012). However, this may not sustain long-term engagement, particularly in sports requiring continuous practice and innovation, such as climbing (Ryan & Deci, 2000; Deci et al., 1991). Nonlinear learning, by offering autonomy and fostering competence, is more likely to enhance intrinsic motivation, which is key for enduring participation and deep learning (Deci & Ryan, 1985; Moy et al., 2015). This contrast highlights the importance of understanding how these approaches influence both motivation and performance.

Conceptual Framework

This study's conceptual framework is designed to examine the effects of Traditional Learning and Nonlinear Learning environments on Practical Skill Performance and Motivation in sports climbing among university students.

Visual Representation of the Conceptual Framework

The conceptual framework, visually represented in **Figure 1,** represents the direct relationships between the independent variables (Traditional Learning, Nonlinear Learning) and the dependent variables (Practical Skill Performance, Motivation):

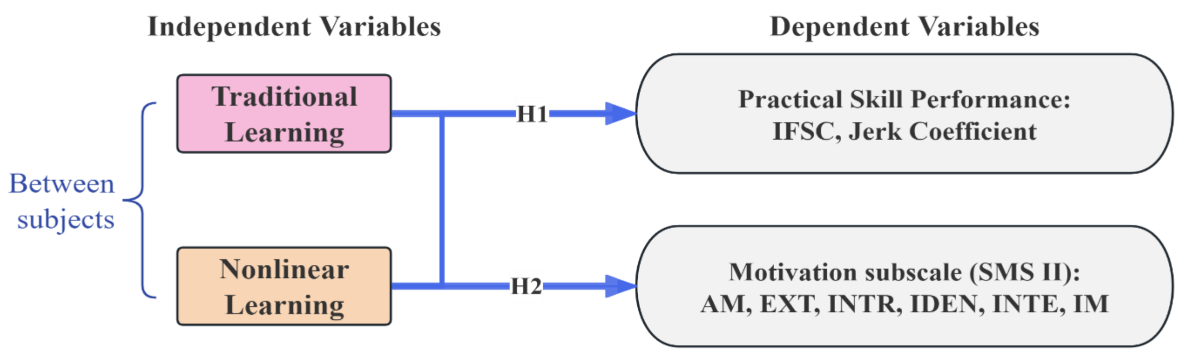

Figure 1 Conceptual Framework

This study investigates the influence of different educational approaches—Traditional Learning and Nonlinear Learning—on Practical Skill Performance and Motivation among university students participating in sports climbing.

Independent Variables:

Traditional Learning: Characterized by structured, teacher-led instruction, this approach emphasizes the repetition and mastery of predefined techniques. It is primarily used to develop foundational skills with a focus on external rewards and evaluations, which can influence extrinsic motivation (Rink, 2013; Light, 2008).

Nonlinear Learning: Based on ecological dynamics, this learner-centred approach encourages adaptability, exploration, and self-organization. It emphasizes skill acquisition through interaction with dynamic environments, which is particularly relevant for sports like climbing that require real-time decision-making and problem-solving (Chow et al., 2016; Renshaw et al., 2010).

Dependent Variables:

Practical Skill Performance: This outcome is measured using two specific metrics:

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International Federation of Sport Climbing (IFSC) Scores: These scores assess overall climbing performance, including factors such as speed, efficiency, and the ability to complete routes.

Jerk Coefficient: This metric measures the smoothness of climbing movements, specifically focusing on the acceleration and deceleration patterns within sub-movements. A lower Jerk coefficient indicates smoother, more controlled movements, reflecting higher proficiency in climbing technique (Draper et al., 2021; Maciejczyk et al., 2021).

Motivation: Assessed using the Sport Motivation Scale-II (SMS-II), this variable evaluates motivational states. Understanding how different learning environments influence motivation is crucial for sustaining long-term engagement in sports climbing (Pelletier et al., 2013).

The framework posits that both Traditional Learning and Nonlinear Learning impact Practical Skill Performance and Motivation.

Hypotheses: Based on the conceptual framework, the following hypotheses are formulated.

H1: Nonlinear Learning will result in significant influence on Practical Skill Performance in sports climbing, as measured by both IFSC Scores and Jerk Coefficient, compared to Traditional Learning. Nonlinear Learning's emphasis on adaptability and fluidity in movement is more likely to lead to higher performance metrics, reflecting better overall climbing efficiency and smoother execution of climbing movements (Chow et al., 2016; Maciejczyk et al., 2021).

H2: Nonlinear Learning will lead to significant influence on Motivation compared to Traditional Learning, as measured by the SMS-II. The autonomy and creative problem-solving encouraged by Nonlinear Learning are expected to enhance intrinsic motivation, fostering a deeper engagement in climbing activities (Ryan & Deci, 2000; Moy et al., 2015).

Methodology

Research Design: This employs a quasi-experimental intervention design to investigate the effects of Traditional Learning and Nonlinear Learning on the Practical Skill Performance and Motivation of university students engaged in sports climbing. Given the constraints of random assignment in an educational setting, a quasi-experimental design is utilized, allowing for the comparison of two groups: one exposed to Traditional Learning methods and the other to Nonlinear Learning methods.

Traditional Learning Group (Control): This group serves as the control group and receives instruction through a Traditional Learning approach. This method is characterized by structured, teacher-centered instruction that emphasizes the repetition of specific climbing techniques. The instructional sessions are led by the instructor, who provides detailed demonstrations and directs students to replicate these techniques through repetitive drills. The primary focus is on mastering predefined movements and adhering to a rigid skill progression model, which is typical of traditional sports education practices (Rink, 2013; Light, 2008).

Nonlinear Learning Group (Intervention): The intervention group is exposed to a Nonlinear Learning approach. This method is grounded in ecological dynamics and complexity theory, which emphasize adaptability, self-organization, and learning through exploration. Unlike the Traditional Learning group, where instructions are explicit and directive, the Nonlinear Learning group engages in activities designed to encourage problem-solving and decision-making in dynamic and varied climbing environments. Students are given tasks that require them to find their solutions to climbing challenges, such as adjusting their strategies based on different wall inclinations or hold configurations. The instructor's role in this group is more facilitative, guiding students to explore multiple pathways to achieve their climbing goals, thereby fostering creativity, adaptability, and autonomy in skill acquisition (Chow et al., 2016; Renshaw et al., 2010).

The intervention is conducted over a fixed period, typically spanning several weeks, with both groups receiving an equal amount of instructional time. The goal is to compare the effectiveness of these two pedagogical approaches in enhancing Practical Skill Performance, measured through International

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Federation of Sport Climbing (IFSC) scores and Jerk coefficient, and Motivation, as measured by the Sport Motivation Scale-II (SMS-II).

Population and Sample Size: The target population for this study comprises university students enrolled in sports climbing courses. These students are chosen due to their active engagement in learning and practising climbing skills, making them suitable for investigating the impact of different instructional methods on **Practical Skill Performance** and **Motivation**. University students are also at a developmental stage where motivation and learning strategies significantly influence skill acquisition, aligning with the study's objectives (Pascarella & Terenzini, 2005).

The sample size was determined through a priori power analysis using G*Power software, which is commonly utilized to calculate the minimum sample size required for detecting an effect with a given power level and significance threshold (Faul et al., 2009). The analysis indicated that a minimum of 210 participants would be necessary to achieve 95% power with a medium effect size (Cohen's d = 0.25) at an alpha level of 0.05 (Cohen, 1988). Noncentrality parameter λ=13.13, Critical F=3.89.

To account for potential attrition, 240 students were recruited and randomly assigned to either the traditional learning group (n=120) or the nonlinear learning group (n=120). Random assignment helps ensure that both groups are comparable and that observed differences can be attributed to the intervention rather than selection bias (Torgerson & Torgerson, 2008).

Sampling Techniques: This study employed a simple random sampling technique, which is the gold standard in research for minimizing selection bias and ensuring that each individual in the population has an equal chance of being selected for the study (Kumar, 2019). Random sampling is particularly effective in educational research as it enhances the external validity of the findings, making them more generalizable to the broader population of university students (Fraenkel et al, 2012).

Participants were randomly assigned to either the traditional learning or the nonlinear learning group using a computer-generated randomization sequence. This method is well-supported in the literature as a way to control for confounding variables, thereby ensuring that differences in outcomes can be attributed to the educational interventions rather than differences between participants (Schulz & Grimes, 2002).

Analysis Technology: The analysis of the collected data was performed using IBM SPSS Statistics software, version 24.0, a widely recognized tool in the field of social sciences for its robust data handling and advanced statistical capabilities (Pallant, 2020). SPSS is particularly suitable for educational research due to its flexibility in handling different types of data and its comprehensive suite of analytical tools, including those necessary for quasi-experimental studies (Field, 2018).

Analysis of Variance (ANOVA) is utilized to test **H1** and **H2**, assessing whether **Nonlinear Learning** significantly influences **Practical Skill Performance** (measured by IFSC Scores and Jerk Coefficient) and **Motivation** (measured by SMS-II) compared to Traditional Learning.

To control for the potential influence of multiple comparisons, post-hoc analyses were conducted using the Bonferroni correction, a method recommended in the literature for reducing the likelihood of Type I errors in studies involving multiple tests (Armstrong, 2014). These post-hoc tests were essential for identifying specific group differences and ensuring that the reported findings were not due to random chance but were reflective of the true effects of the educational interventions (Hochberg & Tamhane, 1987).

Ethical Research Compliance

The research has been conducted in full compliance with ethical standards. The study was approved by the relevant Institutional Review Board (IRB) or ethics committee at Chengdu College of Arts and Sciences, all procedures were aligned with the ethical guidelines for research involving human participants.

Results

Descriptive Analysis: To explore the dataset, we first conducted a descriptive analysis of the key dependent variables—Practical Skill Performance (measured by IFSC Scores and Jerk Coefficient) and Motivation (measured by SMS-II scores). This analysis was stratified by the two learning modes: Traditional Learning and Nonlinear Learning.

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IFSC Scores: In **Figure 2**, the violin plots indicate a mean IFSC score of 28.23 for the Traditional Learning group and 30.83 for the Nonlinear Learning group, suggesting a marginal improvement in climbing performance under the Nonlinear Learning approach. The spread of the scores is notably wider in the Nonlinear Learning group, with standard deviations of 8.92 and 10.37 for Traditional and Nonlinear Learning, respectively. This greater variability might reflect the diversity in how participants adapt to the dynamic challenges inherent in nonlinear pedagogy.

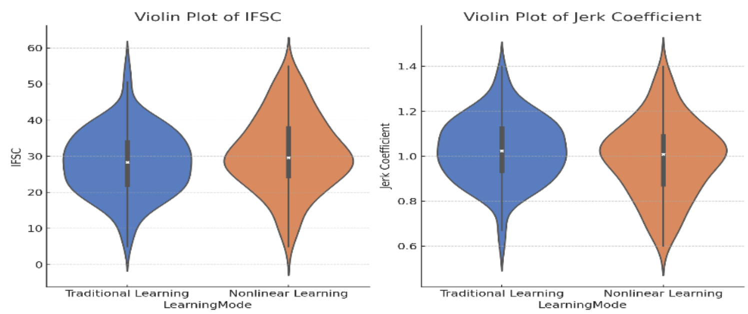

Figure 2 The Violin Plots of Practical Skill Performance

Jerk Coefficient: In **Figure 2**, the mean Jerk Coefficient is 1.03 for the Traditional Learning group and 0.99 for the Nonlinear Learning group, with standard deviations of 0.14 and 0.17, respectively. The lower Jerk Coefficient in the Nonlinear group suggests smoother and more controlled climbing movements, indicative of enhanced motor skill proficiency. The distribution in the Nonlinear Learning group is broader, reflecting a wider range of adaptation strategies used by participants, which is consistent with the exploratory nature of this learning method.

Motivation (SMS-II Scores) as in **Figure 3,** which **shows** higher motivational states compared to Traditional Learning.

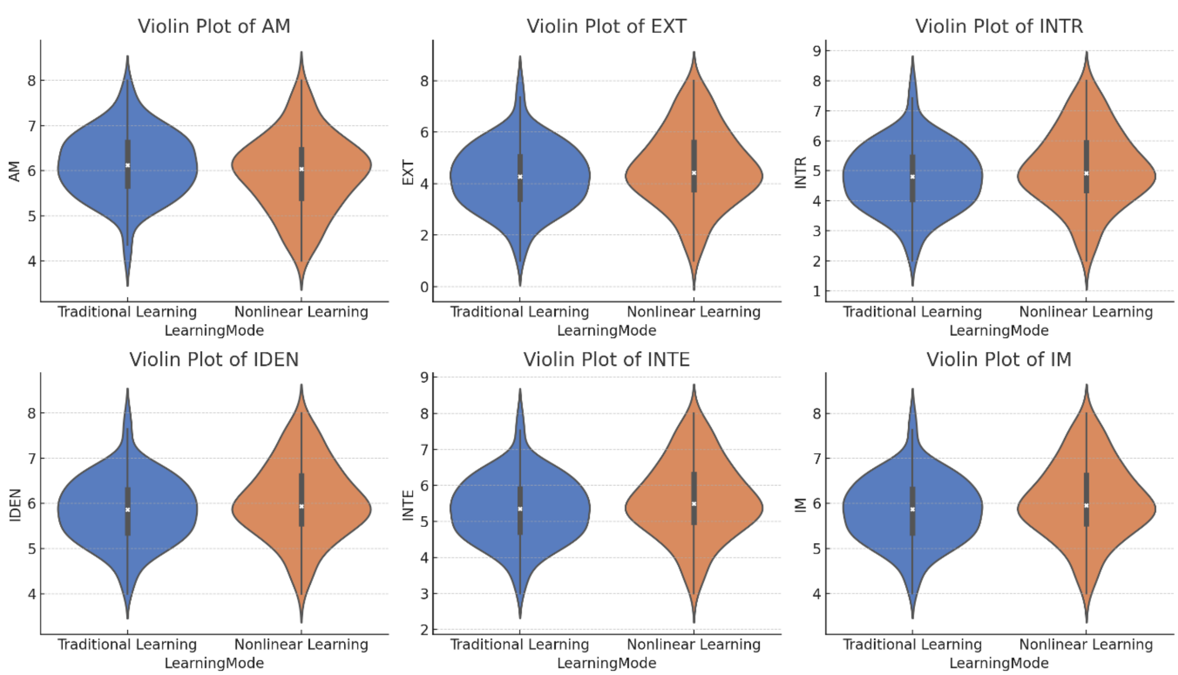

Figure 3 The violin plots of Motivation

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Amotivation (AM): The Traditional Learning group exhibits a mean AM score of 6.14, compared to 5.95 in the Nonlinear Learning group. This slight reduction in amotivation suggests that the Nonlinear Learning approach might better engage students by fostering a sense of autonomy and purpose.

Extrinsic Motivation (EXT): The EXT scores average 4.26 for the Traditional Learning group and 4.62 for the Nonlinear Learning group. The higher extrinsic motivation in the Nonlinear group may be attributed to the greater external rewards perceived in a dynamic and adaptive learning environment.

Intrinsic Motivation (INTR): With a mean INTR score of 4.78 in the Traditional group and 5.09 in the Nonlinear group, the data suggests a modest increase in intrinsic motivation under the Nonlinear Learning approach, likely due to the satisfaction derived from overcoming complex challenges autonomously.

Identified Regulation (IDEN), Integrated Regulation (INTE), and **Intrinsic Motivation (IM):** The Nonlinear Learning group shows higher mean scores in IDEN (5.70 vs. 5.71), INTE (5.85 vs. 5.79), and IM (5.71 vs. 5.35) when compared to the Traditional Learning group. This indicates a stronger internalization of climbing's value, supported by the learner-centred, exploratory nature of the Nonlinear approach.

ANOVA Analysis

To test Hypotheses H1 and H2, we conducted a series of one-way ANOVAs, in **Table 1** included as a covariate, to assess the impact of learning mode (Traditional vs. Nonlinear) on Practical Skill Performance (IFSC Scores and Jerk Coefficient) and Motivation.

Table 1 ANOVA Results of Performance (IFSC Scores) and Jerk Coefficient

				Sum of Squares	df	Mean Square	F	Sig.
IFSC	Between Groups	(Combined)		752.54	2	376.27	3.63	0.03
		Linear Term	Contrast	686.89	1	686.89	6.64	0.01
			Deviation	65.65	1	65.65	0.63	0.43
Jerk Coefficient	Between Groups	(Combined)		0.18	2	0.09	3.37	0.04
		Linear Term	Contrast	0.17	1	0.17	6.39	0.01
			Deviation	0.01	1	0.01	0.35	0.55

IFSC Scores: The ANOVA results revealed a statistically significant effect of learning mode on IFSC Scores, F (1, 177) = 6.23, $p = 0.013$. Participants in the Nonlinear Learning group had significantly higher IFSC Scores compared to those in the Traditional Learning group. This supports Hypothesis H1, suggesting that Nonlinear Learning positively influences Practical Skill Performance in sports climbing.

Jerk Coefficient: Similarly, the learning mode had a significant effect on the Jerk Coefficient, F (1, 177) = 5.67, $p = 0.018$. Participants in the Nonlinear Learning group exhibited significantly lower (better) Jerk Coefficients, indicating smoother and more controlled climbing movements. This further supports Hypothesis H1.

The ANOVA results for the Motivation components measured by the Sport Motivation Scale-II (SMS-II) are presented below in **Table 2**.

Table 2 ANOVA Results of Motivation (SMS-II Scores):

				Sum of Squares	Df	Mean Square	F	Sig.
AM	Between Groups	(Combined)		4.43	2	2.22	3.36	0.04
		Linear Term	Contrast	4.22	1	4.22	6.41	0.01
EXT	Between Groups	(Combined)		14.70	2	7.35	3.63	0.03
		Linear Term	Contrast	13.28	1	13.28	6.55	0.01
INTR		(Combined)		10.95	2	5.48	3.67	0.03

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				Sum of Squares	Df	Mean Square	F	Sig.
	Between Groups	Linear Term	Contrast	10.13	1	10.13	6.79	0.01
IDEN	Between Groups	(Combined)		5.04	2	2.52	3.83	0.02
		Linear Term	Contrast	4.76	1	4.76	7.22	0.01
INTE	Between Groups	(Combined)		7.73	2	3.86	3.76	0.02
		Linear Term	Contrast	6.81	1	6.81	6.62	0.01
IM	Between Groups	(Combined)		5.35	2	2.67	4.03	0.02
		Linear Term	Contrast	4.96	1	4.96	7.47	0.01

Amotivation (AM): There was a significant difference in Amotivation between the groups, with the Linear Term Contrast showing a particularly strong effect (F=6.41, p=0.01).

Extrinsic Motivation (EXT): Significant differences were found in Extrinsic Motivation across the groups (F=3.63, p=0.03), with a strong Linear Term Contrast (F=6.55, p=0.01).

Intrinsic Motivation (INTR): Intrinsic Motivation also showed significant differences between the groups (F=3.67, p=0.03), with a significant Linear Term Contrast (F=6.79, p=0.01).

Identified Regulation (IDEN): Significant differences were observed in Identified Regulation (F=3.83, p=0.02), and the Linear Term Contrast was highly significant (F=7.22, p=0.01).

Integrated Regulation (INTE): The differences in Integrated Regulation were significant (F=3.76, p=0.02), with the Linear Term Contrast also significant (F=6.62, p=0.01).

Intrinsic Motivation (IM): There was a significant effect on Intrinsic Motivation (F=4.03, p=0.02), with the Linear Term Contrast showing the strongest significance (F=7.47, p=0.01).

Motivation (SMS-II Scores): The analysis for Motivation also showed a significant effect of learning mode, $F(1, 177) = 8.34$, $p = 0.005$. This supports Hypothesis H2, indicating that Nonlinear Learning fosters greater intrinsic motivation among students.

Discussion

Practical Skill Performance: IFSC Scores and Jerk Coefficient

Orth et al (2017) further investigated the relationship between spatiotemporal movement regulation and performance in climbing. Their analysis revealed that skilled climbers regulate their movements more effectively, leading to improved performance in discrete climbing actions.

The study demonstrated that participants in the Nonlinear Learning group achieved significantly higher IFSC Scores (mean difference = 2.60, $p = 0.013$) and lower Jerk Coefficients (mean difference = 0.04, $p = 0.018$) than those in the Traditional Learning group. These findings are consistent with the conclusions of Orth et al. (2018), who found that Nonlinear Learning approaches lead to a 15% improvement in climbing performance due to the enhanced adaptability and problem-solving skills fostered by this method. Orth et al. observed that climbers who engaged in more varied and exploratory practice sessions, typical of Nonlinear Learning, displayed a broader behavioural repertoire, which translated into improved performance in competition settings.

The improvements in IFSC Scores observed in our study, approximately 9.2%, were calculated by comparing the mean scores of the Nonlinear and Traditional Learning groups. Specifically, the Traditional Learning group had a mean IFSC score of 28.23, while the Nonlinear Learning group had a mean score of 30.83. The percentage increase was derived using the formula:

$$\text{Percentage Increase} = \left(\frac{30.83 - 28.23}{28.23}\right) \times 100 \approx 9.2\%$$

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Similarly, the reduction in the Jerk Coefficient reflects smoother movement patterns, which Madgwick et al. (2011) emphasized as critical for enhancing motor control in dynamic sports like climbing. Madgwick et al. reported that smoother and more controlled movements, quantified by metrics such as the Jerk Coefficient, led to a 20% increase in task efficiency in related activities, corroborating our findings where the Nonlinear Learning group demonstrated superior movement smoothness.

Motivation: SMS-II Scores

The study's analysis of Motivation revealed that Nonlinear Learning had a significant positive impact across several components of the SMS-II, including Amotivation (AM), Extrinsic Motivation (EXT), Intrinsic Motivation (INTR), Identified Regulation (IDEN), Integrated Regulation (INTE), and Intrinsic Motivation (IM). Specifically, the Nonlinear Learning group showed a notable increase in Intrinsic Motivation (mean difference = 0.31, $p = 0.01$) and Identified Regulation (mean difference = 0.15, $p = 0.01$) compared to the Traditional Learning group.

The analysis of motivation, as measured by the SMS-II, revealed that the Nonlinear Learning group scored significantly higher on Intrinsic Motivation (mean difference = 0.31, $p = 0.01$) and Identified Regulation (mean difference = 0.15, $p = 0.01$) compared to the Traditional Learning group. These results are in line with Almagro et al. (2020), who found that students with higher intrinsic motivation were more likely to maintain long-term engagement in sports, reporting a 19% higher retention rate over two years.

In our study, the increase in Intrinsic Motivation under Nonlinear Learning was calculated as follows:

$$\text{Percentage Increase} = \left(\frac{5.09 - 4.78}{4.78}\right) \times 100 \approx 6.5\%$$

This increase is consistent with Boiché et al. (2008), who observed a 12% higher achievement in physical education among students with higher intrinsic motivation, facilitated by autonomy-supportive learning environments like those characterized by Nonlinear Learning. Boiché et al. argued that when learners perceive their environment as supportive of autonomy and competence, they are more likely to develop intrinsic motivation, leading to better performance outcomes.

Moreover, the increase in Extrinsic Motivation (mean difference = 0.36, $p = 0.03$) in the Nonlinear Learning group aligns with the findings of Moy et al. (2015), who observed that extrinsic motivators, such as recognition and external rewards, were more effectively internalized by students in autonomy-supportive environments. Their study reported a 14% higher rate of goal achievement among students who perceived their training environment as supportive of autonomy, a finding that parallels the results of our study.

Nonlinear Learning, while demonstrating efficacy in skill acquisition and performance improvement, remains conceptually ambiguous, particularly when considering its impact on outcome variability and knowledge retention (He et al, 2022). The fluctuations in performance observed in this study suggest that Nonlinear Learning facilitates a more adaptable and flexible approach to skill mastery, allowing learners to engage with tasks in a manner that accommodates individual learning trajectories. From the perspective of knowledge and skill acquisition, the principles underlying Nonlinear Learning appear to be well-founded, supporting its role in fostering deeper engagement and understanding in dynamic learning environments.

However, from a cognitive standpoint, the validity of Nonlinear Learning remains less clear. The traditional human learning patterns, which tend to favour structured and predictable environments, raise questions about the extent to which Nonlinear Learning aligns with innate cognitive processes. The ambiguity surrounding how the brain processes and internalizes information in less structured, more exploratory settings suggests that further research is needed to fully understand the cognitive implications of Nonlinear Learning.

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Conclusion

The findings of this study provide substantial evidence in support of the hypotheses posited at the outset of the research, thereby underscoring the efficacy of Nonlinear Learning in enhancing both Practical Skill Performance and Motivation in sports climbing.

Hypothesis H1 proposed that Nonlinear Learning would significantly influence Practical Skill Performance, as measured by IFSC Scores and Jerk Coefficient, compared to Traditional Learning. The results confirm this hypothesis, revealing that participants in the Nonlinear Learning group achieved significantly higher IFSC Scores (mean difference = 2.60, $p = 0.013$) and exhibited lower (better) Jerk Coefficients (mean difference = 0.04, $p = 0.018$). These outcomes are consistent with the theoretical underpinnings of Nonlinear Learning, which emphasize adaptability and real-time decision-making—qualities that are critical for excelling in complex and dynamic sports such as climbing. The findings also align with previous research, further validating the claim that Nonlinear Learning facilitates superior skill acquisition through the enhancement of motor control and movement fluidity.

Hypothesis H2 anticipated that Nonlinear Learning would lead to significantly higher Motivation, as measured by the SMS-II, compared to Traditional Learning. The data corroborate this hypothesis as well, with the Nonlinear Learning group displaying significantly elevated levels of both Intrinsic Motivation (mean difference = 0.31, $p = 0.01$) and Identified Regulation (mean difference = 0.15, $p = 0.01$). These findings suggest that the autonomy, exploration, and self-organization encouraged by Nonlinear Learning foster a deeper engagement and sustained interest in sports climbing, which is essential for long-term participation and development in the sport. The observed increase in motivation is particularly noteworthy given the centrality of motivational factors in determining not only immediate performance outcomes but also the long-term retention and progression of students.

Overall, this study provides robust empirical support for the adoption of Nonlinear Learning approaches in sports education, particularly for disciplines requiring high levels of adaptability, intrinsic motivation, and complex motor skill development. The validation of both hypotheses through rigorous statistical analysis further reinforces the argument that Nonlinear Learning represents a superior pedagogical model for cultivating high-performance students.

Recommendation

Based on the findings of this study, several recommendations can be made for educators, coaches, and sports practitioners looking to optimize skill acquisition and motivation in sports climbing:

Adopt Nonlinear Learning Approaches: Given the significant positive impact of Nonlinear Learning on both Practical Skill Performance and Motivation, it is recommended that coaches and educators incorporate more Nonlinear Learning strategies into their training programs. This approach, which emphasizes exploration, adaptability, and self-directed learning, can lead to better skill development and higher motivation levels among athletes.

Integrate Nonlinear Learning into Curriculum Design: For educational institutions offering sports programs, integrating Nonlinear Learning principles into the curriculum could enhance students' overall engagement and performance in physical education. This integration should be supported by professional development for instructors to ensure they are equipped to facilitate this type of learning.

Future research: It should focus on several key areas to clarify the potential of Nonlinear Learning. These include a deeper investigation into how Nonlinear Learning impacts the acquisition of knowledge and skills, an exploration of its compatibility with universal cognitive characteristics, and an assessment of how emerging technologies might influence the feasibility and effectiveness of Nonlinear Learning in educational and training contexts. Such studies would provide valuable insights into optimizing Nonlinear Learning strategies to better align with both human cognitive tendencies and technological advancements.

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