

THE CONSTRUCTION PATH OF FOREST FIRE EXTINGUISHING SKILLS COURSE DRIVEN BY TECHNOLOGY EMPOWERMENT

ZhenYu Liu, LiCheng Wang*, JiaQi Tong

Department of Fire Command, China Fire and Rescue Academy, Beijing 102202, China.

**Corresponding Author: LiCheng Wang*

Abstract: Under the new situation of technology-empowered transformation and upgrading of forest and grassland fire equipment, this study addresses prominent problems in forest fire extinguishing skills course teaching, including disconnection between instruction and combat needs, separation of training and drills, and singular evaluation methods. Guided by the TIE concept (situational teaching, integration of training-combat-evaluation, and new outline guidance), an overall framework for course construction is proposed and established. Through reshaping a three-stage progressive curriculum system, innovating a seven-step teaching method, building skill teaching modules covering personal protective equipment, wind-driven fire extinguishing equipment, and water-based fire suppression equipment, constructing a virtual-real integrated full-scenario training base, and establishing a multi-dimensional process evaluation mechanism, the three-in-one construction of curriculum, training, and evaluation is systematically advanced. Practice shows that students' practical disposal ability and post competence have been significantly improved, providing a reference for forest fire extinguishing skills course construction and teaching reform of similar practical courses.

Keywords: Forest fire extinguishing skills; Course construction; Practical teaching

1 INTRODUCTION

Affected by global climate change, extreme weather disasters such as high temperatures and droughts occur frequently in northern China. The fuel load under forest stands remains persistently high, making forest fire suppression increasingly difficult and risky. Beijing's forest coverage rate is 44.6%, with mountainous areas accounting for over 80% of the city's area, making forest and grassland fire prevention and suppression tasks formidable. As the reform of national comprehensive fire and rescue forces deepens, forest fire response has shifted from seasonal prevention to all-disaster, all-weather readiness, imposing stricter requirements on frontline commanders for adapting to complex fire situations, applying tactics, and coordinating operations.

High-intensity forest fires continue to emerge, and traditional suppression methods struggle to effectively contain fire spread. China's forest fire prevention faces dual pressures: ecological resource protection and complex geographical conditions. On one hand, forest coverage continues to rise, fuel loads increase, and fire danger ratings remain high. On the other hand, key forest areas are mostly distributed in mountainous and steep terrain with rough landforms and inconvenient transportation. Once a fire occurs, difficulties in force projection, equipment deployment, and water source support are particularly prominent. In recent years, major forest fires have exhibited characteristics of sudden onset, destructive power, unprecedented suppression scale, and difficulty in multi-force coordination. Before large-scale high-intensity fires, bottlenecks remain in human-machine integration and heavy equipment deployment. Building a systematic and intelligent new forest fire equipment and talent cultivation system has become a key factor in improving suppression effectiveness, see Figure 1.



Figure 1 Actual Combat Scene of Forest Fire Suppression

In 2026, the forest fire protection major became an undergraduate major in regular higher education institutions, listed under the public security category of the law discipline [1]. As an emerging major, the scientific nature and relevance of its talent cultivation plan, teaching content design, curriculum system construction, practical session arrangement, and professional textbook compilation still need further improvement. Under the new situation of educational informatization and emergency management development, how to guide forest fire extinguishing skills course construction with new concepts has become an important urgent issue.

This study explores the construction path of forest fire extinguishing skills courses, with important theoretical and practical significance. Theoretically, deeply integrating digital-intelligent technology into curriculum and textbook construction explores how digital-intelligent technology reshapes course objectives, content, teaching methods, and evaluation mechanisms, promoting the autonomous knowledge system of forest fire protection discipline. Practically, building a digital-intelligent curriculum system cultivates high-quality compound talents who master both traditional forest fire knowledge and skills and digital-intelligent technology application capabilities, directly serving the modernization of national emergency management systems.

Domestically, in educational digital transformation and digital-intelligent textbook construction, Zhu Zhiting pointed out that digital transformation of education should unfold from multiple dimensions, achieving dynamic update and personalized recommendation of teaching content through digital technology [2]. Li Manli proposed that textbooks in the digital-intelligent era should shift from traditional books to multi-carrier learning, integrating AI tutors and virtual experiments to build a digital textbook system supporting student inquiry [3]. Zhou Jin et al., based on analysis of Ministry of Education exemplary cases, identified that digital-intelligent empowerment of undergraduate teaching features goal relevance, resource integration, personalized models, and scientific evaluation [4]. In digital teaching resource innovation, Li Feng et al. noted that digital textbooks are evolving from electronic texts to intelligent resource entities, embedding learning analytics for student behavior perception and feedback [5]. Gu Xiaoqing et al. pointed out that digital resources should transform toward multi-dimensional interactive guidance and evaluation feedback [6]. Methodologically, the DIKW logic chain establishes a hierarchical information resource construction model [7]. Duan Yucong proposed the DIKWP model, emphasizing that digital textbooks should dynamically adjust knowledge presentation logic based on student learning intent [8]. Wang Jingjing et al. built a knowledge graph by integrating real-time monitoring data and historical cases, providing theoretical support for forest fire digital textbook construction [9]. Zhu Guangyu et al. used knowledge graphs to predict emergency event evolution, providing a technical paradigm for intelligent case library construction [10]. In forest fire skills course construction, Guo Zhengqi et al. proposed that shifting from experiential to data-driven judgment and building smart fire protection and modern governance systems is an inevitable trend [11]. Chang Ning et al. explored practical innovation in the Forest Fire Tactics course, developing digital tools to enhance practical teaching [12]. Zhou Rui et al. improved team combat capability through multi-dimensional indicators and competency quantification models [13].

Internationally, in digital twin technology application, Hazrat et al. pointed out the potential of digital twins in cultivating professional skills in engineering education, allowing immersive learning and simulation of real physical models in virtual environments [14]. In instructional design, Zheng Xiaotao and Ma Linwei proposed a curriculum framework from the perspective of first principles, enhancing learning outcomes [15]. In AI-enabled fire simulation, Wu Zechuan et al. proposed a neural network-based forest fire spread simulation model, which can predict fire behavior under different weather and terrain conditions [16]. In knowledge engineering, Cato et al. applied the DIKW framework to clinical data, demonstrating how artificial intelligence transforms raw data into wisdom-level insights [17]. In digital twin-based fire suppression, Fan et al. proposed a digital twin approach to forest fire re-ignition, simulating suppression effectiveness of UAV-deployed hydrogel agents [18].

The above works advance forest fire skills course construction from different perspectives, but three gaps remain: first, most studies focus on local optimization of individual courses or teaching sessions, lacking overall design and planning at the course construction level; second, digital-intelligent technology integration mainly manifests as tool application; third, a theoretical system integrating situational teaching, training-combat-evaluation integration, and new outline guidance across all course construction elements has not yet been established.

Addressing these gaps, this paper takes the TIE concept as guidance, drawing on the forest fire extinguishing skills course construction practice at China Fire and Rescue Academy, and approaches from three dimensions: curriculum system, training system, and evaluation mechanism, to build the overall framework and propose actionable implementation paths.

2 DEMANDS AND PAIN POINTS OF COURSE CONSTRUCTION

2.1 Talent Demands in the Digital-Intelligent Era

Forest fire protection is a newly established undergraduate major in 2026, under the public security category of law discipline, still in its initial construction stage. China Fire and Rescue Academy is the only institution worldwide offering a directional undergraduate major in forest fire protection. Forest fire-related course construction has over 80 years of historical experience, but transitioning from a professional direction to an independent major is not simply a name change—it involves reconstructing cultivation objectives, rebuilding the curriculum system, recompiling textbook resources, and restructuring training conditions.

Compared to traditional majors, there is no reference experience in talent cultivation planning, curriculum system construction, textbook compilation, training base development, and faculty team building. Additionally, the new major must coordinate with existing fire command and fire investigation majors, reflect forest fire protection characteristics, and align with national comprehensive fire and rescue force position requirements. The rapid development of digital-intelligent technology also demands forward-looking planning. Accelerating forest fire extinguishing skills course construction is not only an internal need for course development but also an urgent requirement for serving the modernization of national emergency management.

With the development of digital-intelligent technology, new technologies and equipment such as UAV fire reconnaissance, intelligent monitoring and early warning equipment, and aviation multi-aircraft coordinated fire suppression will quickly become widespread. Forest fire suppression will shift from traditional experience-driven, manpower-intensive operations to technology-driven intelligent suppression, with operational forms transitioning from single-ground suppression to air-ground coordinated joint operations, posing new challenges for frontline commanders' information gathering and analysis capabilities. The traditional talent cultivation model focused on physical strength and skills can no longer meet the needs of digital-intelligent era forest fire prevention, urgently requiring high-quality compound talents who master both basic forest fire theory and practical skills, and possess digital technology application, cross-knowledge integration, and complex fire scene command decision-making capabilities.

In terms of student composition, forest fire protection students mainly come from two groups: team-origin students and youth students, with significant differences in foundational knowledge, learning interests, and weak areas. Team-origin students have some suppression experience, understand team conditions, and strong discipline awareness, but have narrow professional knowledge and systematic gaps, requiring longer adaptation to new technologies and tactics. Youth students have high political quality and quick acceptance of new things, but lack deep understanding of battlefield environments and the urgency and danger of forest fire suppression, with insufficient adaptability and complex fire line handling experience. This differentiation requires talent cultivation to address diverse needs while strengthening practical ability conversion alongside theoretical foundations, see Table 1.

Table 1 Learning Situation in Forest Fire Extinguishing Skills Course

Analysis Dimension	Team-origin Students (Majority)	Youth Students (Minority)
Knowledge Foundation	Rich practical experience, but theoretical knowledge is fragmented	Strong theoretical learning ability, but lacks practical perception
Learning Motivation	Values skill practicality, focuses on position requirements	Tends to be exam-oriented, insufficient understanding of practical significance
Cognitive Characteristics	Relies on experience, lower acceptance of new tactics and equipment	Adapts quickly to new technology, but weak risk awareness
Ability Gaps	Insufficient logical tactical decision-making, weak theoretical support	Weak on-the-spot adaptability, lacks complex fire scene disposal experience
Ideological-Political Cognition	Identifies with team culture but lacks deep understanding of underlying values	Lacks intuitive experience of professional mission, insufficient ideological identification

2.2 Pain Points in Course Construction

Through reviewing and analyzing the forest fire extinguishing skills course construction practice at China Fire and Rescue Academy, current course construction faces the following prominent problems:

First, disconnection between instruction and combat needs. Theoretical teaching still features lecturing to varying degrees, with one-way instruction and passive student reception, unable to simulate real fire decision-making environments. Practical teaching stays at key point explanation and demonstration, without complex fire scene simulation, and does not timely introduce new equipment and tactics such as UAV reconnaissance and unmanned operations. Some course content updates slowly, creating a disconnect between classroom teaching and actual fire scenes, resulting in weak initial-post application ability.

Second, separation of training and drills. There is a lack of effective transition between basic skill training and comprehensive combat drills. Practical teaching mostly stays at action imitation without situational challenges, making it difficult for students to flexibly apply basic skills in complex fire environments. Training scenarios differ significantly from real fires in complex terrain, variable weather, and uncontrollable fire conditions.

Third, singular evaluation methods with insufficient process-oriented and practical assessment. Course assessment relies heavily on theory exams and single evaluations, with process-oriented evaluation underemphasized. Practical assessment focuses on operational norms rather than combat effectiveness, with insufficient evaluation of students' hands-on ability, cooperative combat capability, and on-the-spot adaptability in complex fire scenes.

3 OVERALL FRAMEWORK UNDER THE TIE CONCEPT

3.1 Core Connotation of the TIE Concept

The TIE concept is an educational philosophy gradually formed through forest fire protection practical teaching reform. Its core connotation includes three dimensions:

T (Teaching in Situation): Using real fire scenes as teaching environments, adopting battle case introduction, situational simulation, and live fire drills to place abstract theoretical knowledge in specific fire contexts, enabling students to understand knowledge and train skills near real fire scenes. Situational teaching is the foundation of TIE, addressing what to learn and how to learn.

I (Integration of Training, Combat, and Evaluation): Emphasizes organic integration of training, combat, and evaluation—guiding training by combat, promoting combat through training, and fostering improvement through evaluation. Training content is operational requirement; operations are the verification of training; evaluation feeds back to improve training, and training is built on operational analysis, mutually reinforcing and cyclically improving. Integration is the core of TIE, addressing what to train, how to train, and how to evaluate.

E (Enlightenment by New Outline): Emphasizes using the newly promulgated forest fire training outline as guidance, fully integrating the content, standards, and requirements into course teaching, training drills, and assessment, ensuring talent cultivation precisely aligns with team position competency standards. New outline guidance is the direction of TIE, addressing whom to cultivate and what standards to achieve.

The three elements of the TIE concept form an organic whole: situational teaching as the foundation, training-combat-evaluation integration as the main thread, and new outline guidance as direction, constituting the complete logical chain of the TIE concept.

3.2 Construction Objectives and Overall Framework

Guided by the TIE concept, the overall objective of forest fire extinguishing skills course construction is: oriented toward national emergency management system and capacity modernization, based on the new situation of forest fire prevention in the digital-intelligent era, with moral education as the foundation, practical orientation as the guide, and digital-intelligentization as empowerment, building a three-in-one construction pattern of curriculum system—training system—evaluation system, and cultivating high-quality compound forest fire protection professionals with political firmness, professional excellence, strong work style, and combat capability. With the goal of cultivating high-quality forest fire skills talents, the TIE concept serves as core guidance, with curriculum system construction, training system construction, and evaluation system construction as three main pillars, supported by intelligent equipment, digital-intelligent technology, practical training, and school-team collaboration as the technology empowerment foundation.

4 IMPLEMENTATION PATHS

4.1 Curriculum System Construction

The curriculum system is the core of construction. Guided by the TIE concept and benchmarked against the new forest fire training outline, a three-stage progressive curriculum system of lower-order, middle-order, and higher-order is constructed.

The lower-order stage focuses on theoretical instruction and individual training, cultivating students' foundational cognitive ability to master basic forest fire theory, fire extinguishing equipment operation, individual fire suppression actions, and safety norms. The middle-order stage emphasizes group training and skill competitions, improving students' integrated ability to master team coordinated suppression, tactical application, and emergency evacuation. The higher-order stage centers on live fire drills and actual fire suppression, strengthening students' practical application ability to enhance comprehensive command decision-making and cooperative combat capability near real fire scenes.

In teaching methods, a seven-step teaching method is innovatively implemented: battle case introduction, theoretical lecture, ideological-political integration, practical operation training, skill competition, live fire drill, and action review, running the TIE concept through the entire teaching process. Battle case introduction arouses student interest through typical forest fire suppression cases. Theoretical lecture systematically covers basic forest fire theory and technical methods. Ideological-political integration weaves combat spirit, professional ethics, and mission responsibility throughout teaching. Practical operation training is conducted in forest fire basic laboratories, fire psychology training fields, and tactical training grounds. Skill competition promotes training and learning through contests. Live fire drills are conducted at live fire drill sites and actual fire suppression scenes. Action review promptly summarizes training gains and corrects action deviations.

In equipment skills teaching, the curriculum system covers three core equipment modules: personal protective equipment, wind-driven fire extinguishing equipment, and water-based fire suppression equipment, enabling students to systematically master operation and maintenance across the full spectrum of forest fire suppression equipment.

Personal protective equipment is the fundamental defense line for protecting firefighters' lives. Course instruction covers forest fire protective clothing, protective helmets, protective boots, flame-retardant thermal fleece, protective gloves, and smoke masks, as shown in Figure 2. Through actual wear, sealing tests, and fire environment simulation training, students proficiently master correct wearing, inspection, maintenance, and emergency evacuation skills.

Wind-driven fire extinguishers are the primary equipment for handling surface fires and steady surface fires. Course instruction uses models such as 6MF-28, STIHL-BR600, and ECHO PB-8010, explaining the dual extinguishing principle of high-speed airflow dispersing combustibles and lowering temperature, as shown in Figure 2. Training focuses on operational techniques under different wind speeds and terrain conditions, while introducing new turbojet engine wind-driven equipment to track power form innovation and energy structure transition trends.

Water-based fire suppression is the decisive means for high-intensity fires and crown fires. Course instruction covers reciprocating water guns, forest fire pumps, high-pressure fine water mist extinguishers, and high-pressure pulse spray guns, as shown in Figure 2, explaining the triple extinguishing effects of heat absorption and cooling, oxygen isolation, and combustible wetting. Training emphasizes pump series water supply in mountainous conditions, hose laying, and fine water mist operation.



Figure 2 Core Equipment System for Forest Fire Suppression

4.2 Training System Construction

China's forest fire equipment mainly falls into three core categories: personal protective equipment, ground fire suppression equipment, and aviation rescue equipment. Personal protective equipment includes flame-retardant suits, protective helmets, fire boots, smoke masks, and individual carrying gear, forming the life defense line for frontline firefighters. Ground suppression equipment covers wind-driven extinguishers, high-pressure pumps, chainsaws, igniters, and various fire vehicles, serving as primary tools for direct fire line attack and fire break creation. Aviation rescue equipment includes helicopters, fixed-wing aircraft, and large UAVs, mainly for aerial fire reconnaissance, bucket water bombing, and force projection. Driven by technology empowerment, personal protective equipment is developing toward lightweight and intelligent design; wind-driven extinguishers are transitioning from fuel-driven to new-energy-driven, from axial fans to turbojet engines; water-based equipment is upgrading toward efficient extinguishing agents, new-energy power, and water-wind combined tactics. The intelligent upgrading of the equipment system imposes higher requirements on students' mastery of new equipment and tactics.

Addressing the characteristics of high risk, high cost, and difficult reproducibility of forest fire training, a virtual-real integrated full-scenario training system of virtual simulation, actual equipment operation, and live fire drills is constructed.

Basic skill training is supported by MR mixed reality technology, designing a fire extinguisher virtual throwing training system and a forest fire equipment disassembly simulation system [3]. The virtual throwing system is developed using Unity3D engine plus MRTK toolkit, integrating the PhysX physics engine to achieve projectile trajectories and explosion effects under different wind speeds, directions, and terrains, supporting multi-person cooperative training and automatic scoring. The equipment disassembly simulation system enables 3D visual disassembly and assembly training for major equipment such as wind-driven extinguishers, pumps, and fire extinguishers, allowing trainees to deeply understand equipment construction and working principles.

Specialized ability training relies on tactical training fields, conducting actual equipment operation training with wind-driven extinguishers, pumps, fire extinguishers, and breaking tools, as well as hands-on training with unmanned operation equipment and self-developed detection equipment, enabling students to master skills through real equipment operation in set scenarios for equipment practice and team cooperative training.

Comprehensive combat drills rely on live fire drill sites and actual fire suppression scenes, conducting comprehensive drills in real fire environments, including red-blue confrontation, extreme fire environment simulation, fire line breakthrough, and fire suppression with cleanup, tempering students' abilities in near-real-combat environments.

The three training levels are connected through practical training scenarios, including complex terrain, extreme weather, team coordination, and suppression-with-cleanup scenarios, combinable according to training objectives. A training data collection and feedback mechanism is established to record students' operational data, assessment scores, and process evaluations, building student competency profiles to support training outline revision and improvement.

Looking ahead, training system construction must closely follow the lightweight, intelligent, and unmanned development trends of forest fire equipment, promptly incorporating new energy wind-driven extinguishers, turbojet fire equipment, unmanned tracked fire vehicles, and intelligent integrated helmets into training content, expanding training scenarios from traditional skill training toward intelligent equipment operation, unmanned cooperative operations, and human-machine cooperative suppression, ensuring talent cultivation iterates synchronously with equipment development and precisely aligns with operational needs.

4.3 Evaluation System Construction

Addressing problems of singular evaluation, overemphasis on theory over practice, and overemphasis on results over process, guided by the TIE concept, a multi-dimensional process evaluation system of theory examination, practical evaluation, drill assessment, combat verification, and comprehensive rating is constructed.

Theory examination mainly assesses students' understanding and memory of basic forest fire theory, equipment technology, and tactics, using closed-book exams, online tests, and course papers. Practical evaluation assesses hands-on ability in equipment use, individual skills, and group collaboration, using on-site scoring and skill competition rankings, with practical course scores accounting for no less than 40% of total course grades. Drill evaluation assesses tactical application, command decision-making, and coordination during comprehensive drills, using directing team assessment and red-blue confrontation scoring. Combat verification incorporates students' actual participation in fire suppression into evaluation, with combat weighting up to 20% for outstanding practical performance. Comprehensive rating combines daily assessment scores, learning attitude, and ideological-political quality on the basis of the four-dimensional evaluation above, providing a comprehensive and objective assessment.

Furthermore, a feedback and continuous improvement mechanism is established, feeding evaluation results back to teaching teams and students, and applying them to teaching plan optimization, training plan adjustment, and personalized tutoring, achieving a cycle of evaluation, feedback, improvement, and re-evaluation.

5 PRACTICAL RESULTS

After one round of teaching practice, the TIE concept-guided forest fire extinguishing skills course construction has shown remarkable results, with quantified improvement in students' practical disposal ability. In combat verification, leveraging the standing forest fire rescue readiness unit, reform results were applied to Beijing's comprehensive forest fire suppression drills and practical training. The participating readiness unit successfully achieved tactical objectives including fire line breakthrough, suppression with cleanup, red-blue confrontation, and three-dimensional fire suppression, demonstrating strong practical disposal capability. Forest fire protection students have successively participated in major forest fire suppression operations in Beijing and the Beijing-Tianjin-Hebei comprehensive drills, successfully completing all tasks and receiving multiple letters of commendation. The practical combat level of the faculty team has continuously improved, and students' learning enthusiasm and professional pride have significantly increased.

6 CONCLUSION

1) Under the new situation of technology-empowered transformation and upgrading of forest fire equipment, the TIE concept—with situational teaching as foundation, training-combat-evaluation integration as core, and new outline guidance as direction—provides advanced conceptual guidance and a systematic methodological framework for forest fire extinguishing skills course construction, effectively addressing prominent problems such as instruction-combat disconnection, training-drill separation, and shallow school-team collaboration.

2) Forest fire extinguishing skills course construction is supported by three main pillars—curriculum system, training system, and evaluation system—empowered by underlying digital-intelligent technologies such as MR, virtual simulation, and intelligent equipment, forming a three-in-one, systematically advanced construction pattern.

3) Practice shows that the TIE concept-guided construction reform has achieved remarkable results, with significant improvement in students' practical disposal ability and post competence, providing a reference for forest fire extinguishing skills course construction and teaching reform of similar practical courses.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

- [1] Wu D, Wang S, Guo Z, et al. Exploration on discipline construction and talent cultivation model of forest fire protection. *Forest Fire Prevention*, 2024, 42(4): 35-39.
- [2] Zhu Z, Hu J. Digital transformation of teacher development: platformization, ecologization, practicability. *E-education Research*, 2023, 44(2): 112-119.
- [3] Li M. Digital-intelligent technology empowering higher education: from static knowledge to dynamic ecology. *China University Teaching*, 2024(3): 15-22.
- [4] Zhou J, Du J. Nonlinear mechanism of digital intelligence empowering high-quality undergraduate teaching. *Research in Higher Education of Engineering*, 2026(1): 110-115.
- [5] Li F, Xiong Z. Breakthrough point of educational digital transformation: design and implementation of intelligent textbooks. *Curriculum·Teaching Material·Method*, 2023, 43(3): 82-89.
- [6] Gu X, Wang X, Li S. How is the development level of digital education resources? Evidence response based on the National Smart Education Platform. *Distance Education Journal*, 2024, 42(1): 45-54.
- [7] Peng D, Huang J, Xiao M, et al. Research on information resource construction model of technology think tanks driven by data. *Think Tank Theory and Practice*, 2025, 10(6): 129-138.

- [8] Duan Y. Research on artificial consciousness governance standard clauses and future industrialization path based on DIKWP model. *Information China*, 2025(4): 56-63.
- [9] Wang J, Luo L, An T, et al. Application research of knowledge graph in emergency management: a review. *China Safety Science Journal*, 2025, 21(4): 189-194.
- [10] Zhu G, Zhang M, Yi Y. Prediction of urban rail transit emergency evolution based on knowledge graph. *China Safety Science Journal*, 2024, 34(1): 188-195.
- [11] Guo Z, Du L. Research on modern forest fire emergency command mechanism construction in China. *Fire Science and Technology*, 2025, 44(12): 1837-1843+1849.
- [12] Chang N, Wang B, Cheng S. Exploration on innovative practical classroom of Forest Fire Tactics course. *Chinese Forestry Education*, 2025, 43(3): 66-69.
- [13] Zhou R, Wang P, Qin J, et al. Research on professional competency evaluation method for local forest fire teams. *Fire Science and Technology*, 2025, 44(12): 1850-1856.
- [14] Hazrat A M, Hassan N M S, Chowdhury A A, et al. Developing a skilled workforce for future industry demand: the potential of digital twin-based teaching and learning practices in engineering education. *Sustainability*, 2023, 15(23): 16433.
- [15] Zheng X, Ma L. Research on curriculum and instruction in digital intelligence empowered engineering education based on first principles. *Frontiers in Education*, 2025, 10: 1659412.
- [16] Wu Z, Wang B, Li M, et al. Simulation of forest fire spread based on artificial intelligence. *Ecological Indicators*, 2022, 136: 108653.
- [17] Cato K D, McGrow K, Rossetti S C. Transforming clinical data into wisdom: artificial intelligence implications for nurse leaders. *Nursing Management*, 2020, 51(11): 24-30.
- [18] Fan W, Zai W, Li W. A digital twin approach to forest fire re-ignition: mechanisms, prediction, and suppression visualization. *Forests*, 2025, 16(3): 519.