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Effect of 12 weeks differential learning vs. classical learning approaches on motor skills related to shot put in healthy young adult

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Purpose: The objective of this study was to compare the effect of 12-weeks of differential learning intervention vs. classical learning in the shot-put for healthy and physically active students.

Methods: In this study, 114 sports science students (64 males; 50 females; age 21.20 ± 2.15 years; body mass: 67.42 ± 12.30 kg; body height: 1.73 ± 0.09 m; BMI: 22.61 ± 1.20 kg.m-1) participated in this study. A total of 114 students completed the study. Students were divided into a differential learning group (DL) ($n = 40$), a classical learning group CL ($n = 39$) and a control group (CG) ($n = 35$). Both DL and CL groups completed a similar 12-weeks learning program with four intervention assessment: shot put test, medicine ball throw, vertical jump tests, five jump test, flexibility test and sprint test.

Results: The results showed that the DL and CL programs significantly improved physical performance ($p < 0.05$) compared to the control group, with the effect size more effective in the DL group than in the CL group after the sixth week (shot-put throw: $d_{DL} = 0.30$), 12 week [shot-put throw: $d_{DL} = 0.49$, $d_{CL} = 0.18$;

throw MB kneeling: $d_{DL} = 0.41$; throw MB standing: $d_{DL} = 0.89$; vertical and horizontal tests: $d_{DL} = (0.55–1.39)$; sprint tests: $d_{DL} = (0.57–0.71)$] and after retention period (14th week) (shot put, $d_{DL} = 0.28$; standing MB throw: $d_{DL} = 0.48$) of learning program. Also, there was a significant improvement for 5JT ($p = 0.026$; $d = 1.29$) performances in the DL group compared to CL group 12 week after learning program. However, no significant group*time interaction was observed for the feeling scale.

Conclusions: Overall, the data suggests that 12-weeks of DL program was more effective and more sustainable than CL in improving technical and physical performance related to shot-put discipline.

KEYWORDS

physical education, motor learning models, upper body power, lower body explosive power, velocity, feeling scale

1 Introduction

In the field of physical education, the pedagogical strategy of teaching motor skills has received considerable attention from theorists and educators, to try and identify strategies to combat the rising increase in reduced motor performance skills and lack of engagement in physical activity (Sortwell et al., 2022). Investigating innovative pedagogical strategies that support educational game teaching and develop a deeper understanding of motor learning processes from a non-linear pedagogical framework can provide a more coherent rationale for implementing instructional progressions (Chow et al., 2006).

Theoretically, the classical forms of learning tend to be founded on the vision of the linear causality, which is highly repetitive and is marked by the evolution of the simple models of movement to the complex (Schollhorn et al., 2012).

The motivation to exercise physical activity is also an important element of physical literacy and facilitated by vibrant mental processes (Steers and Sánchez-Runde, 2017). To be able to give a clear scientific assessment, however, it is necessary that research should correctly define the dependent variables through the separation of motor skill results and the psychological indicators. Motivation, in this case, means the quality of motivation, which extends between autonomous and controlled motivation, which is conceptualized as Self-Determination Theory (White et al., 2021). DL can potentially offer a more supportive learning climate with regard to autonomy and supportively affective experiences than conventional approaches by encouraging exploration and self-organization (Shamshiri et al., 2025; Komar et al., 2022).

Our study is therefore an attempt to compare the same in the shot put as a method of differentiating between the physical performance and psychological quality of the performance through Differential Learning and Classic Learning. According to earlier results implying that DL enhances physical performance (Schöllhorn et al., 2010; Rivera et al., 2024; Tassignon et al., 2021), we postulate that a 12-week intervention program will result in enormous progress of not only physical performance of shot put but the quality of autonomous motivation and affective valence among students, in comparison with conventional linear learning.

2 Materials and methods

2.1 Participants

A priori power analysis was computed using G*Power (Version 3.1.9.2, University of Kiel, Kiel, Germany). The sample size calculation was based on a statistical power of 0.95, alpha error < 0.05. The analysis indicated that a total of 120 students were needed to achieve 95% power.

The sample size was thus deemed quite adequate with 120 participants represented in this research and therefore the statistical analysis can be conducted without doubt based on the underlying data distribution.

Only 114 sport science students (64 males; 50 females; age: 21.34 ± 1.21 years; height: 1.72 ± 0.09 m; body mass: 67.43 ± 13.15 kg; BMI: 22.70 ± 3.86 kg.m-1) completed all stages of the experimental protocol (Figure 1).

The students had different specialties and different sports experiences (4 ± 2 years). They practiced various physical activities in their education such as team sports, combat sports, athletics, gymnastics, etc, with an average of 16 h/week exercising, including two learning sessions in the shot put (2 h/week). For the female students, the testing sessions were carried out in the same phase of the menstrual cycle (early follicular phase; late follicular phase; mid-term of the luteal phase) for each participant to control the menstrual cycle effect using the calendar calculation method (Elorduy-Terrado et al., 2025).

Exclusion criteria for the study included any student with athletic shot-put experience. All students were informed about the purpose of our study without knowing any information about the learning modalities used. Also, no participant student had suffered any neuromuscular or musculoskeletal disease in the 6 months before the start of the study. Students were instructed to avoid all pharmaceuticals or ergogenic products prior to and during the study period. All students participated in a familiarization session prior to the study. The research was conducted in accordance to the Ethical Committee of the High Institute of Sport and Physical Education of Kef, University of Jendouba.

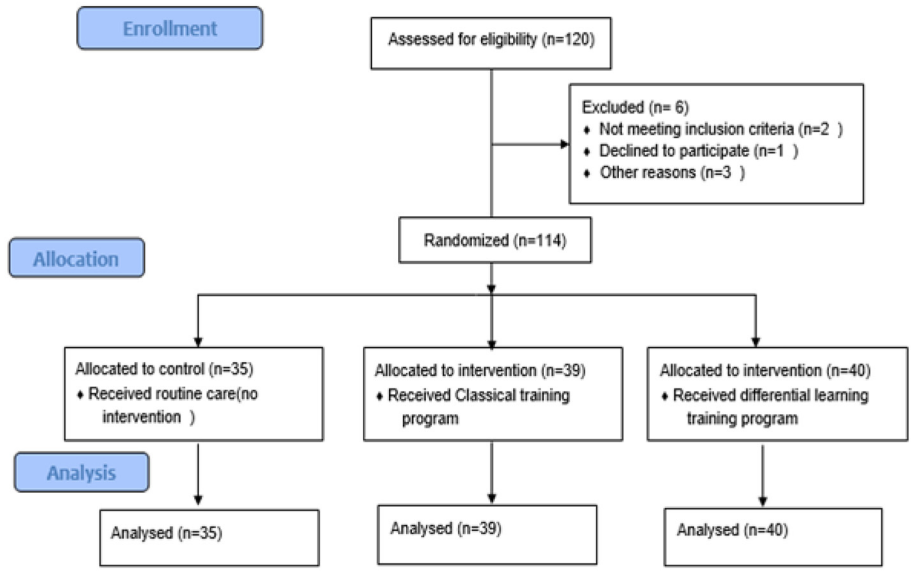

FIGURE 1
Consolidated standards of reporting trials (CONSORT) flow chart for trial recruitment.

2.2 Experimental design

After completing the predictive test session, an independent investigator was asked to randomize three homogenic groups according to their physical performance. The investigator divided the population into a control group ($n = 40$), classical learning group ($n = 40$), and differential learning group ($n = 40$). Of the 120 students, only 114 completed our experimental protocol (control group: $n = 35$; classical learning group, $n = 39$; differential learning group, $n = 40$) during 14 weeks.

The evaluation covered four evaluation period for students in the 1st, 6th, 12th, and 14th weeks. In fact, the measurements were administered before learning (T1: predictive test), during the sixth week (T2: formative test), after 12 weeks of learning (T3: summative test) and 2 weeks after stopping the program (T4:) (Figure 2: study design). The students were verbally encouraged to perform at their maximum effort during testing. To allow statistically reliable comparisons between different types of programs, the T1 confirms that the different groups are homogeneous.

Each learning session lasts 2 hours. Learning sessions were conducted in the evening from 3:00 p.m. to 5:00 p.m. on Wednesday and Friday.

Our study took place in ambient temperatures (October 21, 2021, and January 8, 2022) ranging from 16 to 22 °C and humidity from 40 to 55% with a wind speed <2 m/s. The same investigators conducted all measurements before, during and after learning program.

During the evaluation sessions, the students performed specific physical tests in the shotput that meet the physical and physiological requirements of the discipline: flexibility test, squat jump, countermovement jump, 10-m sprint, 30-m sprint, medicine ball throw (stand-up), medicine ball throw (kneeling) and shot-put test. The evaluation tests were divided into two sessions with a 48-h interval: session 1: SJ, CMJ, 5JT, MB kneeling, flexibility; session 2: sprint 10-m, sprint30-, MB standing, shot put test.

During testing sessions, all students were asked to follow their normal diet. Moreover, students were asked to wear the same sports clothes that they usually wear during physical education sessions. The same investigators conducted all measurements before, during and after a learning program.

2.3 Differential learning

Considering previous studies on differential learning programs in shot put (Beckmann and Schöllhorn, 2006; Hossner et al., 2016), we implemented a 12-week learning program. Differential learning, a non-linear learning approach, consists of offering extreme variations of a movement, which constantly induces new stimulation. The goal of differential learning is to increase the spectrum of motor patterns (Schollhorn et al., 2006). In the present study, students performed 250 exercises during 12 differential learning sessions with a single repetition while following the internal logic of shot-put learning (IAAF). These exercises were carried out using varying angles, amplitudes, speeds, rhythm, forces engaged, starting positions, support holds gesture orientations, angles, available equipment, etc. No instructions were given to the students on how to perform the exercises. Also, no verbal feedback was necessary. The goal was to enlarge the repertory of the motor models.

2.4 Classical learning

The classical learning approach is characterized by many repetitions where the exercises are built in series, progressing from easy to difficult and from simple to complex (Bozkurt and Yeşilçimen, 2023). In fact, during 12 learning sessions, students performed 18 exercises with a total of 250 repetitions, similar to the

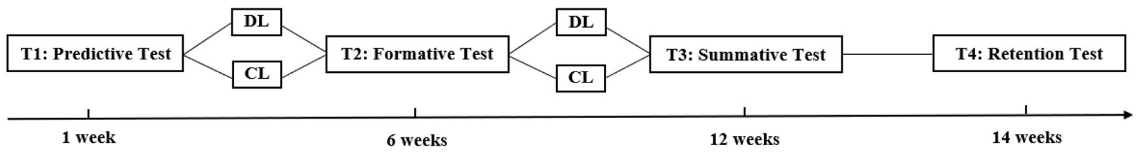

FIGURE 2
Study design. DL, Differential Learning; CL, Classical Learning.

number of repetitions performed in the DL program. Verbal and non-verbal feedback is also necessary during execution (Rodriguez-Lera et al., 2018). The aim was to develop shot-put skills using motor density and feedback quality.

2.5 Fitness assessments

We used physical tests that assess the different specific physical qualities (i.e., strength, speed, flexibility, coordination) in shot put (IAAF).

2.5.1 Shot-put test

The shot-put test was performed with a lateral swing in accordance with the official guide of physical education in Tunisia. The lateral swing test is done with a sideways start with a swing according to the rhythm "Tam-Ta-Tam," namely, left-right-left for a right-handed person. The right foot passes in front of the left foot (a backward step), and the left foot provides the blocking in front of the line (throw high and far) (IAAF). Three trials were performed, with a rest recovery of 03 min between trials. The best distance throw was selected. The put mass was 3 kg and 5 kg for female and male students, respectively.

2.5.2 MB throw test

In standing and kneeling positions of throw, the student had to grasp the medicine ball with the preferred hand and forcefully push the ball from the neck (Negrete et al., 2010). The score was calculated by measuring the distance from the front of the departing line to where the ball landed. For each test position, two trials were performed, with a rest recovery of 1 min between trials. The throw distance was measured for each test position at 0.01 m. MB mass was 3 kg and 5 kg for female and male students, respectively. Pilot data from 114 students collected on two different days were used to confirm the reliability of the test (ICC = 0.899).

2.5.3 Vertical jump tests (SJ, CMJ)

For the squat jump, students performed a vertical jump, starting from a "squat" position (90° knee bend angle). They were instructed to jump as high as possible with both hands around the waist throughout the test and to keep the chest upright. In addition, students were instructed to keep their knees straight during the landing phase (Markovic et al., 2004). For the countermovement jump test, students performed a vertical jump, from a standing position, with an eccentric downward and concentric upward action. They were instructed to jump as high as possible with both hands around the waist throughout the test and to keep the chest upright. In addition, students were instructed to keep their knees straight during the landing phase (Markovic et al., 2004). Jumping performance was evaluated with an infrared jumping system (Optojump Next instrument, Version 1.3.20.0, Microgate, Bolzano, Italy) interfaced with a microcomputer. The jump height (cm) was calculated for both tests. Pilot data from 114 students collected on two different days were used to confirm the reliability of the CMJ test (ICC = 0.891) and SJ test (ICC = 0.876).

2.5.4 Five jump test

This test was performed on the track with appropriate soccer boots. The 5JT consists of 5 consecutive strides with joined feet position at the start and end of the jumps (Chamari et al., 2008). From the starting joined feet position, the participant was not allowed to perform any back step with any foot; rather, he had to jump directly to the front with a leg of his choice. After the first four strides, i.e., alternating left and right feet for two times each, he had to perform the last stride and end the test again with joined feet. If the participant fell back on completing the last stride, the test was performed again). 5JT performance was measured with a tape measure from the front edge of the participant's feet at the starting position to the rear edge of the feet at the final position. The person assessing the landing had to focus on the last stride of the participant to determine the last footprint on the track, as the participant could not always stay on their feet on landing. The starting position was set on a fixed point. Pilot data from 114 students collected on two different days were used to confirm the reliability of the test (ICC = 0.911).

2.5.5 Flexibility test

This test evaluates the extensibility of the hamstring muscles and lower back flexibility (Bozic et al., 2010) by sitting on the floor with your legs straight ahead for this test. Flat feet are positioned against the box. The investigator lays flat on the ground with both knees. A graduated ruler with a range of −25 to +25 is held on the box, and the student gently leans forward as far as they can while holding the greatest stretch for 2 s. The score is determined by the distance (cm). Pilot data from 114 students collected on two different days were used to determine the reproducibility of the test (ICC = 0.795).

2.5.6 Sprint tests

Acceleration and maximum running speed were assessed using a 10-m and 30-m linear sprint test, with a standing start. The sprint test involved running as quickly as possible from a standing starting position, just behind the first pair of photocells. The starting position was the same for each student. Students were positioned 20 cm behind the start line and instructed to run as fast as possible. Performance time was automatically recorded using photocells (Brower timing systems, Salt Lake City, Utah, USA, with an accuracy of 0.01 s) placed 0.5-m above the ground. Students performed two trials with at least 3 min of rest between trials. Pilot data from 114 students collected on two different days were used to confirm the reliability of the test (ICC = 0.923).

2.6 Feeling scale

Affective valence during learning was assessed using the 11-point Feeling Scale, originally developed by Hardy and Rejeski (1989), which captures the pleasure–displeasure dimension of core affect. At each assessment time period (T1–T4), students rated how they felt during the learning period on a bipolar scale ranging from −5 (very bad) to +5 (very good). This measure was treated as an indicator of immediate affective experience during practice, a construct that has been shown to be relevant for understanding engagement and motivational processes in physical education contexts (Zhang, 2025). Pilot data from 114 students collected on two different days were used to confirm the reliability of the test (ICC = 0.907).

2.7 Statistical analyses

Standard deviations and means were used to express the data (SD). Statistical assumptions were verified through Shapiro–Wilk normality tests and Mauchly's sphericity assessments, with Greenhouse–Geisser corrections applied when sphericity was violated ($\varepsilon < 0.75$). Test–retest reliability for all variables was evaluated using Cronbach's intraclass correlation coefficient (ICC). A two-way analysis of variance (ANOVA) was used to evaluate anthropometric measurements, fitness tests, and the Dass-21 (3 groups x 4 times). Partial eta squared (η_p^2) effect size value was taken from ANOVA output and was classified as 0.01 = small, 0.09 = medium, 0.25 = large. Cohen's d (d) was calculated to quantify meaningful differences in the data with demarcations of trivial (<0.2), small (0.2–0.59), medium (0.60–1.19), large (1.2–1.99), and very large (≥ 2.0) (Cohen, 2013). A Bonferroni post-hoc test was performed if group-by-time interactions were found to be significant. Statistical significance was accepted, a priori, at $p \leq 0.05$. Data were analyzed using the SPSS 22 package (SPSS Inc., Chicago. IL).

3 Results

Tables 1, 2 showed the test results before and after 6 weeks of physical education. No discernible baseline difference between the groups was found for any analyzed parameters.

3.1 Throw performance

A significant main effect of time (shot-put test, standing: $p < 0.001$; $\eta_p^2 = 0.207$; MB throw: $p < 0.001$; $\eta_p^2 = 0.522$; kneeling MB throw: $p < 0.001$; $\eta_p^2 = 0.437$) and main effect of group (MB throw: $p < 0.001$; $\eta_p^2 = 0.122$; kneeling MB throw: $p < 0.001$; $\eta_p^2 = 0.073$) were observed for shot-put test, standing MB throw and kneeling MB throw performances (shot-put test, standing: $p < 0.001$; $\eta_p^2 = 0.207$; MB throw: $p < 0.001$; $\eta_p^2 = 0.522$; kneeling MB throw: $p < 0.001$; $\eta_p^2 = 0.437$). A significant group × time interaction was also found for the shot-put test, standing MB throw, and kneeling MB throw performances (shot-put test, standing: $p < 0.001$; $\eta_p^2 = 0.207$; MB throw: $p < 0.001$; $\eta_p^2 = 0.522$; kneeling MB throw: $p < 0.001$; $\eta_p^2 = 0.437$). *Post-hoc* tests revealed significant improvements in physical performance in the differential learning group during the T2 shot-put, $p < 0.001$, $d = 0.30$), T3 (shot-put, $p < 0.001$, $d = 0.49$; kneeling MB throw: $p = 0.041$, $d = 0.41$; standing MB throw: $p = 0.042$, $d = 0.89$, 18.95%) and T4 (shot-put, $p < 0.001$, $d = 0.28$; standing MB throw: = 0.041, d = 0.48), compared to the control group. Also, posthoc tests revealed significant improvements in shot-put performance with the classic learning group were observed during T3 ($p < 0.001$, $d = 0.18$) and T4 ($p < 0.001$, $\eta_p^2 = 0.06$) compared to the control group. In addition, post hoc tests revealed the higher shotput performance and standing MB throw, during T3, with a differential learning group compared to the classic learning group (shot-put: $p < 0.001$, $d = 0.34$; standing MB throw: $p = 0.01$, $d = 0.78$).

3.2 Sprint tests

A significant main effect of time (sprint 10 m: $p = 0.030$; $\eta_p^2 = 0.262$; sprint 30 m: $p < 0.001$; $\eta_p^2 = 0.194$) and the main effect of group (sprint 10 m: $p < 0.030$; $\eta_p^2 = 0.061$) were observed for SJ, CMJ sprint 10 m and sprint 30 m. A significant group × time interaction was also found for sprint 10 m ($p < 0.001$; $\eta_p^2 = 0.262$) and sprint 30 m ($p < 0.001$; $\eta_p^2 = 0.194$). Post-hoc tests revealed significant ($p < 0.001$) improvements for sprint 10 m and sprint 30 m performances in the differential learning group compared to the control group during T3 (sprint 10 m: $p = 0.019$, $d = 0.71$; sprint 30 m: $p = 0.042$, $d = 0.57$). However, no significant change was observed between the differential and classic learning groups during all testing times.

3.3 Jump tests

A significant main effect of time was observed for SJ (p < 0.001; $\eta_p^2 = 0.207$), CMJ (p < 0.001; $\eta_p^2 = 0.522$) and 5JT ($p < 0.001$; $\eta_p^2 = 0.685$) tests. Also, a significant group × time interaction was

TABLE 1 Effect of different learning models on throwing performances.

Variable	Time	Control (mean ± SD)	Classical learning (mean ± SD)	Differential learning (mean ± SD)	Time effect p (η_p^2)	Group effect p (η_p^2)	Time * group interaction p (η_p^2)
Shot-put test	T1	7.49 ± 1.70	7.06 ± 1.48	7.66 ± 1.61	p < 0.001 (0.207)	0.557 (0.019)	p < 0.001 (0.182)
	T2	7.65 ± 1.72	7.60 ± 1.54‡	8.16 ± 1.65*			
	T3	7.44 ± 1.72	7.73 ± 1.53‡	8.26 ± 1.63*♀			
	T4	7.37 ± 1.52	7.46 ± 1.68	7.78 ± 1.66*♀			
Standing MB throw	T1	4.19 ± 2.89	3.84 ± 2.70	5.65 ± 1.15	p < 0.001 (0.522)	0.001** (0.122)	p < 0.001 (0.267)
	T2	5.44 ± 1.16	5.70 ± 1.34	6.17 ± 1.12			
	T3	5.33 ± 1.08	5.36 ± 1.33	6.34 ± 1.19*♀			
	T4	5.37 ± 1.10	5.27 ± 1.20	5.90 ± 1.09*			
Kneeling MB throw	T1	3.93 ± 2.24	3.01 ± 2.22	4.65 ± 0.86	p < 0.001 (0.437)	0.015* (0.073)	p < 0.001 (0.207)
	T2	5.05 ± 1.1	4.81 ± 1.14	5.09 ± 0.84			
	T3	4.77 ± 1	4.61 ± 1.04	5.16 ± 0.88*			
	T4	4.58 ± 1.02	4.82 ± 1.05	4.8 ± 0.81			

*Significant difference between differential learning and control.
♀Significant difference between differential learning and classical learning.
‡Significant difference between classical learning and control.
T1, predictive test; T2, formative test; T3, summative test; T4, retention test.

also identified for SJ ($p < 0.001$; $\eta_p^2 = 0.349$), CMJ ($p < 0.001$; $\eta p^2 = 0.073$) and 5JT ($p = 0.002$; $\eta_p^2 = 0.389$) tests. However, no significant main effect of group was observed for all jump tests ($p = 0.179$–0.804; $\eta_p^2 = 0.009$–0.03). Post-hoc tests revealed significant improvements for SJ ($p = 0.05$; $d = 0.57$), CMJ ($p = 0.05$; $d = 0.55$) and 5JT ($p = 0.011$; $d = 1.39$) performances in the differential learning group compared to the control group only during T3. Also, there was a significant improvement for 5JT ($p = 0.026$; $d = 1.29$) performances in the DL group compared to CL group during T3.

3.4 Feeling scale

A significant main effect of time ($p = 0.047$; $\eta_p^2 = 0.38$) and the main effect of group ($p = 0.013$; $\eta_p^2 = 0.38$) were observed for the feeling scale. However, no significant group* time interaction was observed ($p = 0.305$; $\eta_p^2 = 0.18$) (Figure 3).

4 Discussion

This study aimed to evaluate the effectiveness of differential learning (DL) compared to classical learning (CL) in improving physical attributes related to shot put performance in a physical education context. As predicted, students exposed to DL demonstrated superior improvements in shot put performance and medicine ball throw, as well as in speed, jumping ability, and coordination. These gains were evident both at the post-intervention assessment (T3) and after a 2-week retention period (T4), supporting the robustness of the learning effects. In contrast, no significant differences were observed between groups for flexibility, suggesting that the benefits of DL may be more pronounced for explosive and coordinative capacities directly related to shot put performance.

To our knowledge, this is one of the few studies to investigate the impact of DL on shot put–specific skills in a physical education setting. Although the present study focused on university students, previous research suggests that the benefits of DL extend to athletes with different learning volumes and experience levels (Schollhorn et al., 2006). One possible explanation for this advantage lies in the high degree of practice variability inherent in DL, reflected in the large number of task variations implemented within each session. Such variability may promote broader information acquisition and more adaptable motor solutions, thereby supporting improvements in key biomechanical determinants of shot-put performance, such as release speed, launch angle, and release height (Zhang and Alahmadi, 2022).

The effectiveness of DL observed in the present study is consistent with foundational principles of practice variability and non-linear learning (Gaulhofer and Streicher, 1924; Henz and Schöllhorn, 2016). By reducing prescriptive instruction and encouraging exploration, DL allows learners to self-organize their movement patterns in response to task constraints. This process may enhance the adaptability and stability of motor patterns, which is particularly relevant for complex, explosive skills such as shot put, jump and sprint as reported by previous studies (Rivera et al., 2024; Tassignon et al., 2021; Schöllhorn et al., 2010). Although one study reported no significant differences in shot put distance between students using CL and DL approaches (Kok et al., 2020), methodological differences such as intervention duration, task design, and participant characteristics may account for these discrepancies.

TABLE 2 Effect of different learning models on physical performance.

Variable	Time	Control (mean ± SD)	Classical learning (mean ± SD)	Differential learning (mean ± SD)	Time effect p (η_p^2)	Group effect p (η_p^2)	Time * group interaction p (η_p^2)
SJ	T1	26.96 ± 6.23	28.14 ± 6.15	28.18 ± 6.15	$p < 0.001$ (0.349)	0.405 (0.030)	$p < 0.001$ (0.609)
	T2	26.99 ± 6.21	28.37 ± 6.49	28.42 ± 6.49			
	T3	24.99 ± 6.21	28.24 ± 6.49	28.67 ± 6.49			
	T4	25.09 ± 6.21	27.91 ± 6.49	28.62 ± 6.49			
CMJ	T1	28.52 ± 6.80	28.89 ± 6.90	28.95 ± 6.90	$p < 0.001$ (0.73)	0.771 (0.009)	$p < 0.001$ (0.571)
	T2	28.6 ± 6.80	29 ± 6.90	29.59 ± 6.75			
	T3	28.55 ± 6.80	29.70 ± 6.90	32.24 ± 6.75			
	T4	28.62 ± 6.80	29.62 ± 6.90	29.67 ± 6.75			
Flexibility	T1	0.71 ± 2.21	0.33 ± 1.21	1 ± 2.27	$p < 0.001$ (0.754)	0.804 (0.024)	0.790 (0.084)
	T2	1.43 ± 1.13	1.67 ± 1.21	2 ± 2.27			
	T3	0.71 ± 1.60	0.33 ± 1.37	0.88 ± 2.23			
	T4	1.14 ± 1.07	1.17 ± 0.98	1.75 ± 1.75			
Sprint 30 m	T1	5.05 ± 0.70	4.87 ± 0.41	4.71 ± 2.38	$p < 0.001$ (0.194)	0.058 (0.050)	$p < 0.001$ (0.198)
	T2	5 ± 0.65	4.82 ± 0.39	5.04 ± 0.58			
	T3	4.78 ± 0.39	5.01 ± 0.67	5.07 ± 0.6*			
	T4	5.13 ± 0.68	4.83 ± 0.41	5.07 ± 0.59			
Sprint 10 m	T1	2.08 ± 0.45	2.08 ± 0.17	2.08 ± 1.03	$p < 0.001$ (0.262)	0.030* (0.061)	$p < 0.001$ (0.159)
	T2	2.09 ± 0.24	2.04 ± 0.17	2.09 ± 0.22			
	T3	2.01 ± 0.16	2.12 ± 0.22	2.15 ± 0.23*			
	T4	2.05 ± 0.16	2.12 ± 0.22‡	2.16 ± 0.23			
5JT	T1	7.14 ± 0.73	7.10 ± 0.82	7.11 ± 0.78	$p < 0.001$ (0.272)	0.179 (0.021)	$p < 0.001$ (0.368)
	T2	7.16 ± 0.79	7.23 ± 0.77	7.46 ± 0.75			
	T3	7.11 ± 0.84	7.26 ± 0.76	8.16 ± 0.63*♀			
	T4	7.13 ± 0.78	7.23 ± 0.73	7.98 ± 0.69			

*Significant difference between differential learning and control.
♀Significant difference between classical learning and control.
‡Significant difference between classical learning and control.
SJ, Squat Jump; CMJ, Countermovement Jump; 5JT, Five Jump Test; T1, predictive test; T2, formative test; T3, summative test; T4, retention test.

Importantly, the present findings indicate that the advantages associated with DL were maintained after a 2-week retention period, reinforcing the interpretation that the observed improvements reflect genuine learning rather than temporary performance effects. Previous work has shown that DL can produce benefits that persist several weeks after the intervention (Schollhorn et al., 2006). In addition, evidence from a juggling task suggests that practice variability might be associated with neural adaptations related to motor learning (Scholz et al., 2009). While the present study did not include neurophysiological measures to verify these underlying processes, such theoretical frameworks offer a speculative basis for understanding the durability of the learning effects observed here.

Beyond motor performance outcomes, the present results tentatively highlight the psychological relevance of DL. Notably, students in the DL group reported more positive affective valence, as measured by the feeling scale, compared to their peers in the CL and control groups. Nevertheless, since the group × time interaction is not significant with regard to this variable, these findings in terms of affective states should be viewed with reservations. Although affective valence during practice is a proximal measure of engagement, the insinuation of the more influential psychological effect is indicative.

The diversity of motor tasks and practice conditions associated with DL may contribute to this effect by creating a more stimulating and challenging learning environment (Afonso et al., 2025; Teixeira et al., 2025). According to the challenge point framework, appropriately increased task challenge can enhance learning and motivation when matched to learners' skill levels (Guadagnoli and Lee, 2004). In addition, recent motivational and attentional accounts of motor learning emphasize that conditions supporting autonomy and positive expectations can facilitate both performance and learning (Wulf and Lewthwaite, 2016). In this sense, the combination of practice variability and reduced prescriptive control characteristic of DL may help provide a preliminary explanation for the co-occurrence of improved performance outcomes and more positive affective experiences observed in the present study.

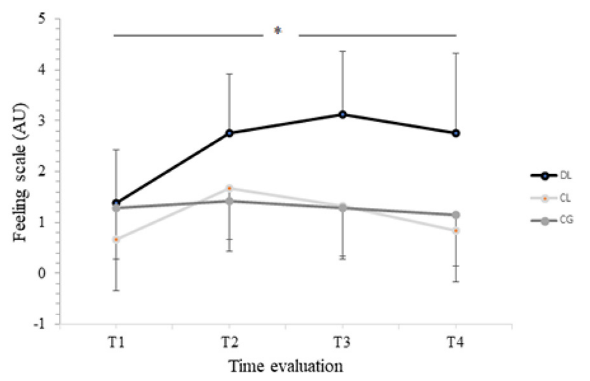

FIGURE 3
The effect of 12 weeks of differential learning vs. classic learning on feeling scale. Data are presented by mean values (±SD); *significant group effect; T1, predictive test; T2, formative test; T3, summative test; T4, retention test.

Taken together, these findings suggest that DL represents a pedagogical approach capable of addressing both the physical and potentially psychological dimensions of learning in physical education. By integrating practice variability with conditions that may enhance engagement and affective experience, DL appears to offer a viable alternative to more traditional, prescriptive instructional models. Future research should extend these findings by examining the effects of differential learning across different age groups and educational stages, including secondary school students, and by incorporating more comprehensive psychological measures, such as motivation quality, perceived autonomy, and perceived competence. Longitudinal and multi-method designs may further clarify the mechanisms through which differential learning influences the interaction between technical, physical, and psychological components of performance in physical education contexts. It is important to note that this study presents some limitations that should be acknowledged. First, the sample consisted exclusively of physically active university students without prior shot-put experience, which limits the generalisability of the findings to other populations such as adolescents, elite athletes, or individuals with different learning backgrounds. Second, no biomechanical or neurophysiological measurements were included, which prevents any definitive conclusions regarding the underlying biological mechanisms. Third, the lack of a significant group × time interaction regarding affective measures suggests that the psychological benefits of DL require further empirical validation using more comprehensive constructs (e.g., perceived autonomy, competence, or motivation quality) were not evaluated. These limitations should be considered when interpreting the results and addressed in future research.

5 Conclusions

As indicated in this study, a DL methodology applied over a 12-week physical education programme tended to be better than a CL in enhancing technical performance and physical performance results pertaining to shot put. The participants who were exposed to DL exhibited better gains in throwing performance, explosive strength, speed and coordination, and some of the gains were retained even after a 2-week retention period. Although these gains were statistically significant, it is important to mention that the magnitude of effects was moderate and large, based on the measure of physical attribute.

Combined, the current results indicate the inclusion of DL as an educational tool that can deal with the motor aspect of the learning process, and potentially provide an advantage to the psychological aspect of it. The results must however be cautiously generalized to other age groups or levels of skills due to the nature of our sample. To physical education teachers, especially at the undergraduate level, DL is one of the possible options to the conventional teaching methods, providing them a framework that could result in the improvement of the performance development and possibly a positive experience in the learning process. The research should be furthered to establish such psychological tendencies and to identify the long-term effects of such pedagogical changes.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethical Committee of the High Institute of Sport and Physical Education of Kef, University of Jendouba. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

HF: Writing – original draft. NJ: Writing – original draft. SH: Writing – original draft. IS: Writing – original draft. DB: Writing – original draft. NO: Writing – original draft. PF: Writing – review & editing. AS: Writing – review & editing. RF: Writing – review & editing. LB: Writing – review & editing. JT: Writing – review & editing. PA: Writing – review & editing. JR: Writing – review & editing. AM: Writing – review & editing. AR: Writing – review & editing. RG-P: Writing – review & editing. AB: Writing – original draft.

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Conflict of interest

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The authors PF, JT, LB, AR, SH, AS, JR, RG-P, AB, and NO declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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