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Teaching reform and exploration on AI-integrated teaching for fire protection engineering major under the background of smart fire protection

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Abstract
Against the backdrop of the national AI+ Initiative and the rapid iterative development of the smart fire-protection industry, the fire-protection sector has seen growing demand for interdisciplinary engineering talents who master traditional fire-protection theories such as fire dynamics and building fire-protection, and possess capabilities in big-data analysis, machine-vision recognition and intelligent risk assessment. The conventional teaching mode for domestic fire-protection engineering majors currently faces practical contradictions: course content falling behind advances in smart fire-protection technologies, impossibility of physical experiments in high-risk fire scenarios, insufficient reserve of interdisciplinary teaching staff, single-sided practical evaluation approaches, and inadequate industry-education integration. Based on the requirements of Emerging Engineering Education and post requirements of the smart fire-protection industry, this paper analyzes realistic motivations and existing bottlenecks for AI-integrated teaching reform in fire-protection engineering. It puts forward the general reform philosophy of upholding core specialty content and empowering with AI technologies. Teaching reform is explored systematically from seven dimensions: revision of talent-training objectives, reconstruction of curriculum systems, innovation of classroom teaching modes, development of virtual-real integrated practical platforms, construction of multi-dimensional evaluation systems, cultivation of interdisciplinary teaching teams, and establishment of industry-university collaborative education mechanisms. A five-in-one implementation path for AI-integrated teaching is constructed, covering theoretical teaching, virtual simulation, engineering practice, research training and industrial practice. Countermeasures are proposed for practical challenges emerging in reform implementation, including students' misuse of AI tools, imbalanced discipline integration, and pressures from teaching-resource investment. Teaching practices show that this reform scheme effectively narrows the gap between classroom teaching and post requirements of industries, enhances students' comprehensive competence to solve complex smart fire-protection engineering problems, and provides references for digital teaching reform of fire-protection engineering and safety science and engineering majors in peer domestic universities.

Keywords: Smart fire protection, fire protection engineering, artificial intelligence, teaching reform, emerging engineering education, industry-education integration

Introduction
With the large-scale deployment of artificial-intelligence technologies including Internet of Things (IoT), machine vision, deep learning and digital twin in the fire-protection domain, smart fire-protection construction in China has entered the phase of large-scale application. AI-enabled fire-smoke identification, electrical-fire early-warning, intelligent operation and maintenance of fire-protection facilities, fire-scenario deduction and auxiliary emergency-decision systems have been widely deployed in key sites such as large-scale urban complexes, metro tunnels, energy-storage power stations and chemical industrial parks. This transformation drives the fire-protection industry from conventional passive disaster prevention toward a digital mode featuring proactive perception, intelligent assessment and precise early warning. Competent authorities including the Ministry of Emergency Management and the National Fire and Rescue Administration have issued policy documents to advance the digital transformation of fire protection and accelerate the promotion and application of smart fire-protection technologies, putting forward new requirements for digital and intelligent skills of practitioners. Industry surveys indicate that fire-protection technical-service institutions and smart-fire-protection technology enterprises generally report that numerous graduates majoring in fire-protection engineering have solid grounding in traditional fire-protection theories yet lack understanding of emerging technologies such as AI-driven hazard identification, fire-protection big-data analysis and digital-twin-based fire deduction. Consequently, such graduates cannot quickly adapt to posts for smart fire protection, resulting in a persistent shortage of interdisciplinary talents in the industry.

As an engineering discipline subordinate to safety science and engineering, fire-protection engineering's conventional talent training focuses on classic knowledge systems including combustion theory, building fire-protection design, fire-protection water-supply and drainage, smoke control and exhaust engineering, as well as fire-detection and alarm systems. Experimental teaching mostly adopts demonstrative and validating experiments based on physical fire-protection equipment. Given high temperature, toxic fumes and explosion risks of fire, real-fire scenarios cannot be reproduced in teaching environments. Engineering problems such as fire evolution in large-scale complex buildings and emergency dispatch can hardly be trained via physical experiments. A long-standing teaching dilemma persists: theories can be easily instructed while actual combat scenarios are hard to replicate. Under conventional teaching modes, students understand fire-evolution laws mostly via textbooks, codes and limited physical practical training. They receive no systematic training for the full-chain logic of smart fire protection: perception, transmission, analysis, assessment and response. A notable mismatch emerges between talent supply and industrial upgrading.

Emerging Engineering Education calls for conventional engineering majors to proactively respond to industrial changes, promote interdisciplinary integration, and cultivate innovative talents capable of tackling complex engineering problems. Artificial intelligence shall not be simply superimposed onto fire-protection courses. Instead, AI thinking, algorithm tools and big-data capabilities shall be integrated into the competency framework for fire-protection-engineering talents, while core theoretical foundations of fire protection shall be preserved to avoid over-technologization that dilutes core content such as fire mechanisms, fire-protection codes and engineering design. Some domestic universities have carried out explorations such as virtual-simulation teaching and micro-specialty construction for fire-protection majors. Nevertheless, complete AI-integrated curriculum systems, teaching modes and evaluation mechanisms remain to be improved. Many reforms stay at the level of tool demonstration without realizing in-depth knowledge coupling.

Accordingly, targeting talent demands of the smart-fire-protection industry and practical bottlenecks in fire-protection-engineering teaching, this paper conducts research on AI-integrated teaching reform. A complete and implementable reform framework is constructed, difficulties in reform implementation and their resolution paths are analyzed, and practical ideas are provided for the digital transformation of fire-protection-engineering majors.

Development of Smart Fire-Protection Industry and New Competency Requirements for Fire-Protection-Engineering Talents

1. Application Status of Smart Fire-Protection Technologies

Smart fire protection relies on sensor networks, machine vision, edge computing, large-scale models and digital-twin technologies to realize all-weather dynamic monitoring of building fire-protection facilities and fire-risk sources. Current mainstream application scenarios include image-recognition-based intelligent fire-smoke detection, big-data-driven electrical-fire early warning, AI-enabled inspection of fire-protection facilities, fire-evolution deduction via building digital twins, intelligent trace analysis for fire investigation, and intelligent auxiliary decision-making for emergency rescue.

Conventional fire protection depends on manual inspection and fixed-point alarming, suffering from delayed hazard detection, high labor costs and high missing-detection rates. AI technologies can mine and analyze massive monitoring data to identify early hidden fire risks. Digital-twin platforms can reproduce the full process of smoke spread and personnel evacuation in building fires, providing simulation support for scheme optimization and emergency drills. Nevertheless, practical challenges emerge in the implementation of smart-fire-protection systems: data silos among equipment from different manufacturers, high false-alarm rates of AI recognition in complex environments, shortage of real-fire samples for model training, and operation-maintenance personnel who understand neither fire-protection codes nor algorithm logic. The effectiveness of numerous deployed intelligent equipment cannot be fully exerted. Addressing such industrial pain points requires a large number of engineering and technical personnel with interdisciplinary backgrounds.

2. Deconstruction of Core Competencies for Fire-Protection-Engineering Talents in the Smart-Fire-Protection Era

Core competencies of conventional fire-protection-engineering talents center on understanding combustion and fire mechanisms, building fire-protection design, selection and design of fire-protection systems, construction, inspection and acceptance of fire-protection projects, and fire-risk assessment. Following iteration of the smart-fire-protection industry, structural expansion has taken place in post competency requirements. Digital interdisciplinary capabilities are added to original professional competencies, which can be divided into four competency modules.

First, fundamental fire-protection professional competencies: mastery of fire dynamics, building fire protection, fire-protection water-supply and drainage, smoke control and exhaust, automatic fire-alarm systems, fire-protection laws, regulations and technical standards. Competence to complete conventional fire-protection-engineering design, risk assessment and detection-based assessment. This module serves as the foundation of the major and shall not be weakened amid AI integration.

Second, data perception and processing capabilities: understanding of IoT architectures for smart fire protection; competence to interpret fire-protection sensor data, conduct cleaning and statistical analysis of multi-source fire-protection data, identify fire risks behind monitoring and alarm data, and distinguish equipment malfunctions from real fire hazards. Students are not required to develop underlying algorithms in depth, yet they shall understand input-output logics of algorithms and conduct fire-protection-professional verification for AI assessment outputs.

Third, intelligent-simulation and engineering-application capabilities: proficiency in BIM, FDS and Pathfinder fire-simulation tools; capacity to conduct fire deduction and personnel-evacuation simulation with AI tools, establish models for building fire-protection systems via digital-twin platforms, deploy machine-vision-based tools for fire-hazard identification, and participate in scheme design, system commissioning and effectiveness evaluation for smart fire-protection projects.

Fourth, comprehensive assessment and engineering-innovation capabilities: capacity to conduct comprehensive risk assessment for new-type complex scenarios such as energy-storage power stations and large-scale transportation hubs by integrating fire-protection theories, monitoring big data and simulation results; ability to dialectically treat outputs of AI tools, identify defects of algorithm misjudgment, refrain from blind reliance on artificial intelligence, uphold engineering thinking, and possess capabilities for engineering-scheme optimization and technical-problem troubleshooting, together with sound professional ethics and safety-responsibility awareness.

Major Bottlenecks in Conventional Teaching of Fire-Protection-Engineering Majors

Combining actual teaching practices of fire-protection-engineering majors in multiple universities and feedback from employers in the industry, six major contradictions exist between current teaching systems and talent-training objectives for smart fire protection.

1. **Outdated Curriculum Systems and Insufficient Interdisciplinary Integration**

Existing training programs are dominated by conventional fire-protection courses. Content related to artificial intelligence and big data is mostly scattered in elective courses without systematic knowledge chains. Some universities merely offer general-education courses titled Introduction to Artificial Intelligence. Courses are isolated from one another, failing to deeply integrate machine vision and data analysis with professional courses such as fire detection, risk assessment and fire investigation. When learning AI knowledge, students fail to figure out its application in fire-protection-engineering scenarios; when studying professional courses, they lack digital perspectives. A phenomenon of disconnection between fire protection and AI arises. Textbooks fail to keep pace with industrial iteration. Existing textbooks contain limited content on practical smart-fire-protection cases and AI-enabled applications in fire early warning and digital-twin-based deduction.

2. **Infeasibility of Physical Experiments in High-Risk Fire Scenarios and Constrained Practical Teaching**

Fire experiments involve high-temperature conditions, toxic fumes and explosion risks. Large-scale real-combustion experiments are prohibited in university laboratories. Physical practical training can only cover partial operations such as commissioning of alarm controllers and demonstration of sprinkler systems. Physical teaching environments cannot be built for complex-scenario fires including high-rise-building fires, tunnel fires, thermal runaway fires of energy-storage facilities and chemical fires. Conventional experiments are mostly validating experiments. Comprehensive and design-oriented engineering training is insufficient. Students receive inadequate training for risk assessment and emergency response in complex-disaster scenarios and lack intuitive understanding of fire evolution, which imposes objective constraints on cultivation of practical capabilities.

3. **Prominent Shortage of Interdisciplinary Teaching Staff and Gaps in Teachers' Knowledge Structures**

Most teachers for fire-protection-engineering majors have backgrounds in safety science or fire-protection engineering without systematic training in artificial intelligence, big data and digital-twin-system development. Teachers majoring in computer science or artificial intelligence lack fire-protection-professional knowledge, making it difficult to deliver interdisciplinary courses of fire protection + AI. Most teachers can instruct conventional fire-protection theories yet have insufficient in-depth understanding of system architectures for smart fire protection, principles of machine-vision-based fire-smoke identification, fire-protection big-data processing and engineering applications of digital-twin simulation, which hinders implementation of classroom reforms. Two-way channels for faculty mobility between universities and enterprises are not smooth, and front-line smart-fire-protection engineers from industries give in-class lectures on a limited frequency.

4. **Rigid Teaching Modes and Insufficient Active Innovation among Students**

Classroom teaching remains dominated by teacher-centered lecturing. Cases are mostly derived from conventional fire-protection projects, and resources of real-world smart-fire-protection engineering cases are insufficient. Course assignments are mostly standardized design topics, lacking comprehensive tasks from real-world enterprise projects. Students mostly receive knowledge passively and seldom receive training to independently analyze complex engineering problems with simulation and AI tools. Their capabilities to analyze and address non-standard and complex smart-fire-protection-engineering problems need improvement.

5. **Single-Sided Assessment and Evaluation Approaches Unable to Measure Comprehensive Engineering Competencies**

Conventional course assessment relies on final written examinations and course reports, emphasizing memorization of knowledge points. Weights for assessment of practical-simulation operation, data analysis, engineering-scheme design and comprehensive-assessment capabilities are relatively low. Practical-training assessment depends on teachers' subjective scoring. Quantitative evaluation indicators are absent for rationality of students' simulation-parameter setting, standardization of AI-tool utilization and feasibility of schemes. Meanwhile, the popularization of generative artificial intelligence poses new challenges to course assessment: distinguishing students' independent thinking outcomes from AI-generated content.

6. **Inadequate Industry-Education Integration and Limited Conversion of Real-World Industrial Resources for Teaching**

Industry-university cooperation in many universities stays at the level of enterprise lectures, short-term site visits and graduation internships. Real-world monitoring datasets, project cases and system platforms from smart-fire-protection enterprises can hardly be opened for teaching due to data-security and commercial-confidentiality concerns. Disconnection exists between teaching projects and real-world engineering tasks of enterprises. Students have limited access to cutting-edge smart-fire-protection equipment and platforms during their studies. As a result, they have to re-learn post-specific skills after graduation, leading to mismatch between knowledge acquired at university and job-site requirements.

General Philosophy and Objectives of AI-Integrated Teaching Reform

1. **General Philosophy of Reform**

Adhere to the principle of upholding core fire-protection content and empowering with AI technologies. Guided by industrial demands and the philosophy of Emerging Engineering Education, this reform shall not transform fire-protection-engineering major into an artificial-intelligence major. Instead, taking core knowledge of fire-protection engineering as the main thread, artificial intelligence, big data and digital twin shall be integrated as tools and mindsets into the whole process of talent training to avoid misplaced priorities.

Guided by Outcome-Based Education (OBE), talent-training objectives shall be revised centering on core post competencies of smart fire protection. The curriculum system shall be reconstructed, and content of core professional courses shall be updated with AI-integrated elements. A virtual-real integrated practical-teaching platform shall be developed; classroom-teaching modes shall be innovated; a multi-dimensional evaluation system covering professional capabilities, digital competencies and critical-thinking capabilities for AI-tool application shall be established; interdisciplinary teaching teams shall be built; channels for industry-university collaborative education shall be opened. A five-in-one teaching chain shall be constructed, covering theoretical teaching, virtual simulation, engineering practice, research training and industrial practice, so as to cultivate interdisciplinary fire-protection-engineering talents who understand fire protection, master data analysis, excel in assessment and are competent in practical application. Meanwhile, risks brought by artificial intelligence shall be addressed: students shall be guided to rationally utilize AI tools, strengthen engineering critical thinking, and guard against tool misuse and intellectual inertia.

2. Specific Reform Objectives

Talent-training objectives: Revise talent-training programs for fire-protection-engineering majors and clarify positioning for interdisciplinary talents. Graduates shall firmly master conventional fire-protection theories and codes and standards, understand principles of smart-fire-protection technologies, complete scheme design, simulation deduction and risk assessment for smart-fire-protection projects, conduct professional verification for AI outputs, and adapt to posts such as smart-fire-protection engineering, technical services and emergency management.

Course teaching: Complete content upgrading of multiple core professional courses, develop a set of teaching cases integrating fire protection + AI, reform classroom-teaching approaches, promote project-oriented and problem-driven teaching, and enhance training for complex-engineering-problem solving in classrooms.

Practical platforms: Establish a virtual-real integrated practical-teaching system. Virtual simulation shall offset deficiencies of experiments for high-risk scenarios, while physical practical training consolidates operational capabilities for conventional fire-protection equipment, realizing mutual complementarity between virtual simulation and physical practical training.

Evaluation and teaching staff: Construct multi-dimensional course-evaluation systems, form development paths for interdisciplinary teachers, improve industry-university collaborative-education mechanisms, and develop replicable reform paradigms.

Implementation Paths for AI-Integrated Teaching Reform of Fire-Protection-Engineering Major under Smart-Fire-Protection Background

1. Revise Talent-Training Programs and Optimize Talent-Training Objectives and Graduation Requirements

Revise talent-training programs and update graduation competency requirements in accordance with post competency demands of the smart-fire-protection industry. Add entries related to digital-engineering capabilities on the basis of original graduation requirements. Explicitly require students to understand application boundaries of artificial intelligence and big data in fire-protection domains, utilize simulation and data-analysis tools to address fire-protection-engineering problems, dialectically evaluate outputs of intelligent systems, and possess capabilities for analysis and design of smart-fire-protection engineering schemes.

Within the framework of talent-training programs, coordinate general-education courses, professional-foundation courses, major courses and practical segments. Add general-education content for artificial intelligence in the general-education module; supplement big-data fundamentals and basics of Python-based data analysis at the professional-foundation level; conduct content transformation for core major courses; set up elective courses oriented toward smart fire protection. Where conditions permit, a micro-specialty for smart fire protection can be opened for students of this major and other safety-related majors, delivering modular teaching on smart-fire-protection systems, AI-enabled fire-smoke identification, digital-twin-based fire protection and big-data-driven fire-protection risk assessment.

2. Reconstruct Curriculum Systems and Promote AI-Integrated Transformation of Core Major Courses

Adopt the one-course-one-strategy principle for curriculum transformation. Three modes shall be differentiated: developing new interdisciplinary elective courses, embedding content into existing major courses, and upgrading course design and graduation projects. Avoid blindly adding a large number of new courses so as not to impose excessive academic burdens on students.

2.1 Supplement Underlying Digital Knowledge in Professional-Foundation Courses

Set up Fundamentals of Fire-Protection Big-Data Analysis at the professional-foundation stage, focusing on scenario-specific data processing rather than in-depth underlying-algorithm development. Teaching content covers statistics of fire-monitoring data and extraction of risk features. Students shall learn to interpret data from smart-fire-protection platforms, master utilization of basic data-analysis tools, understand input-output logics of machine-learning models, and identify advantages and limitations of algorithms.

2.2 Conduct Embedded Content Transformation for Core Major Courses

Original course frameworks shall not be overturned. Smart-fire-protection and AI-application cases shall be embedded into knowledge points of conventional core courses to realize knowledge coupling.

Fire Detection: Apart from principles of conventional detectors, add machine-vision-based fire-smoke identification and multi-sensor-fusion-enabled intelligent alarming. Analyze strengths and triggers of false alarms for AI image recognition. Explain architectures of smart-fire-protection alarm systems combined with engineering cases.

Fire-Risk Assessment: Introduce big-data-driven regional fire-risk assessment, illustrate approaches for AI-enabled building-hazard identification and risk grading, and deliver case teaching based on urban fire-statistics datasets.

Fire Dynamics and Smoke Control and Exhaust Technology: Illustrate simulation iteration for smoke spread by integrating AI-optimized FDS simulation. Carry out project-oriented simulation training for tunnel and underground-space fires.

Fire Investigation: Supplement AI-enabled fire-trace identification and multi-source-surveillance-video-assisted fire-traceability content. Explain application boundaries of artificial intelligence in fire investigation, and emphasize that AI-driven assessment shall not completely replace on-site physical-evidence analysis.

Fire-Protection-Engineering Course Design: Part of design topics shall be upgraded into comprehensive smart-fire-protection design tasks, for instance, scheme design of smart-fire-protection systems for large-scale commercial complexes. Students shall complete fire-protection design as well as layout of perception nodes, risk-monitoring schemes, and effectiveness evaluation via simulation.

2.3 Set Up Characteristic Elective Courses to Expand Interdisciplinary Capabilities

Offer elective courses such as Smart Fire-Protection Technologies, Digital Twin and Fire-Protection Simulation, and Application of AI in Emergency Response. Focus on engineering application via case-based and project-oriented teaching, explain system architectures and practical implementation difficulties, and avoid complex-algorithm deduction.

2.4 Upgrade Graduation Projects and Strengthen Comprehensive Training

Encourage topics for graduation projects oriented toward smart fire protection, for example, research on machine-vision-based fire-identification schemes, digital-twin-based fire deduction for large-scale buildings, and analysis of big-data-driven electrical-fire early warning. Implement the dual-supervisor system with professional teachers and enterprise engineers. Some topics for graduation projects shall be adapted from real-world enterprise projects. Meanwhile, formulate specifications for AI-tool utilization: students shall mark segments where AI tools are deployed. Principle deduction and result verification shall be emphasized to prevent direct copying of AI-generated schemes. Priority shall be given to assessment of students' professional-analysis capabilities for outcomes.

3. Innovate Classroom-Teaching Modes and Promote Problem-Oriented and Project-Based Teaching

Break the single teacher-lecturing mode and adopt the teaching mode of problem orientation + case-driven learning + AI-assisted classrooms. Introduce real-world industrial challenges into classrooms. Take real-world engineering problems such as metro fires, thermal-runaway risks of energy-storage power stations and intelligent operation-maintenance of large-scale complexes as teaching carriers. Guide students in groups to complete scheme investigation, simulation modeling, data analysis and comparative argumentation of schemes.

Adopt the collaborative-classroom mode of teacher + AI digital teaching assistant. AI undertakes auxiliary work including basic literature retrieval, preliminary debugging of simulation parameters and generation of draft schemes. Teachers devote more energy to guiding students in critical analysis, verifying whether AI outputs comply with fire-protection codes and fire mechanisms, and identifying errors and loopholes in AI-generated content. Organize thematic seminars in classrooms on topics such as Causes of false alarms of AI-based fire-smoke identification and Limitations of digital-twin-based fire simulation, to cultivate students' dialectical thinking and dispel blind faith in artificial-intelligence tools.

Make full use of MOOC resources and virtual-simulation teaching resources. Push short videos of smart-fire-protection engineering cases before class, organize group seminars in class, and assign comprehensive minor projects after class. For instance, in the course of fire-risk assessment, provide students with desensitized regional fire-protection statistical datasets. Students shall conduct mining of risk features in groups and deliver risk-assessment reports.

4. Build a Dual-Driven Practical-Teaching Platform of Virtual Simulation + Physical Practical Training

The biggest contradiction in practical teaching of fire-protection engineering lies in the impossibility of reproducing real-fire scenarios. Virtual simulation shall offset deficiencies of physical experiments, and physical practical training consolidates operation of conventional equipment. The two approaches complement each other, and virtual simulation shall not completely replace hands-on physical training.

4.1 Upgrade Conditions for Physical Practical Training

Improve conventional fire-protection laboratories to guarantee physical practical training for fire-alarm, water-supply-and-drainage, smoke-control-and-exhaust systems, so that students can conduct hands-on system commissioning and troubleshooting to consolidate conventional practical skills. Introduce partial smart-fire-protection hardware such as AI-enabled visual-detection terminals and IoT-based fire-protection monitoring modules to carry out practical training for equipment commissioning and alarm-data analysis.

4.2 Develop AI-Empowered Virtual-Simulation Practical Environments

Virtual simulation of fire evolution: Adopt FDS, Pathfinder and PyroSim combined with AI-assisted parameter optimization to deliver simulation training for smoke spread and personnel evacuation in high-rise-building, tunnel and energy-storage-site fires. Students can repeatedly set parameters for different scenarios and observe fire-evolution laws without risks of real-combustion experiments.

Practical-training platforms for smart-fire-protection digital twins: Deploy teaching-version digital-twin platforms for three-dimensional modeling of building fire-protection equipment. Simulate sensor alarms and equipment malfunctions to train students for risk assessment and deduction of response schemes. The AI module records students' operation trajectories and delivers operational feedback.

Comprehensive virtual drills: Set up comprehensive projects for emergency response to fires in large-scale complexes. Students shall complete the whole process including hazard identification, alarm assessment, emergency-resource dispatch and optimization of evacuation schemes.

Note: Virtual simulation focuses on training for mechanism understanding and scheme-design thinking. Disassembly, assembly and joint-commissioning of key equipment shall rely on physical laboratories to prevent students from only seeing virtual equipment without operating real-world systems.

5. **Establish Multi-Dimensional Course-Assessment and Evaluation Systems**

Targeting features of AI-integrated teaching, abandon the mode where final written examinations determine grades. Construct multi-dimensional assessment systems combining process-oriented evaluation and competency-oriented evaluation, to balance assessment of knowledge memorization, practical simulation and engineering critical-thinking capabilities, while addressing assessment challenges brought by generative AI.

Total course grades consist of multiple components: classroom seminars (20 %), minor course projects and simulation reports (35 %), mid-term tests (20 %), and final assessments (25 %).

Process-oriented assessment: Focus on quality of group-project deliverables, rationality of simulation-model parameters, and logical rigor of scheme argumentation. Assess whether students can verify and revise AI outputs and identify defects of intelligent schemes, rather than merely evaluating textual quality of reports.

Practical-simulation assessment: Assign constrained tasks. Students shall complete simulation modeling and data analysis within prescribed time and deliver on-site scheme deduction, so as to reduce room for large-scale AI-generated assignments finished after class.

Optimization of final assessments: Reduce rote-memorization questions and increase analytical questions for complex engineering cases. Present smart-fire-protection engineering scenarios and require students to analyze strengths and defects of systems and propose optimization schemes, to assess engineering critical-thinking capabilities.

Formulate specifications for AI-tool utilization: Clarify allowable application boundaries of AI tools in course syllabi. Require marking of AI-assisted segments in reports. Core principle deduction and key argumentation shall be finished independently by students. Conduct progress checks for graduation projects, prioritize verification of scheme logics and simulation outcomes, and identify excessive AI-dependence lacking independent thinking.

Introduce partial quantitative indicators for practical-training assessment: rationality of simulation-model parameters, accuracy of hazard identification, and compliance of schemes with fire-protection codes. Combine teachers' comprehensive evaluation and reduce the proportion of purely subjective scoring.

6. **Develop Interdisciplinary Dual-Qualified Teaching Teams**

Teaching staff constitute the key to reform implementation. Targeting deficiencies in teachers' knowledge structures, adopt a two-way approach of in-house cultivation plus external recruitment.

First, improve competencies of in-house teachers: Organize teachers of fire-protection-engineering to participate in special training on smart fire protection, digital twins and big-data applications; encourage joint teaching-research activities with teachers of computer-science disciplines to co-develop course cases; support teachers to participate in on-site engineering practices in smart-fire-protection enterprises to accumulate front-line project experience.

Second, promote two-way faculty mobility between universities and enterprises: Invite technical directors and senior engineers from smart-fire-protection enterprises to serve as off-campus supervisors, deliver lectures on practical-engineering cases and guide course design and graduation projects; organize regular lectures addressing technical difficulties encountered in real-world projects.

Third, establish interdisciplinary teaching teams: Teachers of fire-protection-engineering deliver teaching on fire mechanisms, fire-protection codes and engineering design; teachers of computer-science provide technical guidance for data-analysis and simulation tools. Conduct collective lesson-preparation and jointly develop teaching cases to resolve knowledge blind spots of teachers from single disciplines.

7. **Deepen Industry-Education Integration and Open Channels for Conversion of Industrial Resources into Teaching Resources**

To resolve disconnection between teaching and industries, the core is to convert desensitized real-world enterprise resources into teaching resources.

Co-develop teaching resources: Cooperate with smart-fire-protection enterprises to sort out engineering cases and desensitized monitoring datasets on the premise of data desensitization, and build teaching-case libraries. Enterprises shall open simplified teaching-version platforms for students' course-oriented training.

Co-build practical-training bases: Develop off-campus practical-training bases for smart fire protection. Organize students for on-site visits and post-oriented internships to understand the complete workflow of construction, commissioning and operation-maintenance of smart-fire-protection projects.

Introduce simplified real-world enterprise projects as course assignments: Adapt actual enterprise projects for teaching purposes and adopt them as topics for course design and college-student-innovation projects. Students complete scheme design in groups, with comments and guidance from enterprise engineers.

Leverage disciplinary competitions and college-student-innovation projects to guide students to participate in innovative smart-fire-protection projects, convert classroom knowledge into innovative practical deliverables, and enhance capabilities for solving real-world engineering problems.

Key Challenges in Reform Implementation and Countermeasures

In the advancement of AI-integrated teaching reform, practical challenges emerge including tool misuse, imbalanced integration scales and pressures of resource investment. Response mechanisms shall be established in advance.

1. **Guard against Students' Excessive Reliance on AI Tools and Deterioration of Professional Critical-Thinking Capabilities**

Generative artificial intelligence can rapidly output simulation schemes and report texts. Some students directly copy AI outcomes without mechanism-oriented thinking, and even overlook fire-protection codes. AI outputs often contain errors in fire-protection-code compliance and fire-mechanism logics. Without constraints, students' basic professional competencies may deteriorate.

Countermeasures: First, repeatedly clarify positioning in teaching: AI serves as an auxiliary tool and shall not replace engineering thinking and professional judgment. Set up special cases in classrooms demonstrating typical errors in AI-generated fire-protection schemes to train students' screening capabilities. Second, define utilization boundaries for tools: principle deduction and key argumentation shall be completed independently by students, and AI-assisted segments shall be marked in reports. Third, increase assessment segments for on-site practical operation, on-site modeling and in-class time-constrained case analysis to reduce proportion of purely after-class reports. Fourth, integrate curriculum-based ideological and political education to strengthen awareness of fire-protection-engineering responsibility: fire-safety schemes bear direct implications for life and property safety. Machine outputs shall not be followed blindly, and assessments must rely on professional knowledge.

2. **Control Integration Scales and Avoid Dilution of Core Content of Fire-Protection Major**

Two extreme tendencies may arise amid reform: formalistic reform merely adding a small amount of AI-popularization content without genuine integration; excessive bias toward algorithm technologies with extensive teaching on underlying deep-learning development, which squeezes class hours for core courses such as fire dynamics and building fire protection and turns the course into an artificial-intelligence-oriented curriculum, thus losing essential features of fire-protection-engineering major.

Countermeasures: Adhere to the principle of fire protection as the foundation, AI as the tool. Reforms shall revolve around complex engineering problems of fire-protection engineering. Curriculum transformation focuses on application-level content: how to leverage AI, simulation and big-data technologies to solve fire-protection-engineering problems. Undergraduate students are not required to conduct underlying-algorithm research and development. All newly added teaching content shall correspond to specific fire-protection-engineering scenarios, avoiding empty discussion of artificial-intelligence technologies divorced from the major. In the revision of talent-training programs, class hours for conventional core courses shall be protected from excessive compression.

3. **Address Pressures of Insufficient Platform-Construction Funds and Shortage of Teaching Resources**

Construction of virtual-simulation platforms and digital-twin practical-training systems requires capital investment. Many local universities are constrained by limited funds and cannot procure complete commercial platforms in one step.

Countermeasures: Adopt the strategy of prioritizing open-source software and phased construction. Prioritize mature open-source or teaching-version simulation software such as FDS and Pathfinder for teaching to reduce pressures of platform procurement. Make full use of fire-protection-related simulation resources on national-level virtual-simulation experimental-teaching sharing platforms. Strive for teaching-version software authorization via enterprise cooperation. Prioritize development of soft resources such as course cases and datasets, and conduct phased iteration of hardware platforms to avoid pursuing full completion in one step.

4. **Data-Security and Commercial-Confidentiality Issues in Industry-Education Integration**

Raw monitoring data of real-world enterprise projects involve building-related privacy and commercial secrets and cannot be directly adopted for teaching.

Countermeasures: All enterprise data applied in teaching must be desensitized, erasing building-location information and sensitive equipment-related data. Rewrite project cases for teaching purposes, retaining engineering logics while removing commercially sensitive information. Adopt simulation-generated simulated datasets to replace raw real-world data, balancing training effectiveness and data security.

Preliminary Outcomes and Reflections on Reform

The above-mentioned reform philosophy has been piloted in partial courses of fire-protection-engineering major in the author's university, implemented in *Fire Dynamics*, *Fire* Detection and course-design segments. Phased outcomes have been achieved via curriculum transformation, project-oriented training and virtual-simulation-based practical teaching. Students have significantly improved their understanding of architectures for smart-fire-protection systems, AI-enabled fire early warning and digital-twin-based deduction. In course projects, students can analyze fire-protection schemes for complex scenarios such as large-scale complexes and tunnels with simulation tools. The proportion of graduation-project topics oriented toward smart fire protection has increased, and more topics for college-student-innovation projects and disciplinary competitions focus on smart fire protection. Feedback from employer surveys shows that students in pilot classes demonstrate markedly better adaptability to smart-fire-protection-related posts than previous cohorts, and can quickly comprehend engineering logics of intelligent fire-protection systems.

Meanwhile, reform practices reveal aspects awaiting improvement. First, high-quality teaching cases of fire protection + AI ready for direct application remain scarce, requiring continuous accumulation in collaboration with enterprises. Second, improvement of teachers' interdisciplinary capabilities constitutes a long-term process. Upgrading competencies of all teachers cannot be accomplished in the short run. Third, students exhibit large gaps in digital foundations. Some students have weak capabilities in data analysis, calling for layered instructional design. Fourth, evaluation systems require continuous iteration to further improve screening mechanisms for AI-assisted deliverables. Teaching reform is not a one-time task and needs dynamic optimization keeping pace with iterations of smart-fire-protection technologies.

Conclusion

Digital transformation of the smart-fire-protection industry brings brand-new challenges to talent training for fire-protection-engineering majors. AI-integrated teaching reform for fire-protection-engineering is not a simple addition of several artificial-intelligence courses but a systematic transformation of the whole talent-training chain. Its core lies in upholding core content of fire-protection-engineering major and adopting artificial intelligence, big data and digital twin as empowering tools, to offset deficiencies of conventional teaching including insufficient practical training for high-risk complex scenarios and disconnection from cutting-edge industrial developments.

This paper constructs a complete reform path from seven dimensions: revision of talent-training objectives, reconstruction of curriculum systems, innovation of classroom modes, development of virtual-real practical platforms, multi-dimensional evaluation systems, cultivation of interdisciplinary teaching staff, and industry-university collaborative education. Countermeasures are proposed for practical difficulties including AI-tool misuse, imbalanced integration scales and resource constraints. Teaching reform calls for dynamic iteration. Subsequent work shall continuously align with industrial technological updates, keep optimizing course cases and practical projects, strike a balance between conventional professional foundations and interdisciplinary digital competencies, cultivate more interdisciplinary engineering talents competent for smart-fire-protection construction, and provide talent support for national fire-safety undertakings.

Declaration of competing interest

The author declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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