International Journal for Housing Science and Its Applications

Publish September 16, 2025. Volume 47, Issue 1 Pages 1018–1028

https://doi.org/10.70517/ijhsa47188

A Biomechanics-Driven Smart Teaching System for Precision Sports Dance Education

Pengjie Zhang[1], Hui Ma[1], Shaobin Zhang[1] and Yan Wang[1,*]

[1] Hebei Agricultural University, Baoding, Hebei, 071051, China

Corresponding authors: (e-mail: Runner1971@163.com).

Abstract With the increasing demand for precision and personalization in physical education, biomechanics has emerged as a pivotal discipline in enhancing the quality of sports dance instruction. This study investigates the integration of biomechanical analysis and intelligent mobile terminals into sports dance pedagogy. It first proposes a system architecture that leverages wearable devices and multimedia teaching terminals to enable real-time feedback, kinematic analysis, and personalized instructional support. Based on national curriculum standards and pedagogical theory, a hierarchical indicator system comprising 3 primary, 10 secondary, and 32 tertiary teaching strategy indicators was constructed and validated using expert consultation and Kendall's concordance test ($W > 0.75$). A weighting system was then applied to rank the importance of each indicator. A case study involving 25 physical dance instructors across six universities was conducted to evaluate current teaching practices and assess the applicability of the proposed strategy framework. Results indicate that most instructors rely heavily on traditional methods such as demonstration and verbal instruction, with limited use of multimedia or theoretical integration.

Index Terms biomechanics, sports dance, wearable devices, intelligent mobile terminals, motion analysis

I. Introduction

In recent years, the field of sports education has witnessed a profound shift toward data-driven and precision-based instruction, with biomechanics emerging as a cornerstone of this transformation. Biomechanics, which systematically studies human motion through the lens of mechanical principles, provides a scientific basis for analyzing movement patterns, optimizing performance, and minimizing injury risk [1], [2]. This capability is particularly significant in disciplines like sports dance, where athletes must precisely coordinate posture, rhythm, balance, and muscle force distribution. Unlike traditional sports, sports dance straddles the boundary between athletic performance and artistic expression, placing exceptional demands on both aesthetic accuracy and technical precision [3].

Traditionally, sports dance education has largely relied on visual demonstration and teacher-student imitation, wherein instructors perform movements for students to mimic. While such methods may foster intuitive understanding, they inherently lack objectivity, repeatability, and real-time corrective mechanisms. Teachers must rely heavily on personal experience and observation, which may lead to inconsistencies in instruction [4], [5]. Furthermore, students often struggle to internalize the biomechanical principles underlying complex movements due to the absence of immediate and quantifiable feedback [6]. These challenges hinder not only the efficiency of technical acquisition but also the depth of understanding and individualization of instruction.

The growing availability of wearable sensors, intelligent mobile terminals, and motion capture technologies has opened new avenues for integrating biomechanics into physical education. These tools can collect real-time data on parameters such as joint angles, angular velocity, ground reaction force, and center of mass trajectory, transforming qualitative instruction into a measurable and adaptive process [7], [8]. When paired with intelligent teaching systems, such devices can facilitate interactive feedback, autonomous learning, and scientific evaluation of motor skills. For instance, smart mobile terminals can record student performances, analyze them via embedded algorithms, and provide targeted suggestions to enhance movement precision and safety [9], [10].

Despite the promise of these technologies, current biomechanical teaching systems often suffer from limited flexibility, poor integration across teaching stages, and insufficient support for dynamic classroom environments. Many platforms operate under laboratory conditions or require specialized technical personnel to manage data acquisition and analysis [11]. This lack of practicality impedes widespread classroom adoption. Moreover, few studies systematically evaluate the pedagogical impact of biomechanical tools in a real-world educational context, particularly in sports dance instruction where artistic and technical dimensions must be harmonized [12].

To address these limitations, this study proposes an integrated sports dance teaching system that combines biomechanics-based feedback with intelligent mobile terminal applications. The system comprises four key modules: a multimedia teaching resource library, a mobile terminal-based real-time feedback platform, motion data acquisition devices (e.g., cameras and wearable sensors), and a centralized resource management server. By leveraging these components, the system supports high-frequency feedback loops between teachers and students, enables visual correction of movement deviations, and fosters deeper engagement with biomechanical principles [13], [14]. Teachers can demonstrate, record, and playback student movements while providing in-the-moment guidance projected onto large classroom displays. Students, in turn, can access personalized feedback and participate in discussions before and after class.

This paper further establishes a scientifically grounded evaluation framework for teaching strategies by employing expert surveys, indicator construction, and consistency validation through Kendall's harmony coefficients. The comprehensive analysis revealed key weaknesses in current teaching approaches, such as over-reliance on teacher demonstration, underutilization of theoretical support, and limited student-centered practice strategies. In response, the proposed system introduces a structured, quantifiable, and adaptive instructional paradigm that promotes technical mastery, theoretical understanding, and injury prevention.

II. Methods

Through an investigation and analysis of the teaching processes in certain physical education courses and student classes, it was observed that the predominant approach to physical education dance instruction relies on teacher demonstrations. In this traditional format, students primarily observe the teacher's movements during class and subsequently attempt to imitate them under the teacher's guidance. The incorporation of modern educational technology is limited, typically involving teachers playing instructional videos during class. This method often requires additional teaching support personnel to operate equipment, increasing the complexity of class organization [15].

Students are generally limited to observing their movements in mirrors during practice. While this approach works for some sports movements, it proves ineffective for others where self-observation is impractical. Furthermore, using mirrors can divert students' attention, hampering their focus during practice. Interviews with instructors revealed additional challenges. Many teachers reported the inability to use blackboards during physical dance instruction and highlighted the difficulties of integrating theoretical teaching conducted in classrooms with the practical nature of dance courses.

The introduction of intelligent mobile terminals has significantly enhanced the compatibility of teaching processes and resources. These tools expand class content and foster improved communication between teachers and students, as well as among students, both before and after class. Such integration demonstrates potential for creating a more interactive and cohesive learning environment for physical education dance courses.

II. A. System structure design

The overall architecture design of the teaching system for the needs of teachers and students in the process of teaching physical dance is shown in Figure 1.

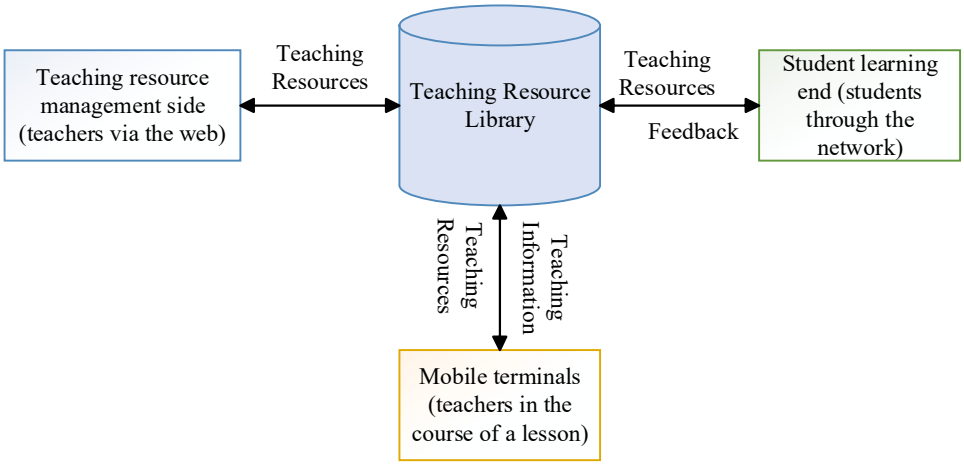

Figure 1: Overall architecture design

Teaching resource library: It is mainly used to store high-quality teaching resources used by teachers in the course of lesson preparation. Teachers can store their multimedia courseware and videos according to their lesson planning, and also provide

help for students to pre-study and review in class. In addition, a discussion forum is deployed in the learning resource server to facilitate student-student and student-teacher communication.

Teaching resource management terminal: It mainly provides teachers to upload and download multimedia information and teaching resources. Teachers can access through web pages without restricting their geographical location, and they can access through computers and wireless mobile terminals, while communicating with students and colleagues, fully reflecting the combination of teaching and learning.

Mobile terminal: mainly used for teachers in the process of class, teachers can access the teaching resources in the server through the mobile terminal in the process of class, if not in the wireless network coverage of the venue, teachers can also download the content of the class to the mobile terminal in advance, convenient for use in class. The teacher can also connect the mobile terminal to the multimedia projector in the course of the lesson to realize the same screen of the mobile terminal and the projection, which can easily combine the course and multimedia technology to realize the writing of the teacher's board in the process of teaching physical dance. Teachers can also take videos and photos of students' movements in the teaching process and play them on the big screen, and make timely corrections to students' technical movements, which can greatly improve the efficiency of the classroom and increase students' motivation in class. The teacher can also upload the files and videos of the class process to the server [16].

Student side: Mainly provides students with pre-study and review before and after class, as well as discussion of learning content in the discussion forum.

II. B. Intelligent mobile terminal application design

According to the analysis, the teaching system for mobile terminals within the need to carry out local area network environment to work, for this part of the structure design as shown in Figure 2.

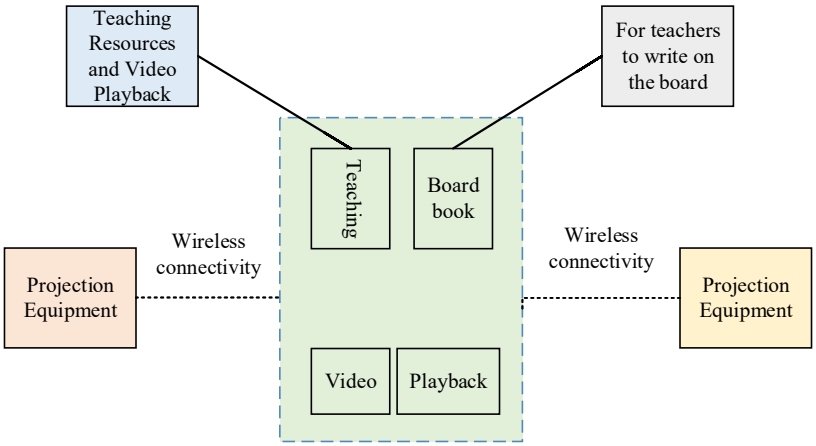

Figure 2: Intelligent mobile terminal application structure design

In addition to the basic functionality, the mobile terminal and projection system also enable dynamic interaction between the teacher and students. For example, the teacher can pause the video or image displays at key moments to provide real-time corrections or feedback on students' movements. This facilitates a more personalized learning experience and ensures that students receive immediate guidance on improving their posture, form, or technique.

Furthermore, the system supports the integration of motion analysis software, allowing for detailed biomechanical evaluations of students' movements. By analyzing parameters such as joint angles, speed, and alignment, the system can provide quantitative feedback on the quality of students' dance movements. This objective data enhances the teacher's ability to track students' progress over time and offer targeted recommendations for improvement [17].

The use of this technology also fosters greater student engagement. With the ability to view their own movements from different angles on the projection screens, students are more actively involved in the learning process, increasing their awareness of both strengths and areas for improvement. This approach not only makes learning more interactive but also promotes a deeper understanding of biomechanical principles, encouraging students to make informed adjustments to their movements.

Moreover, the system supports remote learning by allowing students to access recorded lessons and feedback outside of class hours through mobile devices, enhancing learning flexibility and reinforcing concepts taught in class. This combination of real-time feedback, motion analysis, and accessible learning resources helps create a more holistic and effective learning environment for dance students.

II. C. Interactive teaching in physical dance classroom

The interactive teaching mode of students learning physical education based on mobile intelligent terminal devices is shown in Figure 3.

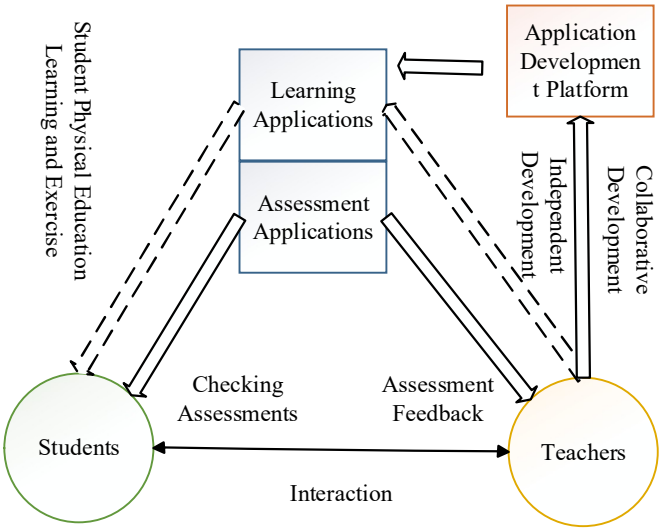

Figure 3: Interactive learning model of physical education based on mobile terminals

II. D. Construction of physical education dance teaching strategy indicators

After collating the literature and books related to physical education teaching strategies, the structure indexes of physical dance teaching strategies were initially constructed based on the National Curriculum Plan for Physical Education Undergraduate Programs in General Higher Education Schools and the Theory of Physical Education Teaching. After the indicator questionnaires were collected, the mean value of each item was calculated based on the score assigned to each indicator by the experts, and the results are shown in Table 1 and Table 2.

Table 1: Mean values of the first- and second-tier indicators in the first round of expert survey

Primary Indicators	Average value	Secondary Indicators	Average value
A Instructional preparation strategies	4.50	A1 Analysis of students' learning situation strategy	4.40
		A2 Selecting teaching content strategies	4.30
B Instructional implementation strategies	5	B1 Diversified introduction strategies	3.10
		B2 Presentation strategy	4.35
		B3 Explanation strategy	4.90
		B4 Practice strategy	4.50
		B5 Instruction strategy	4.15
		B6 Thinking guidance strategy	3.50
		B7 Cooperation and communication strategy	3.40
C Instructional evaluation strategy	4.40	C1 Differentiation of evaluation criteria strategy	4.20
		C2 Evaluation content comprehensiveness strategy	4.85
		C3 Diversification of evaluation subjects	3.75
		C4 Diversification of evaluation methods	3.85

Table 2: Mean values of indicators at three levels in the first round of expert survey

Tertiary indicators	Average value
A11 Technical skill level	4.80
A12 Theoretical knowledge base	4.50
A21 Sorting out the structure of physical education materials	4.35
A22Integrate the content of other subjects	4.15
A23 Orchestrating the overall knowledge framework	3.70
B11 Question-based introduction	4.85
B12 Project-based introduction	4.35
B13 Music-based introduction	4.65
B21Visualization with pictures	3.65
B22Processing with video	4.25
B23Detailed teacher demonstration	5
B24 Student presentation competition	4.15
B31 “Story” approach to introduction	3.95
B32Teaching of specialized terms	5
B33 Comprehensive knowledge support	4.45
B34Inspiring questions for guidance	4.55
B35 Motivational language encouragement	3.85
B41 Targeted practice content	4.85
B42 Flexible practice format	4.35
B43 Practice in a gradual manner	3.75
B44 Reasonable control of practice load	4.15
B51One-on-one guidance	4.55
B52 Group-based instruction	4.65
B53 Group instruction for error correction	3.75
B54 Theory prompting instruction	3.85
B61 Guiding students’ thinking on the integration of multidisciplinary knowledge	4.25
B62 Inspiring students to apply theoretical knowledge to solve technical problems	4.45
B63 Encourage students to think independently and try to innovate	4.30
B71 Discuss with each other in small groups	4.30
B72 Discuss with each other and the teacher	4.30
C11 Gender differences between men and women	4.30
C12 Differences in learning ability	4.75
C21 Degree of understanding of theoretical knowledge	4.30
C22 Degree of technical skill mastery	4.75
C31 Teacher evaluation	4.65
C32 Self-evaluation	4.35
C33 Intra-group mutual evaluation	4.15
C34 Inter-group evaluation	4.35
C41 Process evaluation	1.25
C42 Summative evaluation	4.25

Based on the results from the table above, the initial physical dance teaching strategy indicators were revised. Indicators with a mean value lower than 3.5 were eliminated. For example, the mean value of the B1 diversified introduction strategy index was 3.15, the B6 cooperative communication strategy index was 3.40, and the B7 thinking guidance strategy index was 3.30, so these three indicators were removed. Following expert recommendations, the secondary index B6 (cooperative communication strategy) was integrated into B4 (practice strategy), with the aim of achieving effective group practice through communication and collaboration. Similarly, the B7 thinking guidance strategy was merged into B3 (explanation strategy), as the objective of providing guidance can be accomplished more effectively through clear explanations[18].

In the second round of expert surveys, the same index screening method was applied as in the first round. Indicators that received objections were revised according to the feedback provided by the experts. After distributing the revised indicators to 20 experts, no significant changes were made, indicating that the experts recognized and approved the revised indicators,

meeting the study's criteria. To assess the consistency and objectivity of the experts' ratings, the Kendall's concordance coefficient formula was employed. The formula used for this test is as follows:

$$W = \frac{\sum Rl^2 - \frac{\left(\sum Rt\right)^2}{N}}{\frac{1}{12}K^2\left(N^3 - N\right) - K\sum\frac{3-n}{12}} \tag{1}$$

$$W = \sum_i^n \frac{\left(R_i - m\left(n+1\right)/2\right)^2}{\left(m^2\right) - n\left(n^2 - 1\right)/12\right)} \tag{2}$$

The results of the indicator consistency test are shown in Tables 3–5.

Table 3: Kendall's harmony coefficients of the first-level indicators

Primary Indicators	Kendall Harmony Coefficient
A-C	0.89

Table 4: Kendall's harmony coefficient for secondary indicators

Secondary indicators	Kendall Harmony Coefficient
A1-A2	0.78
B1-B4	0.85
C1-C4	0.87

Table 5: Kendall's harmony coefficient for the three levels of indicators

Tertiary indicators	Kendall Harmony Coefficient
A11-A12	0.78
A21-A23	0.85
B11-B14	0.87
B21-B25	0.85
B31-B34	0.79
B41-B44	0.67
C11-C12	0.88
C21-C22	0.78
C31-C34	0.84
C41-C42	0.75

The results of Kendall's harmony coefficient calculation show that the structure of 3 primary indicators, 10 secondary indicators and 32 tertiary indicators in the established physical dance teaching strategy is consistent.

In order to provide teachers with better teaching strategies for physical dance, the third round of expert survey ranked the indicators at all levels and calculated the weight values of each indicator according to the results of expert ratings, and the results are shown in Table 6.

Table 6: Indicator weighting values

Primary Indicators	Weighting value	Secondary indicators	Weighting value	Tertiary indicators	Weighting value
A		A1	0.502	A11	0.468
				A12	0.532
		A2	0.498	A21	0.368
				A22	0.307
				A23	0.321
B		B1	0.245	B11	0.202
				B12	0.252
				B13	0.304
				B14	0.245
		B2	0.278	B21	0.165
				B22	0.235
				B23	0.213
				B24	0.222
				B25	0.165
		B3	0.248	B31	0.312
				B32	0.238
				B33	0.265
				B34	0.187
		B4	0.225	B41	0.253
				B42	0.355
				B43	0.261
				B44	0.133
C		C1	0.262	C11	0.472
				C12	0.523
		C2	0.298	C21	0.412
				C22	0.586
		C3	0.232	C31	0.293
				C32	0.245
				C33	0.235
				C34	0.233
		C4	0.208	C41	0.512
				C42	0.488

III. Case study

In this study, 25 physical dance teachers who taught physical dance special classes in six colleges and universities in a Province were surveyed respectively, and the findings were as follows.

III. A. Results and analysis of teaching preparation strategies of physical dance

Teaching preparation strategy is the premise of teachers' teaching activities, including the strategy of analyzing students' learning situation and the strategy of selecting teaching contents [17].

The results of the statistical data in Table 7 and Figure 4 show that 48% of the teachers of physical dance always consider the students' technical level and 36% do not pay attention to the students' knowledge reserve at this stage. This shows that teachers are most concerned about the technical level of students in physical dance before class, and slightly less concerned about the knowledge students have mastered.

Table 7: Statistics of teachers' survey on students' learning analysis strategies (N = 25 unit: People)

Strategies	Always	Often	Sometimes	Rarely	Never
Consider students' knowledge base	3	3	4	6	9
Understand students' technical level	11	9	2	2	1

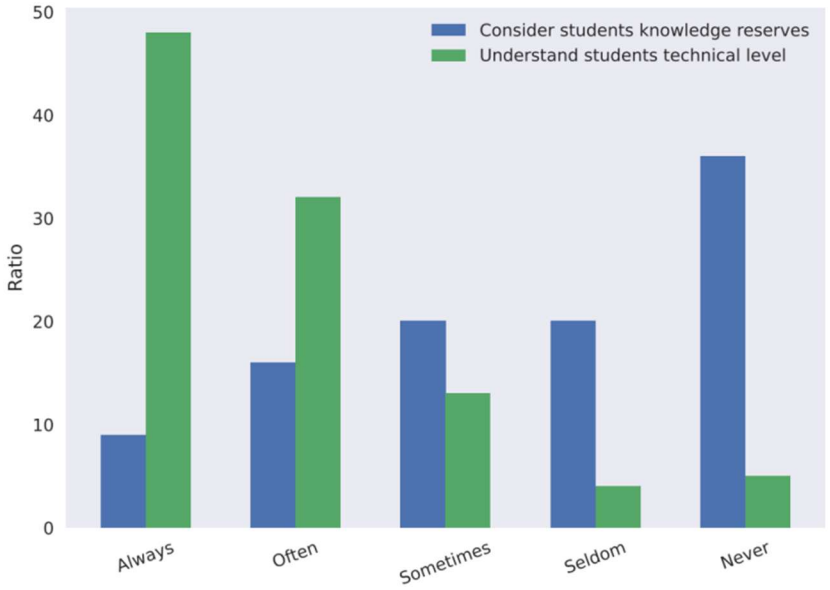

Figure 4: Statistics of the survey on teachers' strategies for analyzing students' learning (N = 25 units: People)

The results presented by the data in Table 8 and Figure 5 show that 76% of the physical education dance teachers' strategies for selecting teaching contents before class sort out the contents of physical education textbooks; 52% of the teachers do not pay attention to the contents integrated with the knowledge of other subjects; and 64% of the teachers do not rearrange the knowledge related to teaching contents. This shows that most physical dance teachers pay too much attention to the teaching content of physical dance itself when they select the teaching content before class, and less to the content of other subjects [18].

Table 8: Statistics of teachers' survey on the strategies of selected teaching contents (N = 25 unit: Person)

Strategies	Always	Often	Sometimes	Rarely	Never
Sorting out the content of physical education materials	18	5	2	0	0
Integrating knowledge from other subjects	1	2	5	6	11
Reorganize the knowledge framework	1	2	1	6	15

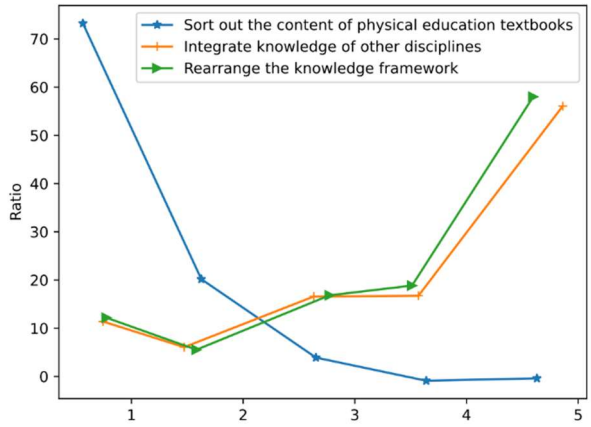

Figure 5: Statistics of teachers' survey on the strategies of selected teaching contents (N = 25 unit: Person)

III. B. Results and analysis of strategies implemented in physical education dance

The strategies implemented in class reflect the teachers' teaching ability and effectiveness, and are the main manifestation of teachers' teaching level and the key link of students' learning. The strategies implemented in class include: Presentation strategies, explanation strategies, practice strategies, and instruction strategies.

According to the results shown in Table 9 and Figure 6, 60% of physical dance teachers frequently use teacher demonstrations to illustrate the details of movements to students, while 40% rarely use visual aids, such as pictures, to present

the teaching content. Additionally, 40% of the teachers never have students perform demonstrations themselves, and 11 out of the 25 teachers surveyed (44%) never allow students to view physical dance videos.

From the analysis of these data, it can be concluded that physical dance teachers primarily rely on a single method of instruction, mainly through their own demonstrations. While teacher demonstrations help clarify the flow of technical movements and are essential for students to accurately imitate the movements, relying solely on this method can lead to a decrease in students' long-term interest in learning. To achieve the desired teaching outcomes, it is crucial for teachers to incorporate a variety of presentation strategies and use them in combination, enriching the learning experience and maintaining student engagement.

Table 9: Survey statistics of teachers' use of presentation strategies (N = 25 unit: Person)

Strategies	Always	Often	Sometimes	Rarely	Never
Using pictures to present	4	6	2	11	2
Use video to show	2	6	5	10	2
Teacher demonstration	14	4	3	4	0
Student competition show	3	2	4	6	10

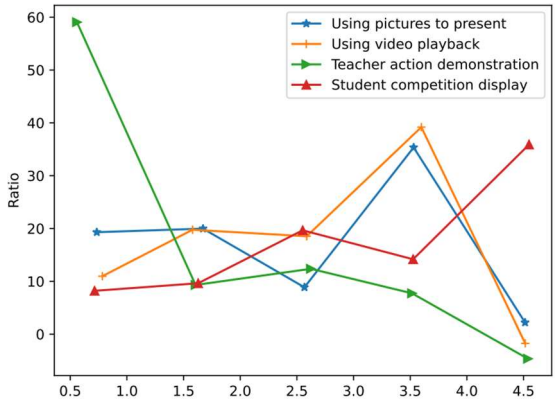

Figure 6: Statistics of the survey on teachers' use of presentation strategies (N = 25 unit: Person)

The results presented in Table 10 show that 40% of the teachers often use the terminology of physical dance to teach; however, the same percentage of teachers rarely use "stories" to improve students' memory of the teaching content; 60% (15) of the physical education teachers rarely use other subjects to support the teaching of physical education and dance. However, 60% (15) of the physical education and dance teachers seldom used other subjects to support the teaching of physical education and dance and to guide their comprehensive thinking; 60% and more than half of the teachers seldom used motivational language to encourage students in the teaching process.

It can be analyzed that physical dance teachers are teachers of art courses, and they pay too much attention to technical movements in the teaching process, but pay little attention to theoretical knowledge which is beneficial to students' technical learning and development, and even do not pay attention to it, which will cause the phenomenon of "knowing the technique but not knowing the theory" among students of physical dance in colleges and universities.

Table 10: Survey statistics of teachers' use of explanation strategies (N = 25 unit: Person)

Category	Always	Often	Sometimes	Rarely	Never
Introduction by "story" method	2	6	4	11	2
Technical terminology	8	9	4	3	1
Comprehensive knowledge support	1	2	2	4	16
Inspiring questions to guide	4	2	5	14	0
Motivational language encouragement	2	5	8	6	4

From the statistics in Table 11 and the results in Figure 7, it can be concluded that 40% of the physical dance teachers would let students practice step by step until they mastered the exercise content; 32% of the teachers seldom used multiple organizational forms to let students practice the teaching content.

The results of the survey showed that a few teachers would use flexible and varied organizational forms to let students practice, while most teachers still organized students' practice in the traditional single practice way. Because of the rigid organization and weak interest, they cannot reach the understanding of the teaching content in the whole practice, and there is no good practice atmosphere, so they cannot promote the overall practice effect.

Table 11: Survey statistics of teachers' use of practice strategies (N = 25 unit: Person).

Strategies	Always	Often	Sometimes	Rarely	Never
Exercise content is targeted	5	8	6	4	2
Exercise form is flexible and diverse	3	8	7	7	0
Exercises in a gradual and progressive manner	9	4	3	6	3
Reasonable control of exercise load	3	2	4	7	9

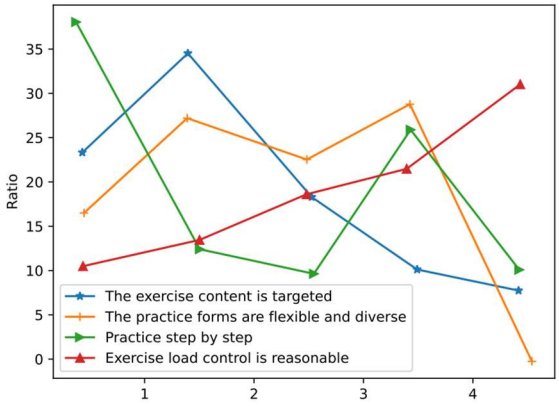

Figure 7: Statistics of the survey on teachers' use of exercise strategies (N = 25 unit: Person)

According to the data presented in Table 12, 52% of teachers consistently use group error correction to guide students during practice sessions; 44% frequently employ group instruction during lessons; 36% often provide one-on-one targeted instruction, while 4% of teachers do not offer individual guidance; and 60% of teachers rarely incorporate theoretical knowledge related to technical movements into their instruction. The majority of teachers rely heavily on one-on-one instruction.

An analysis of these findings indicates that most physical dance teachers tend to focus on group-based instruction, with less emphasis placed on individualized attention. The instruction predominantly revolves around technical aspects of the movements, with fewer teachers incorporating theoretical knowledge as a foundation for the learning process. This gap suggests that starting from theoretical concepts could significantly enhance students' understanding of the technical movements. By offering theoretical insights before diving into the practical execution, teachers can provide students with a deeper comprehension of the principles behind the movements. This approach could also aid in correcting errors more effectively by linking the technical corrections with a conceptual understanding, thus helping students improve both technically and cognitively. Integrating theoretical knowledge into the instructional process would create a more holistic teaching method, fostering better long-term retention and mastery of physical dance skills.

Table 12: Survey statistics of teachers' use of instructional strategies (N = 25 unit: Person).

Strategies	Always	Often	Sometimes	Rarely	Never
One-to-One	7	8	5	4	1
Grouped	10	8	3	4	0
Collective error correction	12	9	3	1	0
Theoretical knowledge tips	1	4	4	16	0

IV. Conclusion

This study comprehensively explored the application of biomechanics and intelligent mobile terminals in sports dance education, from system architecture design to empirical teaching strategy optimization. Through expert surveys and empirical case studies, it was found that traditional sports dance teaching methods exhibit significant limitations in interaction, feedback precision, and theoretical integration. The proposed teaching system introduces a practical framework combining intelligent mobile devices, real-time kinematic analysis, and hierarchical teaching strategy indicators. The empirical data confirm that this

integration can provide timely movement correction, enhance theoretical understanding, and increase student engagement. Moreover, the refined teaching strategy framework—validated through expert scoring and statistical agreement—offers a structured, data-driven foundation for future teaching innovations. By shifting from teacher-centered demonstration to a multimodal and biomechanically informed instruction model, both teaching efficiency and learning outcomes are significantly improved. This approach not only supports technical skill acquisition but also cultivates a deeper understanding of motion mechanics, promoting safer and more effective sports dance training environments.

Ethical approval

Not applicable.

Conflict of interest

The authors declare no conflict of interest.

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