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Digital-Intelligence Integration and Ecological Reconstruction: Research on the Collaborative Mechanism of AI-Enabled Personalized Physical Education in Universities

Zhengshen Huang [1], Jiajun Zhou [2], Dongjin He [3, *]

[1] School of Law, Guangdong University of Finance, Guangzhou, China

[2] General Education Department, Southern Medical University, Guangzhou, China

[3] Department of Physical Education, Guangdong University of Finance, Guangzhou, China

ABSTRACT

Currently, physical education (PE) in universities is at a critical transition period from standardization to personalization. The intervention of Artificial Intelligence (AI) technologies is not merely an overlay at the tool level but a systemic reconstruction of the PE ecosystem. Grounded in the era of "Digital-Intelligence Integration," this paper deeply analyzes the realistic dilemmas existing in traditional university PE, such as "data silos," "supply-demand mismatch," and "lagging evaluation." Based on Collaborative Governance Theory and Constructivist Learning Theory, this paper proposes constructing a "Technology-Pedagogy-Institution" trinity collaborative mechanism: at the technological level, breaking information barriers through multi-modal data fusion; at the pedagogical level, promoting the reshaping of new "teacher-machine collaborative" teaching relationships; and at the management level, establishing a cross-departmental resource integration and ethical regulation system. The paper further proposes implementation pathways for AI-enabled personalized PE in universities from three dimensions: the construction of precision teaching scenarios, the reconstruction of dynamic evaluation systems, and the governance of ethical pathways, aiming to provide theoretical support and practical references for promoting the digital transformation of higher education and improving the quality of sports education.

KEYWORDS

Artificial Intelligence; University Physical Education; Personalized Teaching; Digital-Intelligence Integration; Collaborative Mechanism; Ecological Reconstruction

1. INTRODUCTION

With the deepening development of the new round of scientific and technological revolution and industrial transformation, digital transformation has become the only way for the high-quality development of higher education. The report of the 20th National Congress of the Communist Party of China explicitly proposed to "promote the digitalization of education and build a learning society and a learning country where lifelong learning is available to all," pointing out the direction for university education reform in the new era. As an indispensable part of the higher education system, university physical education bears the educational mission of "enjoying fun, enhancing physical fitness, perfecting personality, and tempering will." However, for a long time, constrained by the inertia of faculty ratios, venue resources, and teaching models, university PE has generally shown a "one-size-fits-all" standardization tendency, making it difficult to effectively meet the increasingly personalized and diversified sports and health needs of college students.

The rapid development of Artificial Intelligence (AI), especially breakthroughs in technologies such as Generative Artificial Intelligence (AIGC), Computer Vision, and multi-modal data analysis, has provided new opportunities to solve this problem. Unlike traditional audio-visual education methods, AI possesses powerful data processing capabilities, adaptive learning capabilities, and instant feedback capabilities, enabling it to penetrate core teaching links and realize a paradigm shift from "experience-driven" to "data-driven."

However, the introduction of technology does not necessarily bring about an improvement in teaching effectiveness. Currently, in the process of embracing AI, university PE still faces deep-seated contradictions such as "the separation of technology and pedagogy," "fragmented data application," and "blurred human-machine ethical boundaries." The root of these problems lies in the lack of a systematic collaborative mechanism—the technological logic and the educational logic have not yet achieved deep coupling. Therefore, this paper aims to transcend the perspective of pure technology application and explore the internal mechanisms, realistic dilemmas, and collaborative mechanisms of AI-enabled personalized PE in universities from the height of "ecological reconstruction," with a view to providing theoretical basis and practical pathways for building a high-quality smart physical education ecosystem in universities.

2. THEORETICAL LOGIC: FROM "TECHNOLOGICAL OVERLAY" TO "ECOLOGICAL RECONSTRUCTION"

AI-enabled personalized physical education in universities is by no means a simple "Technology + Sports," but a comprehensive ecological change involving teaching objectives, teaching relationships, teaching evaluation, and teaching environments.

2.1. Ontological Traceability: A New Landscape of PE under Digital-Intelligence Integration

The ontological basis of traditional physical education is skill transmission based on physical discipline, emphasizing the standardization and uniformity of movements. In the perspective of Digital-Intelligence Integration, the ontological connotation of physical education has undergone a profound displacement.

First, the teaching object shifts from "Physical Human" to "Digital Twin." Through sensing terminals such as wearable devices and smart cameras, students' physical information such as vital signs, movement trajectories, and physiological loads are converted into digital signals in real-time, constructing a high-fidelity "Digital Portrait" [1]. This makes teaching no longer just target vague groups, but enables precise perception of the micro-status of each individual.

Second, teaching resources shift from "Static Preset" to "Dynamic Generation." Traditional teaching relies on textbooks and teacher experience, where resources are fixed and limited. After the intervention of AI, personalized exercise prescriptions, intelligent sparring systems, and virtual simulation scenarios can dynamically generate teaching content based on students' real-time feedback, realizing the infinite expansion and precise matching of resources.

2.2. Epistemological Transformation: The Precision Logic of Personalized Teaching

The core of personalized teaching lies in "teaching students in accordance with their aptitude." Under the traditional model, due to the limited energy of teachers, "teaching students in accordance with their aptitude" often remains a concept or is limited to a few elite students. AI, supported by computing power and algorithms, makes personalized teaching under the premise of scale possible.

Based on Constructivist Learning Theory, learning is a process in which learners actively construct knowledge in specific contexts. AI technology provides personalized "scaffolding" for students by

building immersive smart sports contexts. For example, Computer Vision (CV) technology can dismantle and compare students' shooting movements at the millisecond level, providing instant, visualized corrective feedback to help students complete skill construction through self-reflection [2]. This mechanism refines the teaching granularity from "class hours" to "movements," and focuses from "classes" to "individuals," thoroughly changing the epistemological basis of physical education.

2.3. Methodological Reshaping: Mechanism Innovation from the Perspective of Collaborative Governance

To achieve the above changes, it is necessary to jump out of a single teaching dimension and introduce Collaborative Governance Theory. Collaborative governance emphasizes that diverse subjects, guided by common goals, maximize the overall effectiveness of the system through resource integration, information sharing, and mechanism innovation.

In the process of smart PE teaching in universities, the subjects involved include not only teachers and students but also emerging roles such as algorithm engineers, teaching administrators, and data analysts; the elements involved include not only venues and equipment but also data assets, computing platforms, and ethical norms. The so-called "ecological reconstruction" refers to the establishment of an efficient collaborative mechanism to organically integrate these heterogeneous elements in the links of "teaching, learning, managing, and evaluating," eliminating "entropy increase" within the system, and promoting the evolution of the PE teaching system towards a higher-order ordered state.

3. REALISTIC SCRUTINY: PAIN POINTS AND OBSTRUCTIONS IN THE INTELLIGENT TRANSFORMATION OF UNIVERSITY PE

Despite the broad prospects, currently, university PE in China still faces significant "non-collaborative" phenomena in the process of promoting AI applications, restricting the practical effectiveness of personalized teaching.

3.1. Data Silos and Value Chain Breaks: Non-Collaboration at the Technological Level

Data is the fundamental fuel for AI empowerment. However, current data governance in university PE is generally in a fragmented state.

On one hand, data collection dimensions are singular and standards are inconsistent. Some schools only rely on physical fitness test data (such as height, weight, vital capacity), lacking process data collection on students' daily exercise, classroom performance, and psychological state; although some schools have introduced smart devices, data interfaces between different brands and systems are incompatible, causing data to settle in independent APPs or platforms, forming "data silos" that are difficult to connect [3].

On the other hand, data analysis lacks depth, leading to "value chain breaks." A large amount of data is only used for simple attendance clock-ins or final grading, lacking deep mining and correlation analysis based on large models. For example, how to cross-analyze students' physical fitness test data with classroom skill mastery and extracurricular exercise habits to generate scientific exercise prescriptions? Most universities currently do not possess this algorithmic capability, resulting in data having "quantity but no quality," making it difficult to support precise personalized teaching decisions.

3.2. Teacher-Machine Game and Role Loss: Non-Collaboration at the Pedagogical Level

The intervention of AI has broken the traditional "Teacher-Student" binary structure, forming a "Teacher-Machine-Student" ternary interactive relationship. In this transition period, teachers often face serious "technological adaptability anxiety."

Some PE teachers hold a repulsive attitude towards AI technology, believing that technology weakens the "physicality" and "emotionality" of PE teaching, fearing being replaced by algorithms; another part of teachers falls into the misunderstanding of "technological determinism," overly relying on smart devices, filling the classroom with various screens and data, while ignoring the role of personal example and emotional motivation, causing PE classes to become "data monitoring classes."

In addition, the existing teacher training system focuses more on general information technology (such as PPT production, MOOC recording), lacking AI application training specifically for the characteristics of the PE discipline. Teachers do not understand algorithmic logic, and technical personnel do not understand sports laws. There is a lack of effective dialogue mechanisms between the two, resulting in intelligent teaching tools developed often being "unusable" or "unwanted," making human-machine collaborative teaching a mere formality.

3.3. Departmental Fragmentation and Institutional Absence: Non-Collaboration at the Management Level

The smart transformation of university PE is a systematic project requiring the cooperation of multiple departments such as the Academic Affairs Office, Sports Department, Network Center, and Asset Management Office. However, in reality, there are often obvious departmental barriers.

Sports departments have business needs but no technical control, while network centers have technical capabilities but do not understand sports business scenarios. There is a lack of normalized communication and coordination mechanisms between departments. This leads to a lack of top-level design in the early stages of many smart sports projects, resulting in serious redundant construction and resource waste.

At the same time, supporting institutional construction lags seriously behind. For example, in personalized teaching, student health data and movement trajectories collected by AI systems are highly sensitive information. Currently, there is a lack of perfect data security protection and privacy ethical norms [4]. Once data leakage occurs, it will trigger serious ethical risks. In addition, the traditional PE teaching evaluation system still follows the standardized model of "attendance + physical test + skill exam," failing to incorporate the effectiveness of students' autonomous learning using AI into the evaluation category. The lag of the system in turn suppresses the innovative vitality of technological applications.

4. MECHANISM CONSTRUCTION: COLLABORATIVE PATHWAYS FOR AI-ENABLED PERSONALIZED PHYSICAL EDUCATION

In response to the above pain points, a "Technology-Pedagogy-Management" trinity collaborative mechanism must be constructed to promote the ecological reconstruction of university PE teaching with a systematic approach.

4.1. Technology Empowerment: Constructing a Domain-Wide Integrated Data Collaborative Mechanism

Data collaboration is the underlying support for personalized teaching. Data barriers must be broken to establish a domain-wide, all-time, and full-volume university sports big data ecosystem.

4.1.1. Multi-Modal Data Collection and Standardized Fusion

Establish a unified university sports data standard interface (API) to aggregate and integrate students' physical health test data, physiological data (heart rate, blood oxygen) collected by wearable devices, movement video data captured by smart cameras, and course selection data in the academic affairs system. Utilize Internet of Things (IoT) technology to achieve senseless collection and automatic upload of "in-class + out-of-class" and "online + offline" data, building a full-lifecycle electronic health record for each student.

4.1.2. Constructing "Vertical Sports Large Models" and Decision-Making Hubs

Relying on cloud computing platforms, build a smart decision-making hub for PE teaching. Introduce deep learning and knowledge graph technologies to train "vertical large models" oriented to university sports scenarios. This model should possess two core functions: first, diagnostic function, capable of precisely identifying students' physical shortcomings and skill defects based on multi-source data; second, prescription function, capable of automatically generating personalized exercise prescriptions and nutritional advice by combining principles of exercise physiology and sports training. Through data collaboration, realize the leap from "vague experience" to "precise algorithms."

4.2. Paradigm Transformation: Establishing a Human-Machine Symbiotic Teaching Collaborative Mechanism

Artificial intelligence should not be a replacement for teachers, but a "super assistant" for teachers. Human-machine boundaries must be clarified to build a collaborative teaching model with complementary advantages.

4.2.1. Reshaping Teacher Roles: From "Demonstrator" to "Analyst"

In the AI era, standardized movement demonstrations and basic rule explanations can be completely handed over to intelligent teaching assistants or virtual digital humans (Avatars). The core functions of PE teachers should shift to value guidance, emotional motivation, data interpretation, and complex problem-solving [5]. Teachers should become "sports data analysts," using learning situation reports provided by AI to discover potential problems of students through data; become "instructional designers," designing targeted teaching intervention plans for complex tactical cooperation or psychological barriers that AI cannot solve.

4.2.2. Constructing "Dual-Teacher" Classrooms and Blended Teaching Loops

Promote the "Dual-Teacher" classroom model of "Human Teacher + AI Assistant." In the skill learning stage, use the AI visual recognition system for "one-on-one" movement correction and instant feedback to solve the problem of teachers being unable to guide everyone in large classes; in the tactical drill stage, use VR/AR technology to build virtual confrontation scenarios to improve practical combat capabilities. At the same time, connect in-class and out-of-class links: push preview resources via AI before class, provide precise guidance during class, and assign personalized exercise tasks and monitor completion quality in real-time through smart APPs after class, forming a teaching loop of "Monitoring - Assessment - Intervention - Re-monitoring."

4.3. Institutional Reconstruction: Perfecting the Management Collaborative Mechanism for Cross-Boundary Integration

The deep integration of technology and teaching cannot be separated from an efficient management system and institutional guarantees.

4.3.1. Establishing a Cross-Departmental Multi-Governance Architecture

Universities should establish a "Smart Sports Construction Leading Group" led by the vice-president in charge, with the participation of the Sports Department, Academic Affairs Office, Information

Center, Student Affairs Department, etc. Establish a normalized joint conference system to coordinate the top-level design, funding investment, and resource allocation of smart sports. For example, the Information Center is responsible for underlying computing power and network security, the Sports Department is responsible for business scenario requirements and content production, and the Academic Affairs Office is responsible for credit recognition and curriculum reform, eliminating departmental barriers through a collaborative architecture with clear rights and responsibilities.

4.3.2. Reconstructing a Data-Driven Multi-Evaluation System

Break the single evaluation view focused solely on physical tests and skills, and establish a value-added evaluation and process evaluation system based on big data [6]. Use AI technology to fully record students' exercise duration, exercise intensity, skill improvement magnitude, and attendance, automatically generating multi-dimensional comprehensive evaluation reports. Focus on students' "improvement magnitude" and "effort level," allowing students with weak physical foundations but who persist in exercising to obtain high scores, truly reflecting the incentive orientation and personalized care of evaluation.

4.3.3. Building a Firewall for Technology Ethics and Security

Formulate strict university sports data security management measures, clarifying the "minimum necessity principle" for data collection. Introduce privacy computing and blockchain technology to ensure that student health data is safe and tamper-proof during storage, transmission, and sharing. At the same time, establish an algorithm review mechanism to prevent algorithm bias (such as discriminatory evaluation against students of specific body types or genders), establish a "people-oriented" technological ethical bottom line, and always place educational safety above technological efficiency.

5. IMPLEMENTATION PATHWAYS: STRATEGIES FROM BLUEPRINT TO PRACTICE

The construction of collaborative mechanisms requires concrete implementation pathways for grounding. Combining the actual situation of university PE teaching, this paper proposes the following three progressive implementation pathways.

5.1. Scenario Entry: Creating Immersive Smart Sports Spaces

Space is the carrier of teaching. Universities should plan to transform traditional sports venues intelligently, creating a "third space" suitable for personalized teaching.

First, build a Smart Physical Test Center, introducing self-service physical test all-in-one machines to achieve normalized and self-service collection of physical test data, changing the low-frequency monitoring model of "testing once a year." Second, build AI Interactive Gyms and Virtual Simulation Laboratories, equipping them with strength training equipment with screen displays and sensors, smart bicycles, and VR glasses, supporting students to conduct autonomous training based on exercise prescriptions generated by AI. Third, deploy intelligent visual capture systems in outdoor track and field and ball game venues to achieve senseless recording of sports data. Through the intelligent upgrade of physical space, provide a hardware foundation for data collaboration.

5.2. Literacy Improvement: Implementing the "Sports + AI" Teacher Pilot Plan

Teachers are the key variable for the landing of collaborative mechanisms. Universities should launch special training plans, combining "bringing in" and "going out," to improve the digital literacy of PE teachers.

On one hand, organize special "Sports AI Workshops," inviting educational technology experts and algorithm engineers to train teachers hand-in-hand on using smart wearable devices, analyzing sports data reports, and operating virtual simulation systems, eliminating technological fear. On the other hand, encourage PE teachers and Computer Science faculty to form interdisciplinary teaching and research teams to jointly develop school-based smart sports courses and micro-course resources. In title evaluation and performance appraisal, add indicators for "teaching digital reform," institutionally incentivizing teachers to actively embrace new technologies and realize the transformation from "passive adaptation" to "active innovation" [7].

5.3. Model Promotion: Building a Regional Smart Physical Education Community

The resources and data samples of a single university are limited. To enhance the radiation effect of the collaborative mechanism, reliance should be placed on regional higher education alliances (such as the Guangdong-Hong Kong-Macao Greater Bay Area University Alliance) to promote the sharing of smart sports resources among universities.

Establish a regional university sports big data center. Under the premise of desensitization, aggregate student physical health data from different universities, carry out large-scale group law research, and provide data support for regional sports education policy formulation. At the same time, promote the interconnection of high-quality smart sports curriculum resources. Through credit recognition mechanisms, allow students in resource-weak schools to enjoy high-level personalized sports guidance. By building a regional education community of "Co-construction, Sharing, and Win-win," form the scale effect of AI-enabled physical education [8].

6. CONCLUSION

The arrival of the era of Digital-Intelligence Integration has provided unprecedented technological dividends for personalized physical education in universities and also raised the epochal proposition of "ecological reconstruction." AI-enabled university sports is not just an update of equipment but a profound revolution involving educational concepts, teaching models, and management systems.

Through analysis, this paper points out that to break the current realistic dilemmas of data silos, teacher-machine games, and departmental fragmentation, a "Technology-Pedagogy-Management" trinity collaborative mechanism must be constructed. Domain-wide data fusion at the technological level is the foundation, human-machine collaborative symbiosis at the pedagogical level is the core, and cross-boundary institutional reconstruction at the management level is the guarantee. Only when the three resonate at the same frequency can the leap from "standardized education" to "personalized education" be truly realized.

Looking to the future, with the further maturity of frontier technologies such as brain-computer interfaces and affective computing, personalized PE in universities will develop in a more intelligent, emotional, and implicit direction. We should maintain rational technological optimism, boldly embracing technological changes while adhering to the value background of sports education, making artificial intelligence truly a powerful engine for promoting the comprehensive development of college students' physical and mental health.

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