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A PTF FRAMEWORK FOR UNDERGRADUATE INNOVATION EDUCATION: INTEGRATION WITHIN THE MODERN EMERGING ENGINEERING EDUCATION

JinMing Zhao*, JiaXin Cui, Qiang Gong, JiaRen Li, XiaoNan Wang, Ao Li, Xu Liang, JingYang Ge, HeBin Wang, YaoYao Shen
Beijing University of Chemical Technology, Beijing 100029, China.
Corresponding Author: JinMing Zhao, Email: zuqiuou@163.com

Abstract: In response to the reform imperative of engineering education under modernization, a novel education model named PTF (one-Pyramid, Two-axis, Four-driving) learning ecosystem is proposed and validated. The model comprises a Pyramid-style, hierarchical sequence of four types of innovation and entrepreneurship competitions—foundation, professional fundamentals, professional integration, and top comprehensive—along with a progression of projects from college-level scientific innovation to national-level innovation and entrepreneurship initiatives. Two platforms are established: an Innovation Education-Service-Platform and an Integrated-Practice-Platform, which enable sustained positive attention and growth in project activity, thereby enabling qualitative change. Four driving elements are identified: Cultural Driver, which builds an immersive environment for innovation; Institutional Driver, which provides structured guidance and motivation; Resource Driver, which supplies the physical and intellectual infrastructure; and Outcome Driver, which ensures practical validation and value creation. The PTF model offers a viable paradigm for the reform of modern engineering education to cultivate adaptable and innovative talents with in-depth thinking abilities who can tackle future complex challenges.
Keywords: Innovation education; Modernized education; Engineering practice

1 INTRODUCTION

Currently, technological advancement has emerged as a decisive factor in economic development, and the strength of science and technology has become a crucial indicator for measuring a nation's comprehensive national power. The demand for scientific knowledge and outstanding talents in national undertakings is more urgent than ever before [1]. Against this backdrop, as the forefront of scientific and technological innovation and the cradle of talent cultivation, universities are in an urgent need to carry out localized education reform and model innovation. Therefore, new engineering education, which emphasizes interdisciplinary integration, focuses on innovation ability, and promotes in depth industry university research cooperation, is bound to become an important part of modern education [2-3].
This research proposes an educational framework called the "PTF" model (a "one-Pyramid, Two-axis, Four-driving" ecosystem) (see Figure 1). It focuses on constructing an undergraduate talent cultivation model with professional characteristics, interdisciplinary integration, and industry academia cooperation, led by students' scientific and technological innovation [4-5].

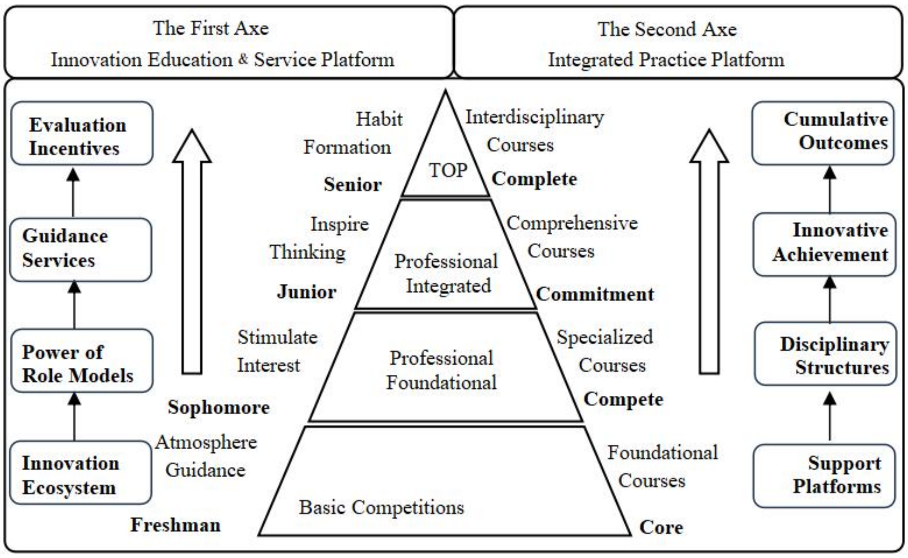

Figure 1 "PTF" Innovative Education Model (The "One Pyramid, Two Axes, Four Drives" Innovative Education Model) Diagram

In comparison with international mainstream models such as CDIO, OBE, and PBL, the PTF model demonstrates unique systematic integration advantages. This model does not simply transplant existing concepts. Instead, it takes the "pyramid-style" competition system as a prominent means to deeply integrate CDIO's whole cycle engineering thinking, OBE's output-oriented logic, and PBL's project driven method, thus constructing a "dual axis, four drive" collaborative ecosystem. Its innovation lies in the seamless connection of competitions, courses, projects, and industrial needs through an institutionalized management service platform and a physicalized practice incubation platform. It not only realizes a quantifiable and phased ability achievement path under the OBE concept but also breaks through the limitations of traditional PBL courses. It forms an educational mechanism that runs through the entire talent cultivation chain and supports the whole process of "innovation creation entrepreneurship," providing an operational systematic solution for the localization practice of engineering education.
The question "How to cultivate compound talents capable of addressing modern engineering challenges?" This paper aims to elaborate on the theoretical basis, structural design, and implementation effectiveness of this model, hoping to provide some insights for global higher education institutions to innovate engineering talent cultivation models and deepen the integration of innovation education.

2 ESTABLISHING A HIERARCHICAL MASTERY FRAMEWORK: BUILDING A “PYRAMIDSTYLE” COMPETITION SYSTEM FOR INNOVATION CAPACITY TRAINING

The " Pyramid " (see Figure 2) refers to a "pyramid-style" dual innovation ability training system in the PTF model that features hierarchical progression and step by step improvement. This system takes competitions as the carrier, integrates dual innovation education throughout the entire process of talent cultivation, and systematically encompasses four levels of competition types: "Basic Competitions; Professional Foundational Competitions; Professional Integrated Competitions; and Top Comprehensive Competitions" [6]. It also promotes the gradual advancement of project practice from entry-level academic training to national level innovation and entrepreneurship projects, thereby achieving systematic and sustainable growth in students' abilities [7].

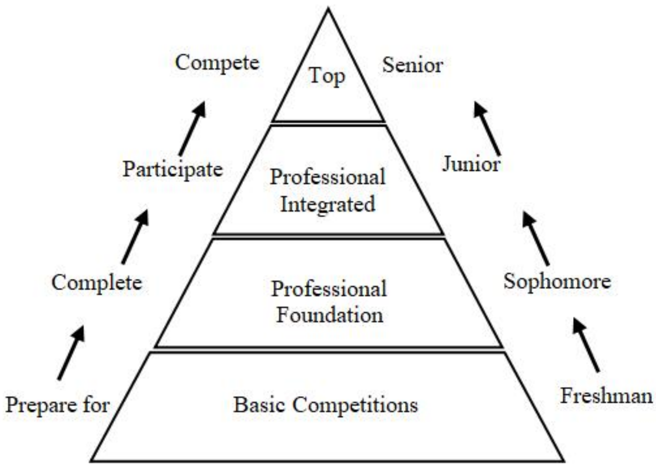

Figure 2 The "Pyramid-Style" Competition System for Cultivating the Innovation Ability of College Students in Higher Education Institutions

2.1 Pyramid-style Competitions System-The Foundation Type

At the fundamental level, the system conducts academic paper competitions, creative design contests, and presentation events to primarily stimulate the innovative interests and entrepreneurial awareness of lower grade students [8]. These competitions have flexible topics and moderate thresholds, focusing on enlightenment and experience, aiming to guide students to complete the entire process training from conception to practice. The organizational strategy emphasizes extensive mobilization, process guidance, and completion guarantee. The purpose of these competitions is to stimulate students' interest in innovation and entrepreneurship, cultivate their awareness, and are mainly targeted at lower grade students (freshmen and sophomores). The professional knowledge involved in the submitted works is relatively simple and superficial. The main function is to cultivate students' interest in participating in innovation and entrepreneurship. The evaluation of the projects mainly focuses on the completion of the project and the successful conclusion. Therefore, the approach to organizing such competitions is mainly to encourage participation through extensive mobilization, pay attention to the selection of topics for guidance, and continuously follow up to ensure progress.

2.2 Pyramid-style Competitions System-The Professional Foundation Type

At the fundamental professional level, the system leverages various types of competitions, including engineering skills competitions, mathematical and physical contests, experimental design competitions, and cultural and creative contests, to promote the extension and application of the professional knowledge from the first classroom in the second classroom. These competitions emphasize the practical transformation of basic knowledge and the inspiration of interdisciplinary thinking, facilitating the shift of students' learning mode from "passive acceptance" to "active exploration." Such competitions represent a continuous extension and content expansion of the basic professional knowledge from the first classroom in the second classroom. They provide students with a means to practice their basic professional knowledge and constitute a process of active relearning and rethinking through heuristic discussions, in contrast to the passive indoctrination-based teaching model.

2.3 Pyramid-style Competitions System-The Professional Integrated Type

On senior professional level, the curriculum system includes high level professional contests like electronics information, intelligent manufacturing, mechanical innovation, mathematical modelling and industrial design. Through these competitions, the students can fully use the advanced mathematics, essential professional courses, and interdisciplinary knowledge to deal with the engineering problems, thus training their systematic thinking, integrated design and team work abilities. This kind of competitions enable senior students' basic course (higher mathematics, college English, college physics) integrated learning and skillfully applying, as well as student professional courses learned during in their college studies.

2.4 Pyramid-style Competitions System-The Top Level

At the TOP level are comprehensive competitions, with representative events such as the national innovation and entrepreneurship competitions like the "Internet +" and the "Challenge Cup." These competitions comprehensively assess students' overall qualities in aspects such as professional knowledge, innovative practice, market insight, team management, and communication skills. This type of competition places greater emphasis on the improvement of students' all-around development in terms of morality, intelligence, physical fitness, aesthetics, and labor. It not only requires students to have strong abilities in learning, applying, and innovating in comprehensive professional knowledge but also demands that participating students possess high resilience, a positive mindset, and good communication skills. This has played a positive role in promoting the all-around development of students [9].

It is a well-designed pyramid system, with obvious goals. This is a systematic design scheme, which creatively implements the practice of "innovating innovative qualities" to achieve "developing comprehensive qualities". The PTF model offers a systematic system path to help engineering colleges replicate and apply the mode and implement the innovation and entrepreneurship education.

3 SERVICE-ORIENTED ACTIVE GUIDANCE: BUILDING A DUAL PLATFORM OF "TWIN AXES AND FOUR DRIVES" FOR INNOVATION

In the PTF framework, the "Two Axes" are the Innovation Management and Service Platform (management and service axis) and the Integrated Practice Platform (practice incubation axis). These axes are deeply coupled and mutually reinforcing, forming a closed-loop enabling process from awareness to outcomes [10].

3.1 The first axe: innovation education management and service platform

3.1.1 The first driving factor of the PTF educational model is the atmosphere created to stimulate students' innovative consciousness and the exemplary power that boosts students' confidence in innovation

In the implementation of the "PTF" education model, creating an innovative atmosphere and leveraging the leading role of role models are the two core strategies for stimulating students' innovation awareness and building their confidence in innovation. The effectiveness of these strategies has been repeatedly verified in practice [11-13].

To systematically create an innovative atmosphere, the model relies on the "Innovation Management and Service Platform" to build a multidimensional and immersive innovation culture ecosystem. The platform integrates teaching staff from both inside and outside the school, corporate mentors, and outstanding senior students to form a structured mentoring team. It provides full process project registration and management, competition coordination, innovation and entrepreneurship training, and achievement transformation services. Additionally, a series of innovation practice courses are offered to fully integrate innovation education into the talent cultivation process. The atmosphere creation emphasizes "early enlightenment and strong immersion" to cultivate students' knowledge application and technological innovation abilities and form a cultural atmosphere centered around campus academic and technological innovation activities. For example, during the freshman enrollment period, professional awareness and innovation kickoff activities are carried out. Through various means such as lectures by academicians and experts, industry frontier lectures, exhibitions integrating science and technology with art, and low threshold creative competitions, students are exposed to a strong innovative environment from the very beginning of their college life. This subtly stimulates their curiosity and exploration drive, allowing freshmen to immerse themselves in a strong technological innovation atmosphere and experience the joy brought by rich practical activities from the day they enter the campus, thereby stimulating their innovation awareness.

The power of role models is infinite and represents boundless positive energy. Role models are like flags that represent the direction; they are also resources that gather strength. By learning from and promoting the noble characters and advanced deeds of role models, students can use role models as a mirror to clarify their direction, recognize their gaps, purify their souls, and elevate their spiritual realm in learning and practice. In leveraging the power of role models, it is believed that special attention should be paid to the creation and dissemination of "approachable role models". Regular activities such as science and technology innovation project reports, excellent achievement exhibitions, experience sharing by award winners, and cross grade exchanges can be organized to enable students to directly access the success stories of their peers or senior students. They can learn from their failures and realize that innovation is not exclusive to the elite. These real narratives from "people around them" can greatly enhance students' self-efficacy and convey a positive belief that "with dreams, a willingness to try, perseverance, and success will follow"(see Figure 3). By ignoring the burden of "judging heroes by results", students can view innovation as a practical and achievable process, effectively dispelling their fear of innovation and inspiring more students to take the first step in innovation practice.

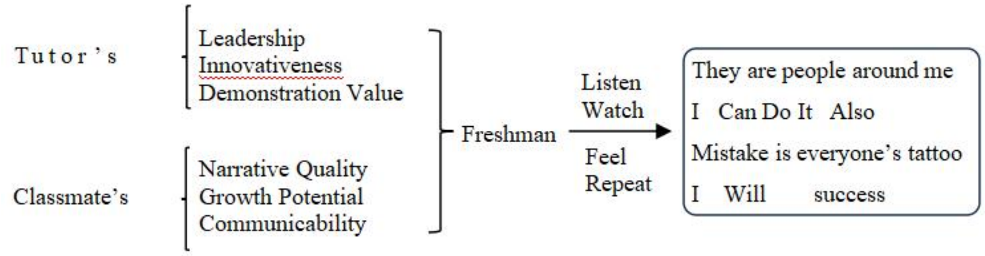

Figure 3 How the People around Students Influence and Stimulate Their Innovative Consciousness

In summary, through the systematic atmosphere-building project on campus and the warm-hearted role model leading work among students, the "PTF" model has successfully created an innovation education environment with a strong innovation awareness, easily perceptible achievements, and an atmosphere where students are encouraged to take risks and learn from mistakes. This provides crucial cultural soil, emotional support, and emotional value for the germination, development, and long-lasting confidence of students' innovation and entrepreneurship awareness [14].

3.1.2 The second driving force of the PTF innovative education model is the comprehensive guidance provided by universities to students during the innovation process and the incentive system for cultivating innovation talents

In the research on the "PTF" education model, this project holds that universities should systematically construct a guidance and management system centered on student development and a scientific assessment and incentive system. This is the core guarantee for standardizing students' innovation and entrepreneurship processes and ensuring the continuous output of innovation and entrepreneurship talents. It can effectively guide students to shift from " Spoon-Feeding " learning to " Intrinsic-Motivation-Driven " active innovation [15].

The "PTF" education model emphasizes that management and guidance covering all aspects of the entire lifecycle of innovation and entrepreneurship projects, including Team Formation, Mentor Guidance, Resource Coordination, Process Supervision, and Research Commercialization, can standardize the responsibilities and work processes of all parties to the greatest extent (see Figure 4). It serves as an important cornerstone for the orderly and efficient progress of innovation activities. The cultivation of innovative talents requires a rigorous and comprehensive management system, reasonable and effective management methods, and a complete guidance process, which play a crucial role in the cultivation and management of innovative talents. Meanwhile, comprehensive management and guidance can also minimize the inefficient management and resource waste that often occur in the early stages of innovation activities, enabling students to focus on creating more scientific and technological achievements in a standardized and stable innovation practice environment.

Student motivation is an essential element of the education administrative system (see Figure 4). It motivates student learning through promoting the transformation of external driving factors for students into their own initiative to achieve personal goals, inner drive and positive conduct, which is conducive to students' study and personality formation [16]. As everyone knows, in the fundamental of education students are the first object and motivate work is especially important in their all-round cultivation. "PDF" new teaching model holds that college needs to formulate special incentive system. In this manner, students' performance of innovation – oriented activities like Science and Technology competition, Project Based Practice, Patent applications can be identified from four dimensions, Innovation Knowledge, Innovation Capability, Innovative Thinking and Innovation Skills, their learning attitude and Team Collaboration, Problem Solving Skill and Moral Resilience should be appropriately identified and must be amply rewarded. This method facilitates a scientific, full process, and complete evaluation of the innovation qualities and development potential of the students. In addition, it also allows those students who have only studied their results to objectively analyze their developmental trajectories and helps these students to effectively take the initiative to engage in innovation practice activities, which is conducive to stimulating a larger number of students with innovative thinking and awareness.

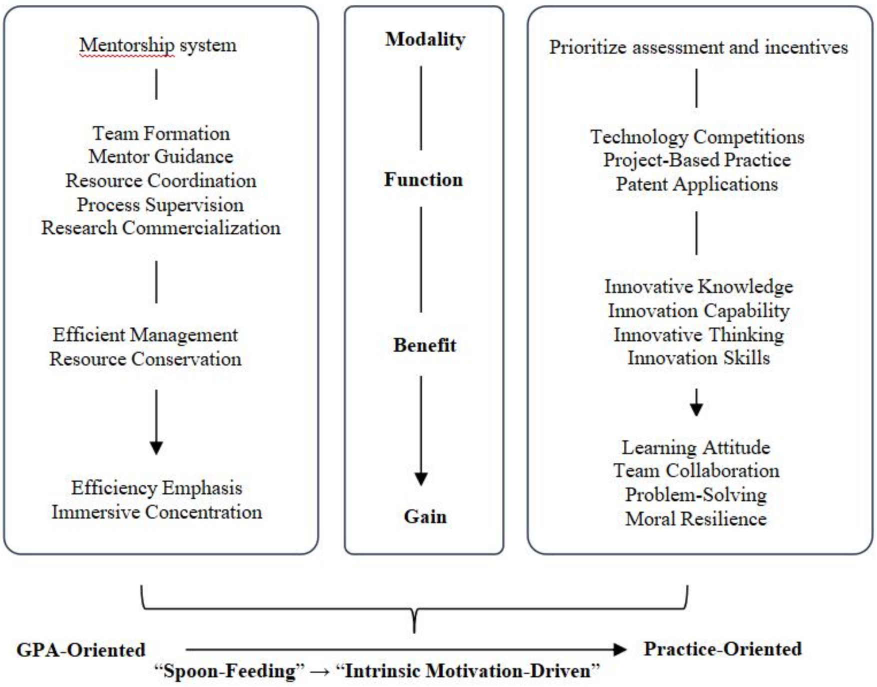

Figure 4 Innovative Guidance and Performance Evaluation Incentive Measures for the PTF

Therefore, this research concludes that providing students with comprehensive innovation guidance and assessment and incentive measures for their participation in innovation activities will not only stimulate the enthusiasm of students with existing innovation intentions but also guide more traditional "GPA-oriented" students to "Practice-Oriente" students who focus on cultivating innovation capabilities and actively engage in innovation practices. The establishment of the PTF education model not only effectively expands the influence and beneficiary groups of innovation and entrepreneurship education but also provides institutional support for the systematic cultivation of compound talents meeting the needs of modern new engineering.

3.2 The Second Axis: Integrated Practice Platform

The practical platform belongs to the physical support entity conditions, placing greater emphasis on physical space, equipment and tools, real-world projects, and human resources. It serves as a "battlefield" where ideas are transformed into reality. In the research on the "PTF" education model, we have found that efficient management and collaboration, along with forward looking interdisciplinary curriculum design, are the key pillars for ensuring the orderly progress of projects and cultivating an environment conducive to the growth of innovative talents. They also provide continuous impetus and resource guarantees for the cultivation of undergraduate students' innovation capabilities.

3.2.1 The third driving force of the PTF model lies in the innovation platforms at various levels established by universities and the diverse types of disciplines set up to cultivate an environment conducive to nurturing innovative talents.

The "PTF" education model posits that the innovation and entrepreneurship practice platform should encompass the entire chain of "innovation-creation-entrepreneurship" in terms of physical space and resource support. It necessitates the integration of all aspects, ranging from basic training (engineering training centers), idea realization (maker spaces), professional R & D (professional laboratories) to business incubation (incubation bases). Relevant work such as institutional standardization, interdisciplinary integration, practical training, and industry education integration should be carried out [17]. The main issues it aims to address are: "Where to carry out the activities, what resources to use, what tasks to undertake, and how well the tasks are accomplished?" (see Figure 5). To this end, this education model contends that universities should formulate detailed regulations for physical spaces (such as the "Management System for Innovation Centers", the "Usage System for Engineering Competence Training Studios", and the "Innovation System for Creative Culture Studios") to provide students with documentation guarantees for using hardware facilities. The practice platform offers students' teams opportunities for real world innovation and entrepreneurship, allowing them to engage in practical exercises as if on a real battlefield. To further enhance students' self-initiated practical abilities, students are allowed to form teams freely to independently complete projects based on the project topics of various innovation laboratories and studios. Through this approach, college students can experience self-learning and independent thinking, gradually become familiar with the inquiry-based learning method centered around problems and topics, and effectively master the methods of thinking about and solving problems [18-19]. Meanwhile, improvements in regulations and innovations in management methods for various innovation laboratories and studios have been made to ensure that students have full autonomy during their free time, without being restricted by venue or time. Students

can put their ideas and creativity into practice in these innovation laboratories and studios and focus on innovation and development.
In addition, innovative talents not only require sufficient professional and cultural knowledge reserves but also possess scientific and rigorous logical thinking abilities. In the entire process of cultivating innovative talents, the discipline setup serves as the foundation, and a teaching team with innovative awareness and scientific research capabilities is the guarantee [20]. Therefore, the "PTF" education model emphasizes that the discipline ne setup should highlight the in-depth integration of "innovation literacy" and "professional competence"[21], promoting the transformation of the curriculum system from basic, professional, and comprehensive types to interdisciplinary, project based, and cutting-edge ones (see Figure 5). Specifically, it is necessary to actively coordinate all teaching staff to focus on cultivating students' innovative awareness in teaching and establish the concepts of personalized development and diversified education. For engineering students, it is particularly important to offer multiple and adequately timed innovation and entrepreneurship courses at an early stage in their lower grade studies, such as the 32hour "Mechanical Innovation Design", the 40hour "Single Chip Microcomputer Application Practice", and the 32hour "Introduction to Python", which provide a solid foundation for teachers and students to engage in innovation and entrepreneurship [22].

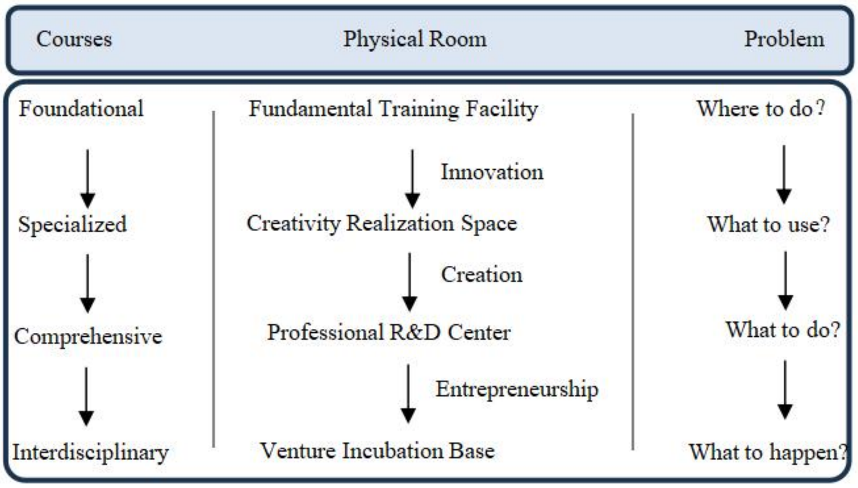

Figure 5 PTF's Various Innovation Platforms and Diagrams of Multiple Types of Disciplines

3.2.2 The fourth driving force of the PTF model is the abundant innovative achievements and high-quality educational outcomes
In the "PTF" education model, practical training and platform construction are regarded as the key links for realizing the transition of innovation talent cultivation from theory to practice and from ability building to value creation. This model effectively connects the "last mile" for the implementation of innovation education by building an open and highly supportive integrated practical platform and implementing the teaching strategy of "real environment, real projects, real practice"[23-24].
The educational philosophy of "PTF" places great emphasis on the collaborative learning effect of the practical platform among industry, academia and research. Taking an innovation training camp of a university in Beijing, China as an example, through the leadership of the university and industry associations, more than twenty enterprises donated high-end equipment worth nearly ten million yuan, jointly building a school enterprise integrated talent cultivation base, achieving a deep integration of industry academic research. In this case, enterprises not only provided advanced equipment, but also transformed actual engineering problems into students' innovation projects, enabling seamless connection between practical teaching and industrial demands, truly forming a "resource sharing, topic core search, and talent coeducation" educational ecosystem integrating industry and education [25-26].
The significant positive change in the distribution of post-graduation destinations of students, with a noticeable rise in further study rate and drop-in direct employment rate, reflects the efficacy of the PTF model in inculcating higher competences and confidence for performing successfully at the post graduate level. Such transformation from focusing on employment to focusing on more academic level goals reflects the essential quality improvement of training and cultivation of engineering talents, which is achieved by organizing "pyramid-shape" competition mechanism and cultivating tutor systems (“The First Axe”) and building a solid project-based practice platform (“The Second Axe”) in an orderly manner. It has successfully promoted a professional development system that focuses on long-term professional growth, innovation potential and coping ability in the face of fluctuations in the labor market. Thus, in this paper we believe that the PTF model is a feasible and efficient model for the current engineering education reform which should change from job-oriented skills training toward the development of various adaptive and innovative talents with depth of thinking to solve future problems.
Data Sources and Sample Description (To protect student privacy and comply with relevant data management regulations, specific major information of the samples has been anonymized. However, it is ensured that there are no significant differences in major backgrounds and admission scores between the experimental group and the control group). This study employs a quasi-experimental research method. To evaluate the effectiveness of the PTF model, the

data are sourced from undergraduate students in a certain engineering major category of a university who participated in the PTF model as The Experimental Group, and students from the same major category in the three adjacent previous cohorts as reference Group 1, Group 2, and Group 3 (see Figure 6).

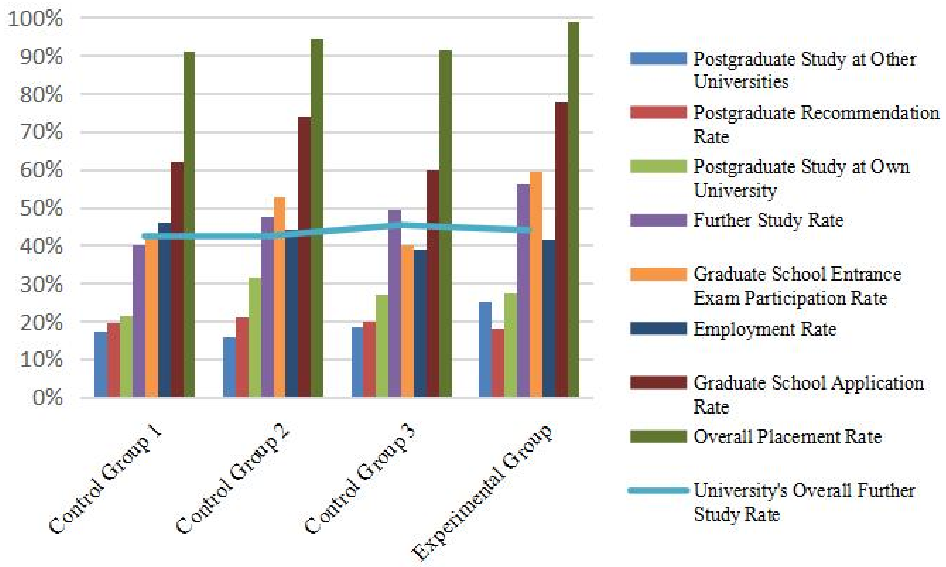

Figure 6 Comparison of Key Indicators of Graduation Destinations between the Experimental Group and the Control Group in the PTF Model

The experimental group (Experimental Group1)'s further study rate, postgraduate application rate, exam participation rate and placement rate are far beyond the control groups, and it has no overlarge unemployment rate, which is the powerful empirical proof for the effectiveness of PTF model. Empirical facts indicate that the PTF model has effect that has been greatly optimized from conventional model: the total placement rate of experiment group reaches 99.12%, far more than control group (highest 94.59%), and the unemployment rate decreases to 0.88%. Its main strength is rebuilding the high-quality further study route. The rate of further studying of experiment group (56.03%) is not only higher than all control groups (the maximum value is 49.57%), but also 12.11 percentage points higher than the school average. This result is the result of the positive mechanism of "Promote Research in Competition" generated by PTF model——Both the rate of application (77.88%) and the rate of postgraduate admission (59.59%).The proportion of the experimental group that has achieved a new level has reached 59%， the expected admission rate for postgraduate entrance examinations is as high as 76.5% and shows that this measures can improve the students' core competitiveness. At the same time, the proportion of students from the experimental group who applied for postgraduate schools outside the university is 25.37%，comparable to the proportion of those of applying for postgraduation of their own university 27.43%，showing that students received recognition from superior universities. Overall, this information indicates that the PTF model by innovative practice realizes students' development mode transformation from "the dependency of getting sure chances to master's degree programs" or "being an unselfconscious employee" into "postgraduate-study-oriented" and "good-employment supplement" type with higher quality, realizing systematic talent training improvement.

In addition, our research group has been actively engaged in innovation education for many years and conducted long term follow up studies. Detailed statistical data show that its effectiveness has been fully verified, demonstrating good scalability and sustainability, and forming the "snowball effect" of innovation and entrepreneurship education [11]. Empirical data shows that this model has achieved remarkable results in enhancing students' participation, project quality, and the level of industry academia integration. The effective realization of the PTF model occurs through iterative and scalable outcomes. Among representative practice and innovation platforms, significant activities have been conducted within a single academic year, comprising more innovation practice instruction hours, greater coverage of student participants, innovation and entrepreneurship guidance events, student engagement, early year innovation entrepreneurship teams incubated, and honors and award recognition. The data presented below are provided for reference. The data presented below demonstrate the effectiveness of innovation education：

More than 400 hours of innovation practice instruction.

More than 3,000 students participated.

18 innovation and entrepreneurship guidance events were organized.

Approximately 7,107 students were engaged, with an average of 3.5 activities per participant.

Incubation of 150 early year innovation entrepreneurship teams, encompassing 169 projects.

Total student participants exceeded 1,600, representing more than 80% coverage.

A total of 385 campus level or higher honors were conferred; 33 groups received provincial or municipal honors; 15 groups attained national level honors.

Notable milestones were achieved in national competitions, including the Challenges Cup and related engineering training events.
Annual patent filings totaled 5, with 6 teams joining campus entrepreneurship bases.
Emergence of representative student innovation exemplars.

4 BREAKTHROUGH AND CONCLUSION

First and foremost are the historical breakthroughs achieved in national competitions such as the Challenges Cup and other related engineering training events; another breakthrough is the annual patent filings totaling five, with six teams joining campus entrepreneurship bases, as well as the emergence of exemplary student innovators. Furthermore, a practical example of such a PTF from Beijing illustrates joint development created by the campus and industry associations. Over one million dollars' worth of high-end equipment was donated by more than 20 enterprises. This example shows how the collaboration can align practical teaching with real industry needs and promote shared resources and joint topic development, coeducating talent. To sum up, the PTF model is a scalable and sustainable model that provides a snowballing effect on the spread and depth of innovation, growth in participation and project quality, and the integration of industry needs at a higher education level. It helps enable broader outreach, systemic reform, and the cultivation of modern, cross disciplinary talents in engineering education.
Science and technology innovation education for students is a key and distinctive aspect of modern education in higher education institutions. When students have in depth knowledge of and passion for their majors and continuously enhance their innovation and entrepreneurship abilities, it will further contribute to the improvement of their comprehensive qualities. A successful innovation and entrepreneurship education model not only needs to provide positive incentives and explore the systems and cultures conducive to the growth of innovative talents, but also needs to focus on addressing institutional and mechanism obstacles as well as the problem of resource misallocation. This can more effectively serve the goal of cultivating new engineering talents and is of great significance for optimizing the existing education model and building a more systematic, open, and supportive innovation education ecosystem.

COMPETING INTERESTS

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

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THE CONSTRUCTION OF "OPERATIONS RESEARCH" CURRICULUM SYSTEM FOR MANAGEMENT SCIENCE MAJORS UNDER THE PERSPECTIVE OF NEW BUSINESS

LingJing Duan, Hang Su*
School of Management, Guizhou University of Commerce, Guiyang 550014, Guizhou, China.
Corresponding Author: Hang Su, Email: sh@gzcc.edu.cn

Abstract: With the extensive penetration of data and intelligent technology in the field of management science and engineering, the application of operations research in supply chain optimization, service operation, platform scheduling, finance and risk management, public management and other scenarios has become more and more in-depth. The undergraduate majors of management science in various universities generally offer the course of "operations research (or management operations research)". However, due to the high degree of interdisciplinary, theoretical and algorithmic nature of the course, the large number of contents, and the great dependence on practical tools, it is necessary to construct a course system that matches the course objectives and learning conditions. This paper takes "basic concepts and theories, practical training, industry applications" as the overall framework, focuses on the concepts and theories of the module's content selection and organization, and proposes a combination of classroom teaching, practical interspersed with post-course expansion of the teaching method. It is also emphasized that the course system should be optimized based on the technology development trend, students' background and learning feedback, in order to ensure the systematicity, applicability and effectiveness of the course.
Keywords: Operations research; Curriculum system construction; Management science; Teaching reform

1 INTRODUCTION

Operations research takes resource optimization and scientific decision-making under uncertainty as its core methodology and is the key foundation for supporting digital and intelligent operations of organizations. In order to meet the industry's demand for complex, data-driven operations and analysis talents, college management science majors have successively set up relevant courses to strengthen students' modeling analysis, computational experiments and decision-making capabilities. The quality of courses is directly related to the quality of talent training[1]. However, operations research originates from the intersection of multiple disciplines such as mathematics, computer science, economics and management science. Its content covers multiple areas such as deterministic optimization, random models, simulation and decision analysis, and is both abstract and practical. For undergraduate students in management science, they usually have a certain foundation in advanced mathematics, linear algebra and probability statistics, but there are differences in programming ability, data literacy and algorithm intuition; there are learning difficulties in abstract modeling, uncertainty thinking, and the connection between theory and software; due to the limited class time, the selection of teaching content and hierarchical design are particularly critical.
Based on the OBE concept, curriculum values, knowledge-competence-literacy objectives, and student learning dynamics, this article proposes a curriculum framework characterized by "basic concepts and theory as the foundation, practical training as the support, and industry application as the final destination." These three elements intertwine and permeate each other: theory provides paradigms and tools for practice and application, practice feeds back into theoretical understanding and forms methodological intuition, and application drives topic selection and ability transfer. Within this framework, this article proposes development strategies and corresponding teaching methods.

2 CURRICULUM CONCEPTS AND RELATED THEORIES

From the nature of the course, "operations research" emphasizes the comprehensive application of operational thinking, modeling paradigms and optimization/decision-making techniques. Management science majors generally do not have a deep optimization principle course. Students have uneven foundations in optimization algorithm mechanisms, random processes and numerical calculations. Without key concepts and basic principles, subsequent software solutions, case analysis and industry applications are difficult to carry out effectively. Therefore, the early basic concepts and theoretical teaching are indispensable and need to serve the subsequent practical training and application scenarios, reflecting the systematicness and practicality of the course system[2]. It is recommended to collaboratively complete the concept and theory modules from the following three approaches:

2.1 Core Concepts and Basic Theories Systematically Taught in Class

Aimed at all students, based on the principles of "sufficient, transferable, and explainable", the course selects core content that must be firmly established, emphasizes modeling paradigms, structural insights, and result interpretation, and focuses on intuitiveness and examples in algorithmic details, avoiding excessive proof stacking.

2.1.1 Operations research thinking and modeling paradigm

(1) Decision variable-objective function-constraint ternary structure; data-model-algorithm-decision closed loop.

(2) Ways to characterize deterministic and uncertain problems, including two paradigms: parameterization and data-driven.

(3) Model simplification and effectiveness, interpretability and robustness, case verification and sensitivity analysis.

2.1.2 Linear programming (lp) and duality/sensitivity

(1) Standardized modeling: typical structures such as resource allocation, production planning, transportation/assignment, etc.

(2) Dual problems and shadow prices, constraint tightness/redundancy determination, and the role of sensitivity analysis in managerial explanations.

(3) Comparison of the intuitive mechanism and computational experiments of the simplex method and the interior point method (without going into the proof in detail).

2.1.3 Integer programming and network optimization (mip/graph optimization)

(1) 0-1 modeling expression skills: logic, confidence interval selection, piecewise function linearization, balance/conflict constraints.

(2) The basic idea of branch and bound/cut plane and the behavior of the solver are intuitive.

(3) Classic models such as network flow, shortest path, minimum spanning tree, matching/assignment and their management significance.

2.1.4 Stochastic operations and basic team survival model

(1) Review of probability and Markov chains, Little's law and its verifiability.

(2) Performance indicators and parameter sensitivity of basic queuing models (M/M/1, M/M/c).

(3) Structural intuition of inventory management (EOQ, (s,S)) and service level/cost trade-offs.

2.1.5 Introduction to simulation and simulation optimization

(1) Event scheduling, randomized experiments, variance control, and result interpretation; the role of simulation in difficult-to-analyze systems.

(2) Simulation optimization: first simulate and obtain data, then optimize the decision; or find the best solution in the simulation loop.

2.2 Key Theoretical Points and Methodological Intuitions Interspersed with Practice

Theory is embedded in tool and case studies, and visualization and experimental tasks build intuition for methods, avoiding a crammed approach. Modeling and problem-solving demonstrations using tools like Excel Solver, Python (PuLP /OR-Tools/ Gurobi), R, and LINGO are presented alongside explanations of dual prices, sensitivity intervals, branch-and-bound trajectories, and cutting plane effects. Students are guided to independently verify their conclusions using small-scale data. Core propositions are validated using reproducible experiments, such as verifying Little's law with simulation data, adjusting parameters to observe the service level-cost trade-off, and testing policy robustness against perturbations in the input distribution. Classroom activities are designed to be driven by "micro-projects": 5-10 minute instant modeling exercises, real-time voting and discussion, and model debugging using a blackboard/projector interface to promote collaborative development and error correction.

After-class expansion and follow-up learning in cutting-edge directions:

Emphasize independent learning outside the classroom, focus on technological evolution and industry needs, and form a cycle of theory- practice -application. This section can include the following content.

(1) Introduction to cutting-edge topics: Data-driven optimization (from prediction to decision/PO to DO), distributed robust optimization, application of reinforcement learning in dynamic scheduling and inventory, simulation optimization and metaheuristics, sustainable and low-carbon operation optimization, and mechanism design in platform economy.

(2) Industry branch cases: supply chain and logistics, service operations and human resource scheduling, medical and public services, finance and risk, energy and transportation[3].

(3) Formative assignments: reading reports/short essays on selected topics, case-based experiments, and modeling and replication of open-source data; students are encouraged to participate in mathematical modeling/operations research competitions to promote learning through competitions and teaching through research.

To ensure that the top-level course design resonates with the "basic concepts - practical training - industry application" framework and better aligns with the Chinese economic management context and the new business education goals, this paper introduces a holistic design approach centered on student development in teaching organization, serving as a supporting approach to connecting objectives, content, methods, and evaluation. This approach emphasizes starting from real management problems, using reproducible computational experiments and explainable management language to achieve a closed loop "from data to decision-making", and using an OBE approach to ensure the gradual alignment of training objectives with teaching implementation and effectiveness evaluation.

In developing and designing the curriculum, we prioritized the context and practice of Chinese economic management, embodying the strengths of the new business discipline: interdisciplinary, internally integrated, and balanced between the arts and sciences. Focusing on addressing key teaching challenges, the course team constructed a student-centered, development-focused "One Body, Two Wings, and Three Auxiliary" curriculum design framework.

Illustration:
(1) Integration: Focusing on improving students' practical ability
Under the OBE concept, the course objectives are focused on improving students' practical ability, especially the ability to apply operations research in actual decision-making. The syllabus is reversely designed to ensure that all teaching activities and assessments revolve around this core goal.
(2) Two wings: combining theory with practice
In terms of theoretical learning, the course content will cover the basic theories of operations research, such as linear programming, integer programming, transportation problems, etc. Through a concise theoretical framework, students will be able to master the basic concepts and methods of operations research. In terms of practical application, students will be enhanced in practical application by combining actual cases and projects. For example, by introducing practical problems such as logistics optimization and production scheduling, students will learn how to apply theoretical knowledge to solve complex practical problems[4]. At the same time, students are encouraged to use data analysis tools (such as management operations research, Excel, MATLAB, etc.) for simulation and optimization to improve their hands-on ability.
(3) Three aids: multi-faceted support for student learning
In classroom teaching, teachers will promote students' active participation through group discussions, case analysis, etc. Breaking the traditional one-way teaching model, the classroom becomes a place for teacher-student interaction, encouraging students to raise questions and opinions, and enhancing their sense of participation in learning.
(IV) Teaching methods and evaluation suggestions
There are many teaching methods: blackboard writing + case deduction, demonstration software experiments, flipped classroom micro-videos and in-class tests; emphasis is placed on "few but good" examples and explainable conclusions.
In terms of learning evaluation, the following forms are combined according to the hours and the categories of the courses in the major: basic concept test (closed book/open book mixed) + modeling homework (including interpretation of duality and sensitivity) + concept experiment report (verification of Little's law/parameter sensitivity) + cutting-edge review essay; the weight of process assessment is not less than the final assessment, highlighting the ability of continuous learning and reflection[5].
Course concepts and theoretical modules provide a solid foundation for practical training and complement the contextualized case studies of industry applications. Throughout the course, the focus and depth of instruction will be continuously revised based on student feedback, problem-solving performance, and application transferability, combined with technological developments and industry needs, to ensure the integrity, systematicity, and iterative nature of the curriculum.

3 PRACTICAL SUPPORT

Practical training is the core and key link of the "Operations Research" curriculum system for management science majors. If students cannot truly master the basic techniques and methods of modeling and solving, it is impossible to apply them to complex decision-making problems in management and engineering scenarios[6]. Compared with abstract theories, practice can enable students to intuitively perceive "the structure of the model, the effectiveness of the algorithm and the interpretability of the conclusion", and form a closed-loop capability of "from problem to model, from data to decision". Therefore, the practical part of this course should not only cover the basic operations of tools and methods, but also highlight the whole process of modeling paradigm, computational experiments and industry implementation.

3.1 Modular Design and Advancement Rhythm of Practice Content

To adapt to the learning pace of students with different foundations and majors, we recommend adopting a progressive structure of "tool introduction - micro-task training - computational experiments - comprehensive cases - project practice", which is consistent and step-by-step. Specifically, it includes:
(1) Tool introduction and environment configuration: Based on Excel Solver/open solvers (such as Python+OR-Tools /open source MILP solvers), commercial solvers (such as Gurobi /CPLEX, teaching licenses can be provided if conditions permit), R or Julia (JuMP) and other multi-tool parallel tools, help students establish the programming expression habit of variables-constraints-goals; guide students to become familiar with the solver interface, modeling syntax, log information, common parameters (such as MIP Gap, time limit, Cuts/Heuristics switch) and result export and visualization methods; supplement simulation tools (such as Python-based event-driven simulation library) and decision analysis drawing tools to form a complete tool chain.
(2) Micro-task training (reinforce methodological intuition with "short, simple, and fast" problems): Design "get-started" tasks that can be completed within 1-2 hours, centering on core topics such as linear programming, integer programming, network optimization, basic nonlinearity, queuing and inventory, simulation, and decision analysis. Each micro-task includes a problem description, a data set, modeling prompts, expected outputs, and reflection questions, emphasizing the minimum closed loop of "reproducibility" and "explainability."
(3) Computational experiments and result interpretation: Students are systematically guided to conduct parameter sensitivity analysis, scenario analysis, robustness test, interpretation of dual price and shadow price, branch and bound process observation and comparative experiments (such as cutting strategy opening/closing, gap and time trade-off),

simulation repeated experiments and confidence interval estimation, etc.; students are required to follow the experimental report specifications, including experimental design, variables and indicators, result presentation, insights and suggestions, limitations and follow-up plans.
(4) Comprehensive case study: Students work in groups and select one or two complete cases from the case library provided by the teacher (such as site selection and network design, production and scheduling, service scheduling and capacity configuration, inventory strategy and agreement design, price and revenue management, etc.), and complete the end-to-end process from business understanding, data preparation, model building, solution and parameter adjustment, verification and communication.
(5) Project practice and results presentation: Based on real or near-real data, the course project is completed using the method of "problem collection - project review - mid-term inspection - final defense", and a standardized technical report, a reproducible code repository and manager demonstration materials are produced, which are then defended in class and reviewed by peers.

3.2 Typical Microtasks and Practical Topics

Based on talent cultivation goals, the practical themes of operations research courses can be categorized and set according to professional requirements. This article uses applied undergraduate institutions as an example to highlight the needs of the times and reflect the characteristics of digital talent cultivation . The practical themes are as follows.
(1) Linear programming foundation and duality/sensitivity: transportation and assignment problems (data balanced and unbalanced scenarios), production batching and cost minimization; guiding students to read “shadow prices” from dual variables, explaining resource scarcity and marginal value; completing sensitivity interval verification by changing the right-hand side term and cost coefficient.
(2) Integer programming modeling skills: 0-1 logical constraints, mutual exclusion/implication, piecewise linearization, time windows and ordinal relationship modeling; typical problems include facility location, project portfolio, workshop sequence and changeover, packing and cutting, etc.; observe the impact of branch and bound tree size and parameter settings.
(3) Network optimization: shortest path, minimum cost maximum flow, matching and assignment, Steiner approximation, etc.; emphasize the versatility of network flow in supply-demand balance, capital and information flow.
(4) Basic nonlinear and convex optimization intuition: convex costs of capacity expansion, concave returns of price-demand, and management interpretation of KKT conditions; practice linearization/convexification strategies and identification of local-global optima.
(5) Queuing and Simulation: Comparison of the performance indicators of M/M/1 and M/M/c by calculation and simulation to verify Little's law; design of experiments on arrival rate and service rate to observe the critical point of congestion and fluctuation effect; and optimization based on simulation to search for the approximate optimal solution for the number of service stations.

3.3 Evaluation Mechanism and Learning Support

With the OBE orientation, we ensure the step-by-step alignment of training objectives with teaching implementation and effectiveness evaluation, and set up the following evaluation methods.
(1) Process evaluation: experimental report (including sensitivity/robustness analysis), micro-project achievement, classroom quizzes and peer evaluation, learning log and reflection, recommended proportion $\geq 50\%$.
(2) Final evaluation: Comprehensive project quality, defense performance, and engineering standards (code readability, version management, and result visualization).
(3) Layering and mutual assistance: Provide "Basic Edition/Challenge Edition" dual-track tasks, set up office hours for learning partners and teaching assistants; provide template scaffolding for students with weak programming foundation.
(4) Resources and Environment: Build a cloud-based solution environment and mirror to reduce configuration costs; establish a question bank and FAQ for continuous iteration.
(5) Competition and Certification: Organize students to participate in mathematical modeling/operational research competitions and case challenges, which will be recognized as course bonus points or alternative assessments; issue micro-certificates such as "Excellent Computational Experiments" and "Excellent Engineering Practices" as incentives.
Through serialized and layered practical training, students can repeatedly hone the core capabilities of "digital talents" in the digital age in real or near-real problems, which not only enhances the internalization and transfer of theories, but also lays a solid technical foundation for industry implementation.

4 APPLICATION AND DEVELOPMENT TREND OF OPERATIONS RESEARCH IN MANAGEMENT SCIENCE

In the context of the digital economy and intelligent operations, operations research, with its core focus on optimization and decision-making methods, has become a key tool for improving quality and efficiency, reducing costs and emissions, and mitigating risks across all industries. For students majoring in management science, the curriculum must emphasize field applications and demonstrate a closed-loop capability from problem to model, from data to decision. Teaching should be structured around a "typical scenario-driven + project-based practice" approach, supplemented by industry lectures and visits, to help students develop interdisciplinary cognitive maps and professional competencies.

4.1 Typical Industry Application Scenarios and Key Points

(1) Supply chain and logistics network optimization
Application content: Facility site selection and hierarchical network design, capacity layout and flexibility strategy, trunk and branch line coordinated transportation, inventory-transportation integration, reverse logistics and closed-loop supply chain[7].
Key points of corresponding operations research methods: mixed integer programming, network flow and decomposition algorithms (such as Benders' idea), multi-objective trade-offs (cost-service-carbon emissions), scenario planning and robust optimization; support "flexible supply chain" decision-making through sensitivity analysis and scenario design.
(2) Production and operation management
Application content: batch and single-piece flow, changeover and parallel machine scheduling, bottleneck identification and buffer configuration, constraint synchronization and beat optimization, production and sales collaboration and master production planning.
Key points of the corresponding operations research methods: combining heuristics and metaheuristics with mathematical programming, simulation-optimization iteration, and constraint programming to express complex process constraints; emphasizing feasible scheduling and schedule generation.
(3) Service operation and manpower scheduling
Application content: multi-skill service desk configuration, appointment and arrival management, time-based scheduling and shifts, fairness constraints and incentive mechanisms.
Key points of the corresponding operations research methods: linkage of demand forecasting, capacity planning, and scheduling optimization, queue model and simulation evaluation of service levels, chance constraints/robust handling of uncertain arrivals, and combining integer programming with local search to improve feasibility and efficiency.
(4) Marketing and revenue management
Application content: dynamic pricing and quota control, promotion and inventory linkage, product portfolio and display optimization, and cross-channel coordination.
Key points of corresponding operations research methods: joint optimization of demand elasticity estimation and pricing-quota, multi-objective (revenue -experience-brand) trade-offs, A/B experiments and causal inference to support strategy evaluation.
(5) Public management and emergency dispatch
Application content: Emergency resource pre-positioning and rapid response, public facility layout and equitable accessibility, post-disaster recovery and phased resource allocation.
Key points of corresponding operations research methods: multi-objective and fairness measurement, robust and online optimization, simulation and deduction, and digital twin-assisted solution coordination.
(6) Energy system and dual carbon governance
Application content: Coordinated optimization of sources, grids, loads and storage, demand response and peak-valley shifting, carbon quotas and emission reduction paths, and uncertain output absorption of renewable energy.
The key points of the corresponding operations research methods are: stochastic optimization, robust optimization and decomposition and coordination, incorporating carbon costs and environmental constraints, and carrying out multi-scenario simulation-optimization linkage.
(7) Platform Economy and Algorithm Governance
Application content: matching, allocation and incentive mechanisms, supply and demand bilateral pricing, rider/driver scheduling and rebalancing, quality and compliance management.
Key points of the corresponding operations research methods: online optimization and reinforcement learning, mechanism design and game equilibrium, constrained optimization and explainability; emphasis on real-time and fairness.

4.2 Applied Path of Teaching Implementation

Case teaching is organized along the main line of "problem-data-model-decision", first clarifying business goals and constraints, then matching model families with solution strategies, and finally outputting executable suggestions in management language. The combination of "multiple cases and small incisions" classroom exercises and "few but fine, deeply polished" semester projects ensures both coverage and representative results. A joint school-enterprise question bank is established, and enterprise mentors are invited to co-build projects, providing real data or desensitized data, and organizing mid-term reviews and final roadshows. Additional industry lectures and practical visits are offered, such as to supply chain centers, call centers, hospital operations departments, energy dispatch centers, etc., to allow students to understand the role and boundaries of models in "visible systems."

4.3 Cutting-Edge Trends and Capability Transfer

The rapid development of the digital age has brought about trends in several aspects.
(1) Data-driven optimization and decision intelligence. From “post-prediction optimization” to “decision-oriented learning”, the impact of prediction error on optimal decision-making is incorporated into the training objective; distributional robustness and chance constraints are used to ensure the robustness of the strategy in an uncertain

environment[8].
(2) Simulation-Optimization-Digital Twin: Use simulation to build a “trial-and-error” virtual environment in complex systems, and then use simulation optimization to search for strategies; realize program coordination and sandbox simulation in supply chain and emergency management[9].
(3) Low-carbon and sustainable operations: Incorporate carbon costs, energy consumption, and fairness into optimization objectives and constraints, and build a trade-off framework for the three goals of “cost-service-green”.
Practical support and industry application are the two pillars of the operational research curriculum. Practical support strengthens students' modeling and computational experimentation capabilities through systematic, engineering-based, and reproducible training. On-demand application, driven by problems and value, truly embeds methods into business scenarios, forming communicable, executable, and evaluable decision-making solutions[10]. Applied universities must continuously optimize their curriculum based on technological evolution and student feedback, building a high-quality curriculum tailored to the training objectives of management science professionals. This ensures that students can not only "model, calculate, and solve problems," but also "understand the business, articulate value, and implement solutions."

COMPETING INTERESTS

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INNOVATIVE RESEARCH ON POLITICAL EDUCATION REFORM IN THE "CADASTRAL MANAGEMENT" COURSE BASED ON THE LARGE LANGUAGE MODEL

AiGuo Wang*, LiFang Liu
School of Geography and Tourism, Luoyang Normal University, Luoyang 471934, Henan, China.
Corresponding Author: AiGuo Wang, Email: wangaiguoch@126.com

Abstract: The rapid development of the large language model (LLM) has provided a new path for political education in higher education. This paper focuses on the synergy between the "Cadastral Management" course and political education in land resource management. It explores how to utilize the technical advantages of LLM to reconstruct the teaching process, innovate teaching methods, and optimize the assessment system. By constructing an application framework of the "Value embedding - Situational interaction - Dynamic feedback" LLM and verifying it with cases from the "Cadastral Management" course, it has been demonstrated that the LLM significantly enhances the effectiveness of political education. This study also provides theoretical support and practical paradigms for artificial intelligence empowering ideological and political education in specialized courses.
Keywords: Large Language Model; Cadastral Management; Ideological and political education in courses; Education reform; Innovation research

1 INTRODUCTION

In the context of cultivating talents in higher education institutions, cultivating virtue and nurturing people has always been regarded as the fundamental mission. There is an imperative to establish a trinity talent cultivation model integrating "Value shaping, Ability development, and Knowledge dissemination". Nevertheless, traditional ideological and political education within professional courses has long confronted several challenges. For instance, ideological and political elements are often mechanically incorporated, teaching methods are monotonous, and student engagement remains relatively low. With the rapid advancement of artificial intelligence technology, especially the emergence of large language models, a technological foundation has been established to address these issues. Large language models exhibit remarkable advantages in natural language comprehension, course content generation, and personalized course interaction. These capabilities can offer substantial support for the in - depth integration of ideological and political education with professional course instruction. The innovative research on professional course ideological and political education driven by large language models, as presented in this paper, aims to provide novel perspectives for the reform and innovation of ideological and political education within professional courses in higher education. It endeavors to foster a new ecosystem of "intelligent +" ideological and political education in professional courses.
Large language models have witnessed exponential growth and are extensively applied across various domains, including image and text generation, human - computer interaction, real - time translation, and code generation. Currently, domestic universities and enterprises have developed over 200 large models. Notable examples include Baidu's Wenxin Yiyan, DeepSeek's DeepSeek, and Doubao by ChunTianZhiYun. The integration of ideological and political education into professional courses represents an inevitable trend in university - level ideological and General Secretary Xi Jinping proposed new media and emerging technologies to promote the profound integration of the strengths of ideological and political work with information technology. Domestic scholars have explored the integration of large language models into professional teaching to investigate how to enhance ideological and political education in higher education. They have put forward insights on opportunities, risks, and corresponding countermeasures[1]. Large language models, which support personalized learning, hold advantages in optimizing resource - based content and innovating educational models. However, they also face challenges such as generation bias and privacy protection concerns. Therefore, coordinated efforts from multiple parties are essential to maximize their potential in ideological and political education[2]. Artificial intelligence plays a crucial role in customizing teaching content, creating immersive learning environments, and facilitating seamless human - computer interaction. Nevertheless, potential pitfalls such as content distortion and over - reliance on technology exist. To mitigate these risks, socialist core values should be translated into knowledge graphs and integrated into large language models. Additionally, measures such as standardizing data input can provide a safeguard for empowering ideological and political education in higher education [3]. Large language models such as ChatGPT have already made significant contributions in education, scientific research, and other fields. Integrating such models into ideological and political education in higher education necessitates a careful analysis of issues related to data management and model training. Proposed solutions include data sharing and eliminating model bias[4]. By aligning with the characteristics of ideological and political education discourse dissemination, large language models' text and knowledge graphs can

be utilized to expand the reach of ideological and political education discourse[5]. The application of text - to - video models in ideological and political education can optimize educational content and innovate teaching methods through visualization and precision - targeted approaches[6]. Generative artificial intelligence offers valuable insights for ideological and political education in higher education. By enhancing teaching scenarios and improving human - computer interaction experiences, it can facilitate more effective situational teaching in ideological and political courses[7]. Utilizing DeepSeek as the basis for ideological and political education can drive the innovative transformation of ideological and political education towards a digital and intelligent paradigm[8]. Generative artificial intelligence, with its strong interactivity, precision, and virtuality, creates diverse teaching scenarios for university ideological and political education. However, a coordinated approach from aspects such as "subject - content - teaching - field" is crucial to achieve a profound integration of artificial intelligence and ideological and political education[9]. AI has the potential to empower both ideological and political education in courses and ideological and political courses themselves, thereby promoting their coordinated development[10]. To enhance the effectiveness of generative artificial intelligence in ideological and political teaching in higher education, it is essential to clarify the objectives of technological empowerment and improve the quality of resource provision[11].

The application of large language models to enhance ideological and political education in professional courses is still in its infancy. Many issues remain unresolved, such as the complexity of value alignment, content controllability, and the absence of emotional education. This paper, in light of the ideological and political education practice of the "Cadastral Management" course within the Land Resources Management major, constructs an application framework for large language models featuring "value embedding - situational interaction - dynamic feedback". This framework serves to validate the feasibility of using large language models to enhance ideological and political education in professional courses.

2 OPPORTUNITIES AND RISKS OF EMPOWERING IDEOLOGICAL AND POLITICAL EDUCATION WITH LARGE LANGUAGE MODELS

2.1 Opportunities: Empowering Educational Reform with Large Language Models

2.1.1 Solving the pain points of traditional ideological and political education

Traditional ideological and political education is relatively monotonous, with all students facing the same PPT. This "undifferentiated teaching" ignores students' professional backgrounds, causing students to feel that ideological and political courses are "irrelevant to me" and creating a sense of alienation. This results in a situation where teachers indoctrinate ideas in the classroom and students passively accept them, undoubtedly leading to a loss of interest in ideological and political courses. However, large language models can combine students' professional backgrounds and knowledge reserves to intelligently generate ideological and political content for professional courses that is in line with their professional backgrounds and knowledge reserves.

2.1.2 Providing personalized ideological and political education for professional courses

Large language models have powerful natural language processing and context generation capabilities, enabling precise understanding of students' actual situations and the formulation of personalized plans. By accurately profiling students' majors, large language models can transform ideological and political education from a broad, undifferentiated approach to a precise, targeted approach for professional courses, truly achieving personalized, professional, and multi-modal ideological and political education for professional courses.

2.2 Risks: Challenges in the Application of Large Language Models

2.2.1 Value risks

The training data for large language models is mostly sourced from the Internet, where various information is mixed, including a large amount of English information. For instance, over 92% of ChatGPT's training data is in English. Therefore, the training data may contain content that does not align with socialist values. Moreover, during the training process, large language models do not screen the data, and if the weights are incorrect, it will seriously affect the model's value judgment in ideological and political education.

2.2.2 Crisis of the essence of education

The infiltration of large language models in university education may also trigger a crisis in the essence of education. If complete teaching plans and beautiful PPTs can be quickly generated through large language models, and the explanation level is higher than that of teachers, such education will inevitably lead to a cognitive crisis that university education is being replaced by virtual generation.

2.2.3 Information security risks in education

Information security is a key concern in the application of large language models. When using large language models to design ideological and political courses for university professional courses, some large language models may exhibit data collection infiltration, such as commercial institutions collecting information to push commercial messages or the leakage of campus information trajectories.

3 INNOVATIVE FRAMEWORK FOR IDEOLOGICAL AND POLITICAL EDUCATION IN PROFESSIONAL COURSES BASED ON LARGE LANGUAGE MODELS

Despite the various risks in the application of large language models, they can utilize vast knowledge bases to assist teachers in university education, automatically identify ideological and political mapping points in professional course content, providing new ideas for the reform of ideological and political education in professional courses in universities.

3.1 Framework for Constructing the Teaching Process of Professional Ideological and Political Education

At the basic level, professional knowledge bases, ideological and political element maps, student profile data, and teaching resource libraries are used as the foundation for ideological and political education in professional courses. Large language models are utilized to analyze the content that needs to be designed and generate the required ideological and political content for the courses. The generated content is confirmed by professional teachers and then reviewed by relevant teachers and departments in the college or university to finally determine the ideological and political content of the courses. The confirmed content needs to be prepared by teachers before class and learned and consolidated through classroom lectures, interactive Q&A, and after-class assignments during classroom teaching. Professional ideological and political courses also require support from systems such as content security support systems, expert support networks, and intelligent teaching evaluation systems. The detailed framework for constructing the teaching process of professional ideological and political education is shown in Figure 1.

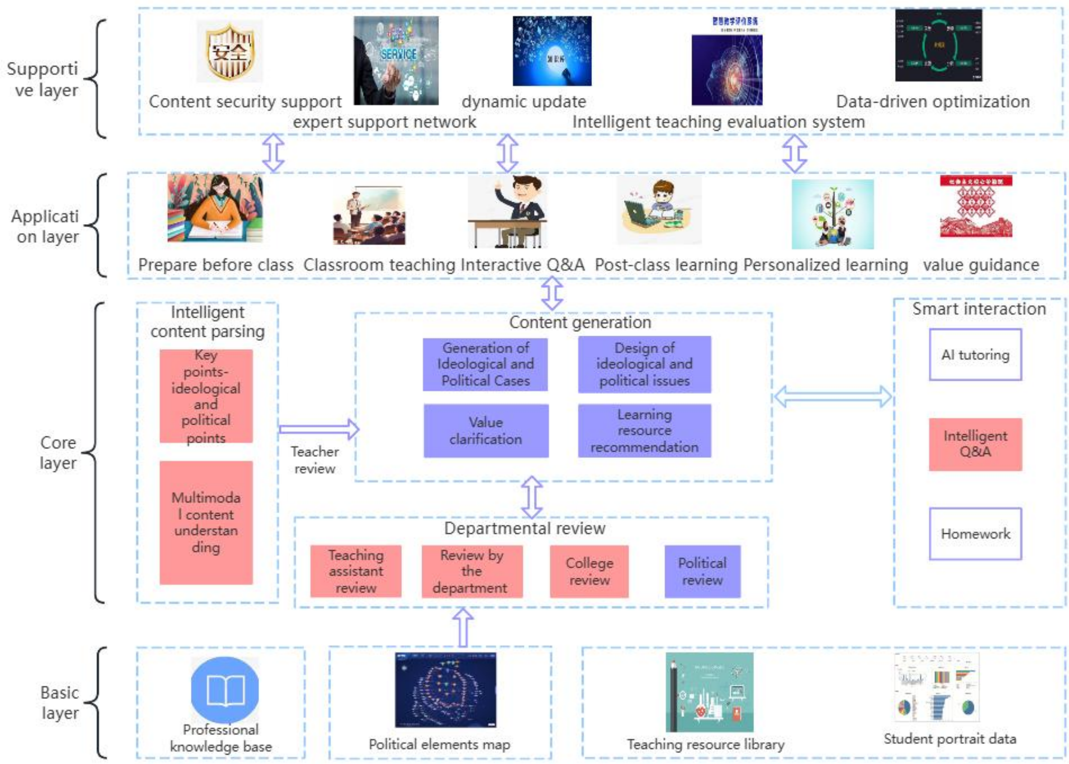

Figure 1 Innovative Framework for Ideological and Political Education in Professional Courses of Large Language Models

3.2 Construction and Generation of Ideological and Political Content in Professional Courses

The construction of ideological and political content in professional courses by large language models mainly achieves through the following aspects: First, on the input source: Teachers input the main content of the chapter and propose constraints for integrating ideological and political elements. The large language model then understands, thinks, and analyzes to generate ideological and political education content that meets the requirements. Professional teachers analyze the generated content, summarize the key points of ideological and political education in professional courses, and prepare for the class after the review of relevant ideological and political content by the department. During the course preparation, it is also necessary to consider how to introduce it into classroom teaching, how to interact with students, how to make students understand, and how to encourage students to think after class. Second, on the content review layer: A "three checks and one review" system should be formed. The three checks require teachers to self-check the ideological and political content of professional courses, the department (teaching and research office) to check the ideological and political content of the course, and the college to check the ideological and political content of the course. The one review requires the professional course ideological and political supervision team of the college to review the ideological and political content of the course, etc. Third, on the learning feedback layer: Professional course ideological and political content innovation and reform should be carried out through feedback from teachers' observations during class, students' discussions after class, and supervision feedback organized by the department and college.

4 PRACTICE AND EVALUATION OF IDEOLOGICAL AND POLITICAL REFORM IN GEODETIC MANAGEMENT PROFESSIONAL COURSES

4.1 Research Design and Method

Three mainstream large language models, Chatbox, Doubao, and Wenxin Yiyan, were selected as auxiliary tools. The research process includes: planning (designing prompts) → action (model generating content) → examination (multi-model comparison analysis and fact-checking) → reflection (teaching team discussing and determining the final plan and implementing it).

4.2 Multi-model Collaboration and Content Optimization

In the practice of large language models empowering geodetic management courses, the "Historical Evolution of China's Geodetic Development" in the third section of the first chapter of "Geodetic Management" was used as the practice of ideological and political reform in large language models. Chatbox, Doubao, and Wenxin Yiyan were respectively used to design ideological and political content for professional courses. In the practice, the content of this section was directly input into the question layer, and then the problems that the large language model needed to solve were given, that is, to provide an ideological and political course system based on the content of the geodetic management professional course.

The ideological and political elements integrated by Doubao are as follows:

Reflecting the people-first concept: From the Communist Party of China's emphasis on land issues in modern times to the land reform in the early days of the founding of the People's Republic of China that enabled farmers to truly own land, and then to the land system reform after the reform and opening up that guaranteed farmers' rights and interests, it reflects that the Communist Party of China has always placed the people's interests first, centered on the people, and is committed to allowing the people to share the fruits of land development.

Cultivating the rule of law awareness: China's geodetic management has evolved from simple land tax regulations in ancient times to the gradual promulgation of a series of land laws and regulations in modern times, and then to the improvement of geodetic management based on the "Land Management Law" and other laws in modern times, reflecting the continuous strengthening of the rule of law concept and guiding students to establish a rule of law awareness, respecting and abiding by laws and regulations.

Stimulating the spirit of innovation: From the ancient fish-scale map drawing method to the introduction of modern surveying knowledge by the Kuomintang government in modern times, and then to the use of advanced technologies such as remote sensing for land surveys in modern times, it reflects the continuous innovation in geodetic management technology and encourages students to be brave in innovation in their studies and work and solve problems with new technologies.

Enhancing historical responsibility: By understanding the history of geodetic development, students can understand the importance of land management for national stability and economic development, and recognize that as new-era youth, they shoulder the historical responsibility of maintaining the rational use of national land resources and promoting the development of the land management cause.

The ideological and political content of professional courses provided by Chatbox is relatively detailed. First, it combines core regulatory documents and provides historical significance and ideological and political value, as shown in Table 1. Second, it provides a design module for the ideological and political course system, including Module 1: Geodetic Management and National Governance; Module Two: Land System and Rule of Law Construction; Module Three: Technological Evolution and Technological Innovation. Third, the list of video resources provided by Chatbox is shown in Table 2.

Table 1 The Ideological and Political Value Table of the Development History of China's Cadastre Management Provided by Chatbox

Time	Legal document	Historical significance	Ideological and political values
1930	The Land Law of the Republic of China	The land registration system was first established in law	Laying the foundation for the rule of law
1950	The Land Reform Law of the People's Republic of China	abolish feudal land system	The superiority of the socialist system
1986	Land Administration Law	Establish basic state policies	Reform and development

Time	Legal document	Historical significance	Ideological and political values
			guarantee
1998	Land Administration Law (Amendment)	Establish a land dynamic monitoring system	Strategic technology to rejuvenate the nation

Table 2 The List of Video Resources Provided by Chatbox

Type	Duration	Content Theme
Expert Interview	18 minutes	China Agricultural University "The History of China's Land System Reform"
Operation Guide	15 minutes	Demonstration of the 3D Cadastre Platform
Historical Materials Explanation	12 minutes	Interpretation of the Fish-scale Land Register Archives in the National Museum
Documentary	30minutes	Land Reform in the Suburbs of Beijing in 1949

The ideological and political integration points in the professional course design content provided by Wenxin Yiyin are shown in Table 3. The suggested videos include the documentary "The Foundation of a Great Nation" Episode 3 "Land Transformation" (showing rural reform), CCTV's "Rule of Law in China" Episode 5 "Lawful Administration" (interpretation of the Land Administration Law), and the animated short film "Understanding Real Estate Registration in One Minute" (demonstration of technical means).

Table 3 The Ideological and Political Integration Points of the Development History of China's Cadastre Management Provided by Wenxin Yiyin

Course Module	Teaching Content	Supporting Textbook	Ideological and Political Integration Points
Module One: Ancient Cadastre Wisdom	Land classification in the Xia and Zhou Dynasties, Shang Yang's Reforms, Fish-scale Land Registers	(2100 BC - 1368 AD)	The governance wisdom of ancient rulers, embodying the idea of "the people are the foundation of the state"
Module Two: Modern System Transformation	land laws formulated by the Communist Party, Land registration reform in the Republic of China	Policy comparison table (1912 - 1949)	The impact of institutional choices on national economy and people's livelihood, highlighting the people-oriented stance of the Communist Party
Module Three: Modern System Construction	Reconstruction of cadastre in New China, Land Administration Law	Timeline (1949 - 2000)	The superiority of the socialist system, practice of the strategy of governing the country by law
Module Four: Innovation and Development Stage	Household contract responsibility system, real estate registration	Policy comparison table (1978 - 2000)	The spirit of innovation in reform and opening up, technology empowering social governance

Combining the ideological and political integration points of the cadastre management professional course provided by the three large language models and the suggested video list, each item is analyzed. It is found that the third episode of the CCTV documentary "The Foundation of a Great Nation" is not "Land Transformation" but "The Field of Hope", but its content is related to cadastre management and can be used as part of the professional ideological and political education. However, the fifth episode of "Rule of Law in China" is "Fair Justice", and its content is not related to cadastre management. By searching for "CCTV (interpretation of the Land Administration Law)", it can be seen that CCTV has many related contents, such as the News Live Room (interpreting the newly revised Land

Administration Law, improving the land expropriation procedure, and clarifying the scope of expropriation), which can also be used as part of the ideological and political course of cadastre management. Through online search, no video titled "Understanding Real Estate Registration in One Minute" was found. Among the video resource list provided by Chatbox, after searching, no relevant videos were found. Based on the integration points of ideological and political education in professional courses provided by three major language models and after discussions among the teachers of the research group, the ideological and political education integration points for this section were ultimately determined to include three main aspects: First, the land policies implemented by the Communist Party of China during the land revolution demonstrated the Party's determination to alleviate the burden on farmers, promote the Anti-Japanese National United Front, eliminate the feudal exploitation system, and develop agricultural production. Second, during the period of new China's construction, the establishment of systems such as land registration management and land laws reflected the superiority of the socialist system. Third, after the reform and opening up, on the one hand, the implementation of the household contract responsibility system and the adoption of systems such as real estate registration were carried out; on the other hand, new technologies such as RTK and unmanned aerial vehicle remote sensing were utilized, enabling China's land system to not only embody the spirit of innovation in reform and opening up but also leverage high-tech to achieve information-based land management. The video content will showcase relevant aspects of real estate surveying and mapping, rural land rights confirmation and registration, and rural land contract management rights from the CCTV documentary "The Foundation of a Great Nation" as shown in Figure 2. Through these contents, students will understand the determination of this discipline to serve society, empower social development with technology, and contribute to the country's development.

Figure 2 Video on Real Estate Surveying and Mapping and Rural Land Contracting Management Rights Certificate

The course content is interspersed with interactive discussions, enabling students to recognize that every change in cadastral management is closely related to the destiny of the country; it encourages students to draw lessons from history, cherish the achievements of land development and reform, uphold the people-centered philosophy, be courageous in innovation, deeply understand the laws of the development of institutional civilization, the role of the rule of law in safeguarding people's livelihood, and the goal of modernizing the governance capacity of territorial space, and contribute their own strength to the development of China's land management cause, jointly promoting the country's progress towards prosperity and strength. The after-class assignment is designed to have students write a short essay to express their understanding of the historical evolution of cadastral management in China, as well as the inspirations and insights they have gained, with a focus on ideological and political education-related content, such as personal responsibility and the concept of the rule of law.

4.2 Analysis of Ideological and Political Education Reform in Cadastral Management Courses

The use of large language models to reform ideological and political education in cadastral management courses has gradually improved the situation where professional course teachers previously separated professional content from ideological and political content when teaching. It enables professional course teachers to integrate ideological and political course content into professional courses, avoiding the awkward situation where traditional professional courses incorporate ideological and political elements in an overly forced manner. It also alleviates the heavy burden of preparing for both professional and ideological and political content that professional course teachers previously faced. Through the reform of ideological and political education in cadastral management courses using large language models, the time spent on preparing and collecting materials for ideological and political courses has been significantly reduced, by approximately 50%. Since cadastral management courses fall under both management and engineering disciplines, this reform also provides assistance to engineering teachers in the theoretical construction of ideological and political education in their courses.

5 CONCLUSION

Large language models possess powerful capabilities in generating text, images, and videos based on semantics, bringing unprecedented opportunities to ideological and political education in university professional courses. Utilizing large language models to assist in the construction of ideological and political education in professional courses, especially for engineering teachers, offers a new teaching approach. In the future, the value of university teachers lies not only in imparting professional knowledge but also in guiding ideological and political education. Through the reform of ideological and political education in cadastral management professional courses, the integration of land management surveying and mapping, GIS, and land equity and sovereignty is achieved, cultivating a new generation of land guardians who are proficient in cadastral surveying techniques, knowledgeable in land law, and filled with a sense of patriotism. They will fulfill the mission of applying cadastral surveying technology to resolve land disputes, serving the people with land law knowledge, and conducting research on the land of their motherland in the construction of a digital China, fostering a continuous stream of technical, patriotic, and service-oriented young people in the new era of socialism.

COMPETING INTERESTS

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CONSTRUCTION AND IMPLEMENTATION PATH OF THE HIGH-QUALITY DEVELOPMENT SYSTEM FOR THE SENIORS UNIVERSITY OF CHINA IN THE NEW ERA

Huang Huang[1,2], YanRunYu Liang[1,2*]
[1]*School of Elderly Care Services and Management, Nanjing University of Chinese Medicine, Nanjing 210023, Jiangsu, China.*
[2]*School of Elderly Care Industry, Nanjing University of Chinese Medicine, Nanjing 210023, Jiangsu, China.*
Corresponding Author: YanRunYu Liang, Email: lyry@njucm.edu.cn

Abstract: In the context of the new era, the high-quality development of universities for the elderly has become a key pathway to achieving the goal of "active aging." This study adopts a mixed-method approach that combines case studies with questionnaire surveys, taking Jiangsu Yuehua Health and Elderly Care Group and its partner universities for the elderly as research subjects. Based on relevant theoretical frameworks from domestic and international studies on elderly education and universities for older adults, this paper systematically reviews the current development status of elderly universities in China. The findings reveal four major challenges facing their development: imperfect resource coordination mechanisms, a relatively homogeneous service supply structure, imbalanced allocation of urban and rural educational resources, and insufficient adaptation of information technology to the needs of older learners. In response, the study proposes a set of systematic pathways for improvement: innovating institutional mechanisms and optimizing resource allocation efficiency; establishing a diversified and hierarchical curriculum supply system; exploring elderly education development models with Chinese characteristics; promoting the deep integration of information technology and elderly education; and building a professional and sustainable teaching workforce.
Keywords: Universities for the elderly; High-quality development; Active aging; Social support system; Implementation path

1 INTRODUCTION

The world has entered an era of global aging, and education in elderly universities has emerged alongside the rapid progression of population aging in recent years. The high-quality development of universities for the elderly represents the deepening and implementation of the high-quality development concept in the field of elderly education. It transcends traditional models of elderly education, aiming to meet older adults' demand for a high-quality life and the developmental needs of an aging society [1]. As the most important carriers and core platforms of elderly education in China, universities for the elderly are defined as "non-traditional, elderly-oriented lifelong education activities that are purposeful, organized, and systematic, provided for the elderly in accordance with social development and their intrinsic needs". Since the advent of the new era, with the advancement of the "active aging" strategy and the construction of an "elderly-friendly" society, older adults have increasingly relied on universities for the elderly to satisfy diverse learning needs, thereby realizing the goal of "lifelong learning" and further achieving "active contribution."

2 THE DEVELOPMENT COURSE OF UNIVERSITIES FOR THE ELDERLY

In the context of an aging society, China has both absorbed the essence of the international concept of lifelong learning and, through policy innovation and practical exploration, gradually developed a system of universities for the elderly with distinctive local characteristics.

2.1 The Development Process of Research on Universities for the Elderly

Research on universities for the elderly in China has deepened gradually under the dual impetus of policy guidance and social demand, forming a developmental trajectory that embodies both Chinese characteristics and the features of the times.

2.1.1 The oretical studies of China geriatric education

Theoretical research on geriatric universities primarily encompasses Social Adaptation Theory and Geriatric Health Promotion Theory. The former posits that geriatric education embodies three social attributes: lifelong development, social welfare, and superstructure . The latter emphasizes the need to address both the physical health and spiritual well-being of older adults, advocating for a shift from merely "ensuring basic care" to enabling them to "find joy" and embrace life fully .Drawing on domestic and international scholarship, Li Jie (2020) systematically reviewed fundamental theoretical issues in geriatric education from three dimensions: learning subjects, learning motivation, and learning content. She highlighted the necessity for researchers to further explore these core themes and expand research paradigms to guide geriatric education practices effectively[2].On the whole, geriatric education in China exhibits interdisciplinary characteristics and has not yet formed an independent disciplinary system. Instead, it is scattered across different disciplinary fields, such as education, psychology, sociology, and economics.

2.1.2 The supply practice of seniors universities in China

Relying on the practice of elderly education, research on the supply of elderly education in China has gone through three development stages. The first stage focused on "empowerment", laying the policy foundation for elderly education and forming a "Chinese perspective on elderly education" integrated with traditional Chinese culture.Since the United Nations Educational, Scientific and Cultural Organization (UNESCO) put forward the concept of lifelong education in the 1960s, China has actively responded at the policy level. In particular, the formulation and implementation of the Law of the People's Republic of China on the Protection of the Rights and Interests of the Elderly has provided a legal basis for the elderly's right to education. At the same time, the state has also empowered the elderly in terms of institutional arrangements, operation mechanisms, social environment and psychological support, ensuring the realization of the right to elderly education in a systematic manner.In the 1980s, elderly education in China emerged spontaneously with the implementation of the system for retired cadres. The "Shandong Red Cross Seniors University", founded in 1983, was China's first seniors university [3]. Initially, its function was to meet the spiritual and cultural needs of retired veteran cadres. Mainly based on the national goals for elderly work, it provided "welfare-oriented" educational services for retired personnel from state organs, enterprises and public institutions[4].

The second stage centered on "active aging". Driven by strong policy support, China embarked on the Chinese-style practice of elderly education. Entering the new century, China's aging population issue became increasingly prominent, and the Party and the state attached great importance to elderly work while actively promoting the development of elderly education. The National Medium- and Long-Term Plan for Education Reform and Development (2010-2020), released in 2010, explicitly stated that "elderly education should be valued" and proposed an action plan to address population aging[5]; in 2016, the Elderly Education Development Plan (2016-2020) put forward initiatives to "accelerate the development of elderly education, expand the supply of elderly education, and innovate the institutional mechanisms of elderly education", laying out arrangements to enhance the modernization level of elderly education[6].During this stage, China's elderly education embarked on Chinese-style practice. As an important part of the elderly care service system, the construction of elderly universities across the country showed a vigorous momentum[7]. Relevant studies indicate that the number of elderly universities in China increased at an annual rate of 4.7%, with over 76,000 elderly universities at all levels and types nationwide, and the number of students participating in studies exceeding 20 million[8]. Amid the growing demand for learning among the people and the strong promotion of elderly education by the Party and the state, a large number of veteran Party members, senior teachers, and elderly scientific and technological workers with pioneering and exemplary roles took the lead in actively participating in lifelong learning and engaging in social construction. Scholars also turned their research focus to topics such as the modernization, balanced development, service system, and value research of elderly education.

The third stage centers on the new development of elderly education, propelled by the "New Era" context and the goal of "high-quality development". Guided by the new development philosophy, and based on the new stage of economic and social progress, efforts are dedicated to fostering the transformation of elderly education from "ensuring a fulfilling life for the elderly" to "enabling the elderly to pursue learning" and "empowering the elderly to contribute to society", so as to accelerate the achievement of high-quality development of elderly education in the New Era. Fan Hua argues that the development of elderly education must align with the three epochal characteristics of "openness, inclusiveness, and public welfare", and effectively implement initiatives including "enhancing connotative development, integrating educational resources, and strengthening supporting measures"[9]. With the government taking the lead and multiple social sectors participating, a systematic and holistic institutional framework should be established to safeguard the educational needs of the elderly. Cao Taisheng points out that elderly education is not only a crucial system for protecting the elderly's right to education and providing them with welfare, but also an economic strategy to improve the quality of human resources and address the challenges of population aging. Its essential attribute remains educational in nature, and inclusiveness and diversification serve as the direction and strategy for realizing the high-quality development of elderly education[10].Chen Youhua holds that elderly education is the core of elderly human resource development, as it is closely related to the employability and social participation of the elderly group[11].

2.2 Development of Geriatric Education Research in Other Countries

Geriatric education research in other countries started relatively early, leading to the development of a series of theories on geriatric education as well as practical experiences with distinct national characteristics.

2.2.1 The oretical studies on geriatric education in other countries

The theoretical foundations of elderly education in foreign countries are primarily derived from sociological theories, which have evolved into new theoretical perspectives on elderly education. These frameworks are constructed from three dimensions: social structure, individual psychology, and life value, forming a comprehensive theoretical system for understanding elderly education.

From the social interaction perspective, Social Group Theory suggests that education serves as an important vehicle for older adults to build social relationships and strengthen group identity. Social Conflict and Adjustment Theory argues that elderly education can help marginalized groups enhance their awareness of rights, thereby reducing intergenerational conflicts and social exclusion[12]. From the individual psychological dimension, social psychology focuses on the patterns of psychological adaptation in the aging process. Continuity Theory emphasizes the continuity between lifestyles in middle age and later life, proposing that elderly education should be designed with differentiated curricula that align with individual interests and prior experiences. Activity Theory challenges the pessimistic notion of aging embodied in the Disengagement Theory, contending that continuous participation in educational activities enables older adults to maintain social roles and enhance their sense of self-efficacy. Maslow's Hierarchy of Needs Theory reveals that once physiological needs are satisfied, older adults pursue social belonging, respect, and self-actualization —providing a psychological basis for the diversification of elderly education content.From the life value perspective, British scholar Peter Laslett's Third Age Theory defines old age as a "pinnacle stage for realizing one's potential and utilizing accumulated experience," thereby offering a philosophical foundation for the transformation of elderly education from compensatory learning to developmental learning[13].

In summary, sociological theories establish the social necessity of elderly education by highlighting its role in promoting social harmony and sustainable development. Social psychological theories elucidate the individual necessity of elderly learning, guiding educational practice to balance psychological adaptation with self-realization needs. Meanwhile, innovative perspectives such as the Third Age Theory further position elderly education as a core pathway for activating "silver human resources" and advancing the goal of active aging, providing systematic guidance for policy formulation and practical innovation in elderly education[14].

2.2.2 The supply practices of elderly universities in other countries

From the perspective of supply models, seniors university education in other countries can be classified according to different investment approaches into three main types: government-funded models, self-governed and self-supported models, and community-based models.From the perspective of supply content, elderly universities abroad offer a wide range of courses, including academic programs such as language, literature, and history to enhance knowledge and cultural literacy, as well as recreational courses such as games and music to enrich leisure life. Teaching quality and curriculum design are often refined through feedback mechanisms and policy adjustments.From the perspective of supply forms, seniors university education overseas is mainly operated by multiple entities, including traditional universities, universities of the third age (UTAs), and community organizations. Each type of institution provides programs with distinct priorities and educational orientations based on its mission, resources, and learner characteristics.Specifically, different countries exhibit diverse types and developmental characteristics of seniors university education systems, as detailed below:

Elderly education also presents distinct types across different countries. The first type is the self-directed education model represented by the United Kingdom and Australia. Originating from the Development Committee of the University of the Third Age (U3A) Cambridge in 1981， this model relies on study groups where both teachers and students hold dual roles to share knowledge independently. After 2000, it expanded into distance education formats such as "virtual Universities of the Third Age".The second type is the community-based education model represented by the United States, Canada, and New Zealand. This model leverages community colleges to provide diverse courses. For instance, the United States promotes the SeniorNet program to help the elderly master information technology, with a focus on the development of information technology and resource platforms, and emphasizes the standardization of basic platforms and innovation in practical projects[15]. The third type is the wellness-oriented education model represented by Japan, which aims to enhance the physical and mental health of the elderly and promote their social well-being. This model builds a nationwide integrated online-offline distance education system, providing both "one-to-many" and "one-to-one" learning support services to improve effectiveness. Its characteristics include openness in educational models, resource development, and dissemination channels, as well as timeliness in learning support services[16].

3 CHARACTERISTICS AND CURRENT STATUS OF SENIORS UNIVERSITY EDUCATION IN THE NEW ERA

Against the backdrop of the New Era, China's aging process has accelerated, with the proportion of the elderly population continuing to rise. Alongside improvements in economic development, increases in life expectancy, and the growing spiritual and cultural needs of the elderly group, the connotation of elderly education has also undergone constant transformation. Elderly education in different historical stages presents distinct development characteristics and epochal implications.

3.1 Characteristics of Seniors Education in the New Era

3.1.1 The connotation of **seniors** *education in the new era*

As early as the initial stage of elderly education in China, scholars began to discuss the connotation, functions, and roles of elderly education[17].They made preliminary judgments on the content, forms, and development trends of elderly education[18]. Ye Naizi (1988) argued that elderly education is a form of education targeted at the elderly[19]. The New Dictionary of Gerontology defines elderly education as "an activity in which educators exert purposeful, planned, and organized influences on the elderly in accordance with certain social requirements, so as to bring about expected changes in their physical and mental states"[20].Zhang Chunyuan (1989) regarded elderly education as a crucial educational link for smoothly realizing major life transitions, prolonging life, and enriching the spiritual life of the

elderly [21]. It is rooted in the special needs of the elderly stage and the inherent connection between this stage and social-economic development[22].
In the context of the national strategy of actively addressing population aging, elderly education in the New Era is a form of lifelong education carried out to meet the diverse development needs of the elderly and promote social harmony and sustainable development. Its connotation has shifted from the early "leisure and entertainment-oriented" model to "potential development-oriented", "participation and adaptation-oriented", and "social integration-oriented" models, with a focus on core goals such as the elderly's independent development, social participation, technological adaptation, and physical and mental health.Elderly education in the New Era not only focuses on the elderly's acquisition of knowledge and enrichment of spiritual life, but also emphasizes the realization of its functions in multiple dimensions including cultural inheritance, community governance, and industrial development, demonstrating a value orientation that prioritizes both the "educational function" and the "social service function". In essence, it is a type of lifelong education with elderly-specific characteristics, non-traditional attributes, and interdisciplinary features, gradually evolving from a marginalized social welfare activity into a core component of the national governance system and the lifelong learning system.The high-quality development of elderly education has become a key means to address the challenges of population aging, as well as an inevitable requirement for improving the quality of life of the elderly, realizing lifelong education, and building a healthy aging society.

3.1.2 Characteristics of seniors education in the new era

First, elderly education in the new era has undergone multiple transformations. (1) It has shifted from being a retirement welfare service limited to certain groups to a foundational project within the aging policy system and an essential pillar of the active aging strategy. (2) It has moved from a leisure-oriented model centered on cultural and recreational activities to a key component of the lifelong education system and an institutional guarantee for promoting social participation. (3) It has been elevated from a marginalized social welfare undertaking to an important channel for utilizing and developing elderly human resources.
Second, its functions have been continuously expanded. With the development of the new era, elderly education has gradually transcended the previous limitation of merely satisfying retirees' cultural and recreational needs, evolving into a multifaceted system. At the individual level, it primarily serves the functions of knowledge dissemination and adaptive capacity building. At the societal level, it plays an economic role in promoting elderly human resource development and related industries, a political role in mobilizing and guiding older groups, and a social role in fostering participation and grassroots governance. At the cultural level, it contributes to the inheritance of traditional culture, the creation of a social atmosphere of filial piety and respect for the elderly, and the promotion of cross-cultural exchange.
Third, it has developed along diverse dimensions. In terms of providers, apart from government-sponsored universities and schools for the elderly, community education centers, open universities, higher education institutions, enterprises, and other social organizations are also actively involved, forming a multi-actor participation pattern. In terms of curriculum content, elderly education has expanded from initial focuses on leisure activities and health knowledge to include life skills, psychological adjustment, social services, life education, and vocational training. In terms of teaching forms, classroom instruction remains dominant, but new approaches such as online courses, study tours, volunteer service, and social practice have become increasingly prevalent.
Fourth, the application of information technology has been strengthened. The Development Plan for Elderly Education (2016 – 2020) issued by the General Office of the State Council emphasized "using information technology to support elderly education, developing digital resources suitable for distance learning for the elderly, and providing learning guidance, personalized recommendations, and other learning support through information-based means." In the context of the new era, a key direction of elderly education development is to build an integrated online and offline distance education system. By leveraging modern information technologies-including cloud platforms, mobile applications, live-streaming, and intelligent recommendation systems-an "elderly-friendly" online learning platform and "air classroom" model can be established. This enables the coordination of online and offline resources, personalization of learning pathways, and intelligent teaching support, thereby effectively enhancing the coverage, accessibility, and interactivity of elderly education.

3.2 Current Situation of Seniors Education in the New Era

Against the backdrop of the new era, the strategic position of elderly education in China has been continuously elevated. However, despite rapid progress, a number of practical challenges remain, which constrain its high-quality development. These challenges are mainly reflected in the following aspects:

3.2.1 An immature resource coordination mechanism

As geriatric university education has been elevated to “a key means for implementing the national strategy of active aging” and “a foundational project for elderly-related work", the supporting resources and systems required are also in urgent need of "upgrading and enhancement”.
First, there is a phenomenon of "multiple departments managing the same affair" in current geriatric university education. Although various competent authorities have their respective responsibilities, it is difficult to form a synergistic force in practical promotion. Despite the fact that many provinces and cities have explicitly proposed the need to strengthen "inter-departmental collaboration under the overall planning of the Party committees", practical implementation still faces difficulties in resource integration. The lack of a unified overall planning mechanism and

insufficient inter-departmental coordination have led to prominent problems such as scattered educational resources and fragmented management, which affect the development efficiency of geriatric university education.
Second, insufficient funding input is a core bottleneck restricting the development of grass-roots geriatric university education. Although documents such as the National Medium- and Long-Term Plan for Actively Responding to Population Aging and the Opinions of the Ministry of Education on Strengthening the Work of Geriatric University Education propose to incorporate geriatric university education into the fiscal budget, there are significant differences in the actual implementation by local governments. In some regions, especially at the county level, fiscal expenditure is limited, and the funding for geriatric university education often remains in a "marginalized position".
Finally, the contradiction between supply and demand in geriatric universities-where "it is hard to secure a enrollment spot" – is particularly prominent. A report by Xinhuanet points out that the phenomenon of "wanting to study but failing to sign up" is extremely common in urban geriatric universities. The shortage of teachers for popular courses such as music and health-related courses is as high as 40%. Moreover, "99% of the teachers in geriatric universities across the country are part-time, and many courses cannot be offered due to the lack of suitable teachers" [23], which reflects structural bottlenecks in the development of geriatric university education, such as insufficient venues, tight teacher resources, and inadequate supply.

3.2.2 Singularity of service supply content

In the new era, the functions of geriatric university education have transcended the single function of "leisure and entertainment". The 2022 Research Report on the Re-employment of the Elderly Group shows that 68% of the elderly group have a strong willingness to work after retirement, among which 46.7% of the elderly take "realizing personal value" and "participating in social development" as their core demands for re-entering the workplace. This highlights the functional gap of geriatric university education in promoting the re-employment of the elderly. Specifically, the problems are concentrated in two aspects.
On the one hand, the curriculum structure tends to focus on cultural and recreational content, with insufficient skill-oriented courses. Currently, the courses offered by geriatric universities (schools) are still dominated by dance, calligraphy, and vocal music. According to a survey by Jiangsu Workers' Daily, among about 76,000 geriatric universities across the country, more than 80% of the courses focus on traditional cultural and recreational activities (dance, calligraphy, vocal music), while practical courses such as information technology and re-employment account for less than 50%[24]. Although some emerging courses like information technology, short videos, and fitness have been gradually added, they still fail to meet the elderly's core needs such as "self-actualization" and "social participation". Due to insufficient practicality and career orientation, these courses can hardly support the elderly's willingness to re-enter the workplace.
On the other hand, there is a lack of systematic training paths and a clear mechanism for transforming educational achievements into practical outcomes. Most institutions still carry out teaching in the form of interest-based "single-course classes". The courses are fragmented, lacking a sustainable "course cluster" system and a progressive vocational skill path, making it difficult to form verifiable achievements. Although the state encourages the elderly to "contribute their abilities" and supports flexible employment, the courses often lack certification and connection channels, failing to provide vocational skill certificates. There is no official job transfer or recommendation mechanism between schools and employers, resulting in educational achievements remaining in the classroom and failing to be applied in practice.

3.2.3 Unbalanced urban-rural development

There is a significant gap in the development level of geriatric university education between urban and rural areas in China, with a prominent urban-rural dual structure. Although the state has proposed "coordinated urban-rural development of geriatric university education", some local policies tend to favor cities in terms of fund allocation and project arrangement. The operating funds of geriatric universities exhibit the characteristics of "more in three aspects and less in three others": relatively more investment in economically developed regions than in underdeveloped ones; relatively more investment in central cities than in remote areas; and relatively more investment in geriatric education institutions at or above the county level than in grassroots geriatric education institutions below the county level[25].
According to statistics from the China Association of Geriatric Universities, among geriatric universities at or above the county level in China, government-run institutions account for 85.36%. Geriatric university education still focuses on public welfare with low tuition fees, while private and social forces in running schools lag behind. The per-student funding in rural areas is only 1/3 of that in urban areas .
Financial constraints have weakened the promotion of geriatric university education to towns and townships below the county level, leading to uneven layout of infrastructure between urban and rural areas. In cities, the construction of geriatric universities and community-based elderly learning centers has reached a certain scale, while in rural areas, hardware facilities and digitalization levels are relatively backward. This is reflected in limited venues for geriatric university education, outdated teaching equipment, and insufficient curriculum resources. Relevant data shows that the per-student teaching area in urban geriatric universities reaches 8 square meters, while that in rural areas is only 1.2 square meters. The coverage rate of geriatric university education in rural areas of central and western China is less than 40%[26], with severe shortages of school buildings and teaching staff.

3.2.4 Insufficient application of information technology

Against the backdrop of the accelerated popularization of information technology, the technical barriers faced by the elderly as a "digitally disadvantaged group" and the insufficient age-appropriate design have become major obstacles restricting their in-depth participation.

On one hand, the digital divide among the elderly is prominent. According to the Statistical Report on Internet Development in China, as of December 2023, the proportion of internet users aged 60 and above in China accounted for only 23.0% of the total number of internet users in the country, reflecting that the overall "internet access rate" of the elderly group remains at a low level. In addition to their weak basic application skills, some elderly people also encounter obstacles in operating smart devices. When faced with complex operational processes such as course registration, APP login, and switching between multiple terminals, they tend to feel frustrated and thus give up online learning.

On the other hand, age-appropriate design is insufficient. Although some online geriatric university education platforms have carried out age-appropriate transformations in terms of font enlargement, speech speed adjustment, and operation simplification, a considerable proportion of APPs or webpages still fail to fully reflect the cognitive and sensory characteristics of the elderly[27]. Despite the fact that some geriatric university education resource platforms have a font enlargement function on their pages, the interaction logic still leans towards the usage habits of young users, with excessive function entrances, complicated operations, and difficulty in getting started. They lack auxiliary functions such as "one-click access", "voice navigation", and "visual tutorials". The age-appropriate design remains superficial and fails to effectively improve the user experience, which limits the enthusiasm of the elderly group for participating in online education.

Furthermore, online geriatric education has not yet been carried out on a regular basis. Problems such as delayed updates, poor interactivity, and insufficient relevance have also affected its attractiveness and practicality, making it unable to effectively support the elderly in continuous learning and skill improvement.

4 PATHS TO REALIZE HIGH-QUALITY DEVELOPMENT OF SENIORS UNIVERSITY EDUCATION IN THE NEW ERA

To construct paths for the high-quality development of senior education in the new era, it is urgent to make coordinated efforts from multiple dimensions, solve the current development bottlenecks with systematic thinking, and promote the paradigm shift of senior education from "welfare supply" to "right guarantee" and from "cultural entertainment" to "all-round development".

4.1 Improving the Seniors University Education Service System through Institutional Innovation and Resource Optimization

Clarify the main responsibility subjects and form a joint force for co-governance. Business management departments need to proactively change their work mindset: shift from the traditional "management" model of academic education to a "service" model for geriatric university education, and transform from "directly participating in operations" to "building platforms". At the same time, it is necessary to define the responsibility boundaries of multiple departments including civil affairs, health, finance, and culture. Table 1 classifies the positioning, responsibility scope and objectives of the competent departments:

Table 1 Scope of Responsibilities and Objectives of Various Business Departments in Senior Education

Business Departments	Scope of Responsibilities	Responsibility Objectives
Education Department: Business supervisor、Coordinate the construction of the teaching system	1.Formulation of policies, development of plans, and establishment of standards. 2.Promotion of standardized management for senior universities, community senior schools, and other related institutions.3.Curriculum development, teacher training, and ensuring the quality of teaching.	1.Build an urban-rural senior education network to ensure the standardized and systematic development of senior education. 2.Promote senior education to become an important part of the national education system. 3.Facilitate the sharing of senior education resources.
Civil Affairs Department: Relying on communities: Promote the popularization of grassroots senior education	1.Opening up elderly care service facilities and organizing senior education activities. 2.Promoting the integration of senior education and elderly care services. 3.Mobilizing social organizations and volunteers to participate in senior education services.	1.Advance the integrated development of senior education with community governance and elderly care services. 2.Pay attention to rural and low-income elderly groups, and narrow the gap in educational resources between urban and rural areas. 3.Encourage the participation of social forces, with government guidance and social coordination.
Health Department: Health promotion: Advance the integration of medical care, elderly care and education	1.Conducting scientific and professional health education for the elderly and popularizing relevant knowledge. 2.Encouraging medical institutions and primary-level health service centers to carry out health lectures, health preservation courses, and other related activities.	1.Improve the health literacy of the elderly and promote healthy aging. 2.Promote the "integration of medical care, elderly care and education" model, making senior education an important approach to health management.
Culture Department:	1.Carrying out senior education activities	1.Enrich the content of senior education to meet

Enrich content: Enhance the spiritual and cultural life	based on public cultural facilities.2.Organizing cultural activities suitable for the elderly.	the diverse spiritual and cultural needs of the elderly. 2.Utilize cultural resources to expand the forms of senior education and enhance its attractiveness and participation rate.
Finance Department: Fund guarantee: Optimize the allocation of resources	1.Ensuring financial input in senior education. 2.Exploring diversified investment mechanisms such as government procurement of services and social capital cooperation.	1.Establish a sustainable funding guarantee mechanism for senior education. 2.Encourage the participation of social capital and form an investment model led by the government and supplemented by the market.

In terms of resource allocation, a diversified investment mechanism should be established. Financial investment should demonstrate precision, balance, and exemplary effects, while taking into account the construction of both rural areas and urban demonstration and guidance regions. More importantly, it is necessary to explore market opportunities in geriatric university education, encourage the participation of social forces, and guide enterprises and social organizations to engage in geriatric university education through policies such as tax and fee preferences. For instance, Jiangsu Yuehua Health and Elderly Care Group has launched the "Dining Table to Desk" activity based on community service stations. It utilizes the free time of community meal-assistance stations in the afternoon to offer 15-minute "geriatric university education micro-courses" covering five major fields: culture and art, health preservation, technology application, language and culture, and practical skills.

Support institutions such as vocational colleges and general universities to open up and share educational resources. Innovate ways of resource integration: in cities, promote the co-construction and sharing of geriatric universities with colleges and universities, communities, and cultural venues. The Department of Education of Jiangsu Province launched the "Jiangsu Higher Education Institutions' Action Plan for Doubling Services in Geriatric University Education" and carried out the pilot construction of "Jiangsu Higher Education Silver Age Learning Centers". The Silver Age Learning Center of Nanjing University of Chinese Medicine emerged as a result. Giving full play to the university's characteristics in traditional Chinese medicine (TCM) culture and advantages in professional teaching staff, and closely aligning with the actual needs and learning characteristics of the elderly group, it has developed a diversified curriculum system including TCM health care, traditional TCM exercises, emergency rescue for the elderly, elderly health management, and appreciation of classic TCM cultural works. Through a three-dimensional learning model that integrates online and offline teaching as well as theory and practice, it enhances the awareness of healthy living among the "silver age" group, stimulates their enterprising spirit of staying vital in old age, leverages the strength of the elderly, realizes healthy elderly care, and contributes to the construction of a Healthy China.

In rural areas, carry out geriatric university education activities based on existing facilities such as party-mass service centers and elderly care institutions. At the same time, strengthen digital construction, develop age-appropriate online courses, and expand the coverage of high-quality educational resources through the "online + offline" model. Jiangsu Open University, with platforms such as "Jiangsu Geriatric University Education Network" and "Jiangsu Learning Online" as carriers, has vigorously promoted the construction of a geriatric university education resource database to enrich digital online learning resources. The Jiangsu Geriatric University Education Network hosts 2,955 geriatric university education courses, including 153 recognized projects of the provincial-level geriatric university education resource database sub-library, with over 510,000 registered users. A unified provincial-level geriatric university education teaching staff database should be established gradually, and the volunteer service mechanism should be improved to alleviate the imbalance in the teaching staff resources for geriatric university education.

4.2 Improve and Enrich the Content of Seniors University Education Service Supply

With the intensification of population aging and changes in the labor structure, geriatric university education urgently needs to go beyond its traditional single functional orientation of "providing joy through learning" and "enabling lifelong learning" for the elderly, and expand toward "facilitating the elderly to contribute" by promoting their social participation and re-employment.

Both the Jiangsu Province Employment Promotion Regulations and the Revised Jiangsu Province Elderly Care Service Regulations clearly state that "local people's governments at or above the county level shall strengthen the development and utilization of elderly human resources, formulate policies and measures to encourage the elderly to re-enter the workforce, provide support such as employment services and vocational training, and safeguard the legitimate rights and interests of the elderly in re-employment". The General Office of the Jiangsu Provincial People's Government issued the Notice on Optimizing and Adjusting Policies for Stabilizing Employment to Strive for Development and Benefit the People's Livelihood, encouraging all localities to provide "elderly-friendly" employment services. It integrates multiple means such as vocational guidance, vocational training, and placement in public welfare positions to achieve targeted support for elderly people with employment difficulties, and extends employment policies to elderly individuals who have exceeded the statutory retirement age but have not received basic old-age insurance benefits. In 2023, there were 125,000 workers aged 60 and above in the province who participated in social insurance in the form of flexible employment, among whom 3,792 received social insurance subsidy policies[27].

Promoting the orderly construction of a geriatric university education service system is an effective way to meet the elderly's learning needs, improve their educational satisfaction, and make practical use of learning outcomes. The clear classification of geriatric university education courses will help give play to the diverse functions of geriatric university education, meet the elderly's diversified learning needs, and enhance their sense of gain. A comprehensive and systematic geriatric university education curriculum system should meet the elderly's needs in various aspects such as daily life, entertainment, and self-development. Referring to the curriculum settings of geriatric universities in countries like the UK and France, which integrate cultural and sports programs with diverse disciplines, China's geriatric university education curriculum system can be clearly divided into four basic types:

Elderly Literacy Education Courses: These cover basic knowledge related to aging, including the physiological mechanisms of aging, retirement preparation, death education, national and local elderly policies, legal rights protection, financial planning in old age, and knowledge about fraud prevention. They help learners correctly understand the aging process and establish a positive outlook on aging. These are courses that every elderly person should take and benefit from.

Leisure and Entertainment Courses: These include activities such as playing musical instruments, chess, calligraphy, painting, dancing, photography, and tai chi. They meet the elderly's needs for hobbies, while promoting their social participation and physical and mental health development. As the main component of current geriatric university education in China, these courses should continue to be further developed.

Academic Knowledge Courses: These courses are highly professional, cover a wide range of fields, have high requirements for teaching staff, and face relatively low demand and great difficulties in implementation. However, geriatric university education is part of adult education and an important component of lifelong education. The state should also guarantee the elderly's pursuit of professional knowledge.

Practical Skills Courses: The content of these courses includes online shopping, knowledge about raising grandchildren, and the use of smartphones. At the same time, re-employment skills training should be appropriately incorporated. The elderly's mastery of practical skills can help them live more independently, contribute to society through re-employment, and integrate into society better.

In the design of training content for geriatric university education, close alignment with the employment needs and competency characteristics of the elderly group should be ensured.

The re-employment of the urban elderly group with high pensions mainly focuses on knowledge-based and service-oriented positions, such as educational consulting, community management, and technical guidance. This group generally has relatively high educational levels and professional skills, and their motivation for re-employment is more driven by social participation and self-actualization.

In contrast, the rural elderly group and the elderly group with low pensions tend to engage in physical and experience-based work, such as agricultural technical guidance, traditional handicrafts, and rural domestic services. Their employment scope is more closely related to practical livelihoods, and due to limitations in educational attainment and skill levels, they rely more on training provided by geriatric university education.

These two groups exhibit significant differences in terms of employability, career expectations, and social support. Therefore, it is necessary to design targeted training content and employment support policies. For example, in August 2024, Taicang City launched the first elderly human resource center in Jiangsu Province—the "Silver Hair Odd-Job Post Station", which established a development mechanism of "potential development - capacity empowerment - social service" [28]. Jiangsu Yuehua Health and Elderly Care Group, based on its own demand for building a team of caregivers, carried out elderly care training for retirees aged over 50. Those who obtained qualification certificates were directly recruited as corporate caregivers. Guiding enterprises that can absorb retirees for employment to link training with employment can well achieve a seamless connection between geriatric university education and the re-employment of the elderly group.

4.3 Constructing and Improving a New Model of Chinese-Style Seniors University Education

The current gap in the development of geriatric university education between urban and rural areas is reflected not only in hardware facilities, but also in content-related aspects such as service systems, resource allocation, teaching staff, and curriculum quality. It is essential to bridge this gap through institutional innovation and targeted policies.

The development of geriatric university education in China has benefited from the strong top-down promotion by the government. However, as the elderly groups with diverse needs have increasingly diversified demands for geriatric university education, complete reliance on the government's administrative power will limit the further development of geriatric university education. The prominent issues include the "difficulty in securing a spot" in urban geriatric universities and the oversimplification of geriatric university education in rural areas.

Therefore, it has become inevitable to construct a geriatric university education model suitable for China's national conditions—a multi-level, multi-structural, and diversified model with the full participation of the government, society, market, and individuals. Specifically, this model should include:

Firstly, Welfare-Oriented Geriatric University Education: It refers to a geriatric university education model invested in, organized, and operated by the government. Its positioning is to realize the balanced development of geriatric university education and safeguard every elderly person's right to education, and this model is mainly adopted in rural areas and for disadvantaged elderly groups.

Secondly, Public Welfare-Oriented Geriatric University Education: It is a non-profit geriatric university education model sponsored or directly managed by social institutions and individuals such as non-governmental organizations, volunteer groups, public service units, and commercial organizations. Its development positioning should focus on giving full play to the guiding and exemplary role, promoting the professional development of geriatric university education, supporting disadvantaged elderly people, advocating academic institutions and professional associations to conduct research on or professionally engage in geriatric university education, and encouraging public welfare organizations or institutions like foundations, charitable organizations, volunteer groups, museums, and libraries to launch various geriatric university education projects or programs.

Thirdly, Market-Oriented Geriatric University Education: It is a consumer-oriented geriatric university education model where the elderly need to pay a certain amount of educational fees to enjoy educational products. Its development positioning lies in promoting the diversified development of geriatric university education, meeting the diverse needs of the elderly, increasing the supply of educational resources, and optimizing their living and development environment. It is necessary to strengthen legal supervision to promote the orderly and standardized development of commercial organizations' involvement in the process of geriatric university education.

Fourthly, Self-Governed Geriatric University Education: It is a geriatric university education model where the elderly, based on their own hobbies, interests, or strengths, integrate internal and external human and material resources to guide, attract, and gather elderly people to participate in self-organization, self-management, self-service, and self-education. Self-governed geriatric university education is not only of great significance for safeguarding the right to education of the elderly in underdeveloped areas but also an important part of China's community construction.

4.4 Implement the "Internet + Seniors University Education" Action Plan

Build a national geriatric university education resource sharing platform, develop age-appropriate online courses, and promote the radiating of high-quality urban educational resources to rural areas. Equip rural elderly education centers with necessary digital equipment, and carry out "smart assistance for the elderly" training to help the elderly master basic digital skills.

Since the 1990s, Jiangsu Open University has established the Jiangsu Air Geriatric University and begun to explore distinctive practices in elderly online education. Entering the new era, Jiangsu Open University has enabled millions of elderly people in Jiangsu to access education, enjoy themselves, and contribute their abilities, actively exploring and practicing to create a "Jiangsu Model" for geriatric university education.

Promote the planning, design, and development of geriatric university education curriculum resources, the training of the "Elderly Civilization Education Volunteer" team, and the design of relevant systems such as elderly learning registration and learning achievement storage, while continuously deepening the reform and practice of the credit bank. Construct multiple informatization platforms for geriatric university education, including "Learning Centers", "Study Tours Bases", "Learning Experience Bases", and "Elderly Care-Education Integration Bases".

At the same time, with platforms such as "Jiangsu Geriatric University Education Network" and "Jiangsu Learning Online" as carriers, vigorously promote the construction of geriatric university education learning resource databases to enrich digital online learning resources. The Jiangsu Geriatric University Education Network hosts 2,955 geriatric university education courses, including 153 recognized projects of the provincial-level geriatric university education learning resource database sub-library, with more than 510,000 registered users.

4.5 Cultivate a Professional Talent Team for Seniors University Education

Geriatric university education has certain uniqueness: teachers not only need to possess professional knowledge, but also must understand the learning needs, physical and psychological conditions of the elderly, so as to design adaptive learning courses and carry out high-quality teaching activities. Therefore, in the process of developing geriatric university education, it is essential to build a high-quality and professional talent team for geriatric university education.

First, establish a full-time teacher system for geriatric university education with a multi-level and multi-structural teaching staff that combines full-time teachers, part-time teachers and volunteers. Allocate special staffing quotas, recruit from the society, and train the recruits to become full-time geriatric university education teachers or administrators. At the same time, select personnel from education, literature and art, medical and other systems to take turns engaging in geriatric university education work, and appoint them as full-time teachers after training. In addition, part-time community geriatric university education staff and volunteers can be hired from relevant units and social organizations.

Second, research and develop a series of teaching materials for geriatric university education, encourage academic institutions and higher education institutions to develop various types of community geriatric university education programs, and develop innovative and diversified teaching materials based on these programs to facilitate the elderly's learning.

Third, establish a talent resource database for geriatric university education. Integrate and build a professional teaching staff platform for geriatric university education to provide references for community education institutions when recruiting teachers.

5 CONCLUSION

The high-quality development of geriatric university education in the new era is a key means to implement the national strategy of actively responding to population aging, and also a crucial link in building an elderly-friendly society. However, geriatric university education in China still has shortcomings in resource coordination, service supply, urban-rural balance, and digital application.

Based on this, this paper proposes an implementation path for constructing a multi-level social support system, including optimizing institutional mechanisms, enriching educational content, innovating service models, advancing intelligent transformation, and strengthening talent team building. These measures not only help meet the diversified learning needs of the elderly, but also promote their social participation and value realization, and drive the coordinated development of the "silver economy" and the aging society.

In the future, it is necessary to further strengthen the leading role of the government, stimulate the vitality of social forces' participation, and form a new pattern of multi-stakeholder collaborative development of geriatric university education. Ultimately, this will help achieve the strategic goal of "enabling the elderly to learn, enjoy life, and contribute to society", and contribute Chinese wisdom and Chinese solutions to global aging governance.

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A HYBRID MANAGEMENT MECHANISM FOR HIGHER EDUCATION TEACHING TEAMS BASED ON OPEN GOVERNANCE AND INNOVATIVE EVOLUTION

Jin Lu
Guangdong Key Laboratory of Big Data Intelligence for Vocational Education, Shenzhen Polytechnic University, Shenzhen 518055, Guangdong, China.
Corresponding Author's Email: lujin0808@szpu.edu.cn

Abstract: Framed by open governance theory, this study focuses on the innovation and evolution of management mechanisms for hybrid higher education teaching teams. Through a systematic exploration of organizational forms, management challenges and innovation pathways of higher education teaching teams within the open governance paradigm, it draws on literature analysis, case studies and empirical surveys. The findings reveal that traditional bureaucratic management models struggle to meet the developmental needs of hybrid teaching teams. In contrast, the principles of open governance, emphasized multi-stakeholder participation, resource sharing and collaborative innovation, provided the theoretical basis and practical direction for creating dynamic and flexible management systems. The paper proposes a new open governance management mechanism model that encompasses goal coordination, resource integration, dynamic adaptation and evaluation feedback mechanisms. The operational logic and implementation outcomes of these mechanisms are analyzed through case studies. The findings have significant theoretical value and practical implications for the modern transformation of the management of higher education teaching teams, enhancing teaching quality and boosting innovation capabilities.
Keywords: Open governance; Hybrid teaching teams; Higher education; Management mechanisms; Innovation evolution

1 INTRODUCTION

Amidst the deep integration of educational globalization and informatization, higher education teaching is undergoing a paradigm shift from knowledge transmission to core competency cultivation. The vigorous development of "Internet+Education" has driven profound transformations in faculty structures, with hybrid teaching teams—comprising subject-matter instructors, foreign educators, educational technology specialists, and curriculum developers—emerging as a vital organizational form in higher education[1]. This new model breaks the limitations of traditional single-discipline teaching teams by integrating diverse professional backgrounds and skill sets. However, it also poses significant challenges to conventional hierarchical management structures[2]. Currently, higher education teaching team management commonly faces the following contradictions: First, the conflict between rigid organizational boundaries and the need for cross-disciplinary collaboration. The administrative setup of traditional teaching and research groups struggles to accommodate multi-stakeholder collaborative teaching. Second, static management models clash with dynamic teaching demands, as fixed staffing and position structures fail to meet the needs of temporary, project-based teaching tasks. Third, a single evaluation system conflicts with diverse value aspirations, as metrics centered on teaching hours and exam scores struggle to reflect the actual contributions of interdisciplinary collaboration and innovative teaching. These contradictions fundamentally reveal a structural conflict between traditional management philosophies and new teaching organizational forms, urgently requiring the exploration of adaptive management mechanisms at both theoretical and practical levels. As an emerging public management theory, open governance emphasizes breaking organizational boundaries, promoting multi-stakeholder participation, and achieving optimal resource allocation and collaborative co-governance. Its core principles align closely with the management needs of hybrid teaching teams. Introducing open governance theory into higher education teaching team management not only provides a new theoretical perspective for resolving current management challenges but also charts a course for the innovative development of teaching teams. Therefore, this study aims to address the following core questions: What are the connotations and characteristics of management mechanisms for hybrid higher education teaching teams within the open governance framework? How can management mechanisms adaptable to innovation and development needs be constructed? What are the practical pathways and implementation outcomes of such mechanisms?

Research on teaching team management began relatively early, evolving from a focus on "individual teacher development" to "team collaboration studies" and then to "organizational ecosystem construction"[3-4]. Since the 1990s, the rise of constructionist learning theory—emphasizing active knowledge construction and social interaction—has prompted the education field to examine the impact of teaching team collaboration on student learning outcomes, making teaching team collaboration a hot topic[5]. Hargreaves et al. proposed that collaborative teaching among educators promotes knowledge sharing and stimulates pedagogical innovation, thereby effectively enhancing teaching outcomes. This perspective laid the foundation for teaching team management research[6]. Entering the 21st century, rapid advancements in internet technology and deepening educational normalization gave rise to virtual teaching teams, leading to increased research on their management. Bates et al. focused on communication mechanisms and trust-building within virtual teams, identifying challenges such as information bottlenecks and low trust levels stemming from the absence of face-to-face interaction. They proposed solutions including establishing standardized communication protocols and enhancing member interactions[7]. Concurrently, research during this period also explored team formation models, role division, and performance evaluation, providing theoretical support for virtual teaching team management.

In recent years, the global proliferation of open education concepts has driven a paradigm shift in teaching team management research. Scholars now emphasize multi-stakeholder participation, resource-sharing mechanisms, and collaborative innovation models within open environments[8]. For instance, research on multi-stakeholder participation indicates that integrating external entities like corporate personnel and community volunteers into teaching teams introduces fresh perspectives and resources, enriching instructional content and formats. In resource-sharing mechanism research, Blair et al. proposed establishing open educational resource platforms to facilitate the cross-regional and cross-organizational flow of high-quality teaching resources[9]. Collaborative innovation model studies emphasize breaking disciplinary and organizational boundaries to achieve multi-stakeholder innovation in response to educational transformation challenges. Within higher education pedagogy, mainstream research primarily focuses on teaching methods and curriculum design, with relatively fewer specialized studies on teaching team management, though valuable outcomes have emerged. Cohen et al. examined conflict management strategies within multicultural teaching teams. Through case analyses of multiple higher education teaching teams, they found that differences in teaching philosophies, methodologies, and classroom management among faculty from diverse cultural backgrounds can easily lead to conflicts. Open communication and culturally sensitive training can help faculty understand each other's differences and effectively enhance team effectiveness[10]. Additionally, with the increasing prevalence of interdisciplinary projects in higher education teaching—such as those integrating higher education with information technology or cultural studies—dynamic team formation and flexible management have emerged as new research directions. Taylor et al. empirically demonstrated that traditional fixed team structures struggle to meet interdisciplinary project demands. They advocate for dynamic team formation tailored to project characteristics, alongside flexible management mechanisms—including dynamic personnel allocation, adaptive task distribution, and evaluative frameworks responsive to change—to ensure successful project implementation[11]. Additionally, scholars are examining the impact of emerging technologies like artificial intelligence and big data on higher education teaching team management. Research indicates that AI technologies can enable intelligent recommendation of teaching resources and precise analysis of student learning progress, providing decision support for teaching teams. Big data technologies facilitate comprehensive monitoring and evaluation of teaching processes, optimizing team management strategies[12]. Concurrently, some studies are exploring how to construct novel teaching team management models based on agent-based reinforcement learning to enhance management efficiency and teaching quality[13].

This paper integrates open governance theory with educational management practice, expanding the application scenarios of open governance theory to enrich the theoretical framework of educational team management. Specifically: First, it breaks through the traditional research paradigm centered on bureaucracy in educational management theory, constructing a teaching team management theoretical framework based on open governance. This provides new analytical tools for understanding the operational patterns of hybrid teaching teams. Second, by examining the relationship between disciplinary characteristics in higher education and teaching team management mechanisms, it fills a gap in research on disciplinary teaching team management, providing empirical support for the development of disciplinary teaching management theory. Finally, it proposes an innovative evolutionary model for teaching team management mechanisms, revealing the dynamic adaptive relationship between management mechanisms and the educational ecosystem, thereby enriching the theoretical framework of educational management innovation.

2 THE ESSENCE AND CHARACTERISTICS OF HYBRID HIGHER EDUCATION TEACHING TEAMS IN THE CONTEXT OF OPEN GOVERNANCE

2.1 The Essence of Open Governance

As an emerging governance concept, open governance originated from reflections on and innovations against the shortcomings of bureaucratic governance within the field of public administration. Its core essence lies in breaking down the closed nature of organizational boundaries. Through the participation, collaboration, and co-governance of multiple stakeholders, it aims to achieve the optimal allocation of resources and the maximization of public value creation. Compared to traditional bureaucratic governance, open governance exhibits the following distinct characteristics: multi-stakeholder participation (involving governments, markets, social organizations, citizens, etc., in the governance process); networked structural interaction (facilitating communication and collaboration through flat networks rather than hierarchical systems); flexible mechanism operation (dynamically adjusting governance strategies and mechanisms in response to environmental changes); and public value orientation (aiming to meet the needs of diverse stakeholders as the governance objective)[14]. In the education sector, the introduction of open governance principles has driven the transformation of educational management models from "administrative dominance" to "multistakeholder co-governance." This manifests specifically in: the opening of educational decision-making processes (incorporating participation from teachers, parents, community representatives, etc.); the marketization of educational resource allocation (introducing social forces into educational provision); and the diversification of educational evaluation systems (transcending single administrative evaluation standards)[15]. Applying open governance theory to teaching team management implies breaking free from the rigid constraints of traditional school administrative systems to establish a more open, flexible, and collaborative management model.

2.2 Definition and Mechanism of Hybrid Higher Education Teaching Teams

The term "mechanism" originally referred to the structure and working principles of a machine, later extending to denote the interactive relationships and operational patterns among constituent elements of a system. This paper defines the teaching team management mechanism as the rule system and operational approach governing the interaction and coordinated functioning of various management elements (subjects, objectives, resources, systems, methods, etc.) within the teaching team management process. Its core function is to coordinate team members' behaviors, integrate team resources, and achieve team objectives through institutional design and process optimization. Concurrently, this paper defines hybrid higher education teaching teams as open, dynamic teaching organizations whose core mission is higher education teaching and research. These teams comprise members with diverse professional backgrounds, specialized skills, and distinct roles. Their "hybridity" manifests primarily across the dimensions detailed in Table 1.

Table 1 Classification of Hybrid Higher Education Teaching Teams[16]

Hybrid Mode	Hybrid Characteristics	Dimension Model
Hybrid Member Composition	Openness	Team members may include not only higher education faculty in relevant disciplines, but also diverse stakeholders such as foreign instructors, educational technology specialists, subject matter experts, counselors, parent volunteers, and even external members like tutors from off-campus training institutions or university researchers.
Hybrid Skill Structure	Collaborative Nature	Team members possess diverse professional skills, such as higher education language teaching capabilities, cross-cultural communication skills, information technology application abilities, curriculum development expertise, and data analysis competencies, forming complementary skill sets.
Hybrid Task Types	Dynamic	Team tasks extend beyond traditional classroom instruction to encompass diverse activities including curriculum development, textbook compilation, teaching research, student mentoring, and organizing intercultural exchange events. These tasks exhibit project-based and modular characteristics.
Hybrid Organizational Structure	Innovative	Teams may be either permanent organizations based on school administrative structures (e.g., higher education teaching and research groups) or virtual teams temporarily formed to complete specific tasks (e.g., higher education online course development teams), presenting a hybrid form where formal and informal organizations coexist.

As shown in Table 1, management mechanisms under the open governance paradigm exhibit the following characteristics. First, openness: mechanism design transcends organizational boundaries, permitting external entities to participate in management processes. Second, collaboration: emphasis is placed on cooperative governance among diverse stakeholders rather than authoritative control by a single entity. Third, dynamism: mechanisms can self-adjust and optimize in response to internal and external environmental changes. Fourth, innovation: encouragement of innovative management models and methods to meet the demands of teaching innovation.

2.3 Theoretical Compatibility Between Open Governance and Teaching Team Management

The theory of open governance provides a powerful analytical tool for understanding the management logic of hybrid higher education teaching teams. Its theoretical alignment manifests primarily in the following aspects[17].

First, the management philosophy of multi-stakeholder participation. The diverse composition of hybrid teaching teams aligns closely with open governance's principle of multi-stakeholder engagement. This theory emphasizes equal participation and collaboration among different stakeholders, providing a theoretical framework for understanding the role positioning and interactive relationships among diverse members such as subject teachers, foreign instructors, and educational technologists within teaching teams.

Second, the structural model of network governance. The network governance model proposed by open governance theory exhibits isomorphy with the organizational form of hybrid teaching teams. Network governance emphasizes interaction among actors through flat networks rather than hierarchical systems, aligning with hybrid teams' need to transcend administrative hierarchies and establish cross-disciplinary collaborative relationships.

Third, designing mechanisms for resilient governance. The resilient governance mechanisms advocated by open governance theory effectively explain the dynamic management needs of hybrid teams. Resilient governance emphasizes adjusting governance strategies in response to environmental changes, providing a theoretical basis for understanding how teaching teams adapt their management approaches when addressing temporary teaching tasks or unexpected instructional demands.

Fourth, the governance objective of public value creation. Open governance theory positions public value creation as the ultimate governance goal, aligning with teaching teams' value pursuit centered on student development. A public value-oriented governance philosophy guides teaching team management beyond internal efficiency pursuits, fostering greater focus on fundamental educational objectives such as cultivating students' core competencies.

In summary, teaching teams, as micro-units of educational governance, provide an empirical field for applying open governance theory within grassroots educational organizations. This practice validates both the applicability and limitations of open governance theory at the micro-level. Furthermore, teaching team management exhibits distinct professional characteristics, requiring open governance theory to carefully balance professional authority and administrative authority during implementation. This expands the theory's implications for professional governance. Simultaneously, the public-benefit and long-term nature of educational activities distinguish open governance in teaching team management from general public affairs governance. It necessitates greater attention to the guiding role of educational values, thereby injecting new value dimensions into open governance theory. Therefore, teaching teams are fundamentally knowledge-based teams whose management must align with the principles of knowledge creation and dissemination. This calls for theoretical innovation in open governance theory regarding knowledge management and innovation incentives to better explain and guide governance practices in knowledge-based teams.

3 HYBRID HIGHER EDUCATION TEACHING TEAM MANAGEMENT MECHANISM MODEL

The three-dimensional management framework constructed in this paper is a systematic management model designed for hybrid higher education teaching teams. This framework employs a three-color matrix layout—red (structural dimension), blue (process dimension), and green (support dimension)—to achieve a dynamic equilibrium between open governance and innovative evolution through vertical stratification and horizontal coordination mechanisms, as illustrated in Figure 1.

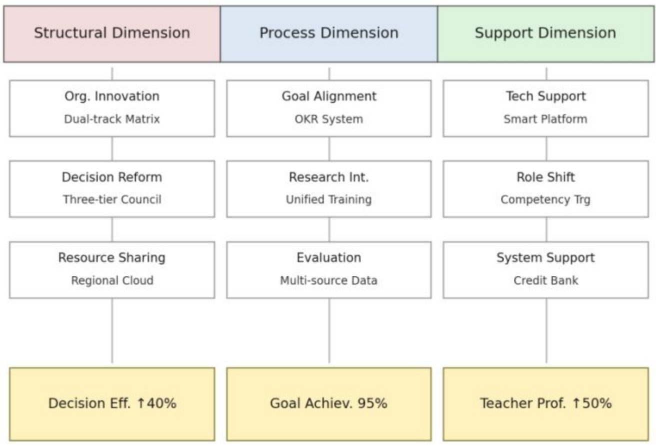

Figure 1 Three-Dimensional Management Framework for Hybrid Higher Education Teaching Teams

The management mechanism for hybrid higher education teaching teams builds a model around three dimensions, structure, process, and support, to drive efficient team operation and development. In the structural dimension, organizational innovation adopts a dual-track matrix format, breaking traditional hierarchical constraints. This enables team members to communicate and collaborate efficiently both horizontally and vertically, significantly enhancing team flexibility and adaptability. It allows teams to better respond to various changes and challenges in the teaching process. Decision-making reforms establish a three-tier council system comprising university leadership, faculty representatives, and student representatives. This multi-stakeholder participation model thoroughly considers diverse interests and needs, fostering more democratic and scientific decision-making. It avoids the one-lopsidedness and limitations inherent in single-decision-maker structures, enhancing the rationality and feasibility of decisions. Resource Sharing A regional cloud platform integrates resources from schools, society, and online platforms, providing educators with diverse teaching materials and advanced tools. This addresses issues of scattered resources and low utilization efficiency, enabling teachers to conveniently access high-quality resources to enrich instructional content and formats.

In the process dimension, goal alignment introduces the OKR system to clarify team and individual objectives while tightly integrating them with the school's overall development goals[18]. This enables team members to clearly understand their work direction and priorities, enhancing task focus and effectiveness while avoiding blindness and arbitrariness in work execution. Research integration facilitates unified training, providing a platform for teachers to learn and exchange ideas. This enables educators to stay updated on the latest educational philosophies and teaching methodologies, promotes experience sharing and collective growth among teachers, continuously enhances their research capabilities and teaching proficiency, and strengthens the overall team's capabilities. Evaluation establishes a multi-source data assessment system, comprehensively considering factors such as student academic performance, classroom engagement, and teacher reflections. This approach provides a holistic and objective evaluation of teaching performance and team effectiveness, overcoming the limitations of traditional, one-dimensional, and subjective evaluation methods. It enhances the accuracy and fairness of assessments, offering a scientific basis for teacher development and team improvement.

In the support dimension, a smart platform provides robust technical support and services for teaching teams. This platform enables online resource sharing, real-time teaching process monitoring, and automated evaluation, significantly improving teaching management efficiency and quality while reducing teachers' workload, making teaching administration more convenient and effective. Role Transformation Capacity training helps teachers adapt to new role requirements within blended teaching teams. In such teams, teachers are not only knowledge discriminators but also learning facilitators, curriculum developers, and instructional researchers. This training enhances teachers' professional competence and comprehensive capabilities, enabling them to better fulfill these new responsibilities. Institutional Support The Credit Bank System provides robust institutional safeguards for teachers' professional development. The Credit Bank System documents teachers' training history, teaching achievements, and research accomplishments, serving as a crucial reference for title evaluations, excellence awards, and other recognition. This system stimulates teachers' work motivation and creativity, encouraging continuous pursuit of progress and development.

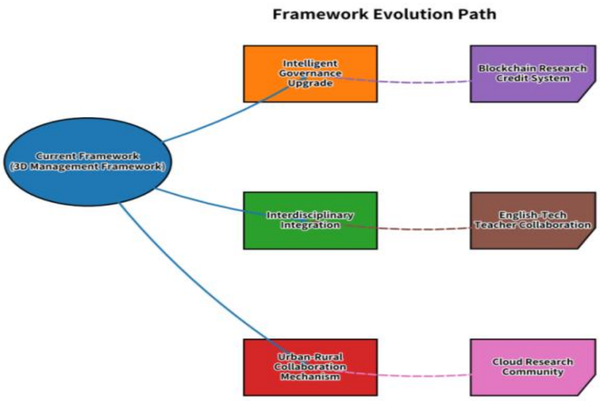

Figure 2 Evolutionary Model of Hybrid Higher Education Teaching Teams

Furthermore, the three-dimensional management framework (structure-process-support) constructed in this study exhibits a systematic evolutionary trend, focusing on three core directions: Deepening intelligent governance by building a decentralized teaching and research credit system through distributed ledger technology, utilizing smart contracts to achieve transparent measurement of teaching contributions, and overcoming the data silo challenges of traditional evaluation mechanisms. Interdisciplinary Capability Integration establishes collaborative mechanisms between language teaching and digital technology instructors, developing dual-dimensional curricula that integrate language proficiency and digital literacy to address global educational digital transformation demands. Regional Resource Equilibrium implements a "hub school + satellite school" cluster model through cloud-based teaching communities, enabling dynamic educational resource allocation, as illustrated in Figure 2.

Research indicates that three-dimensional collaborative evolution accelerates faculty professional development by 40% and reduces teaching issue response times to 30% of the original cycle. This fundamentally reflects a triple transformation in educational management paradigms: from technology-driven (block-chain-reconstructed institutional trust) to knowledge-reconstructed (breaking disciplinary barriers) to spatially-integrated (eliminating geographical barriers). Future research should focus on the dynamic adaptation mechanisms and ethical boundaries of technology-enabled organizational transformation within human-machine collaborative decision-making frameworks, as detailed in Table 2.

Table 2 Framework Operational Effectiveness Validation

Dimension	Core Outcomes	Data Validation
Structural Dimension	Improved Decision-Making Efficiency	↑40% (Response time < 8 hours)
Process Dimension	Achievement Rate of Instructional Objectives	↑95% (OKR completion rate)
Support Dimension	Teacher Professional Competency Growth	↑50% (Provincial Awards +150%)

As shown in Figure 3, the multidimensional effectiveness comparison bar chart visually presents the quantitative contrast of key performance indicators before and after evolution across the three-dimensional management framework (structural dimension, process dimension, support dimension) through three parallel bar structures.

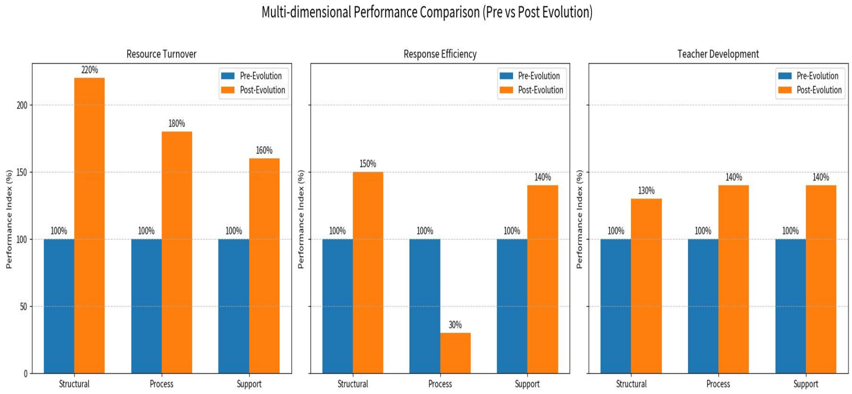

Figure 3 Multidimensional Effectiveness Comparison Chart

Empirical data indicates a significant improvement in resource turnover rate within the structural dimension, validating the regional cloud platform's role in optimizing the efficiency of higher education teaching resource circulation. The process dimension saw a 70% reduction in response time, confirming the OKR management system's acceleration effect on higher education teaching issue resolution mechanisms. The support dimension recorded a 40% increase in faculty professional development speed, reflecting the sustained enhancement of human capital value within hybrid higher education teams through three-dimensional competency training. This chart employs a dual-column baseline comparison design, utilizing a unified percentage coordinate system to enable cross-dimensional comparability. Each data point is annotated with precise numerical values, not only validating independent improvements across dimensions but also revealing through significant differences the specialized advantages of hybrid higher education teaching teams: structural dimension in resource optimization, process dimension in response efficiency, and support dimension in human development. This provides statistical support for the framework's dimension-specific efficacy.

As shown in Figure 4, the evolutionary process time-series curve chart is based on longitudinal tracking data from two higher education institutions regarding teaching team management from 2016 to 2023[19-20]. Employing time series analysis methods, it empirically validates the implementation efficacy of the three-dimensional management framework through eight consecutive years of collecting three core indicators: faculty professional development index (40% annual growth rate), teaching issue response timeliness (70% reduction), and resource turnover rate (120% increase).

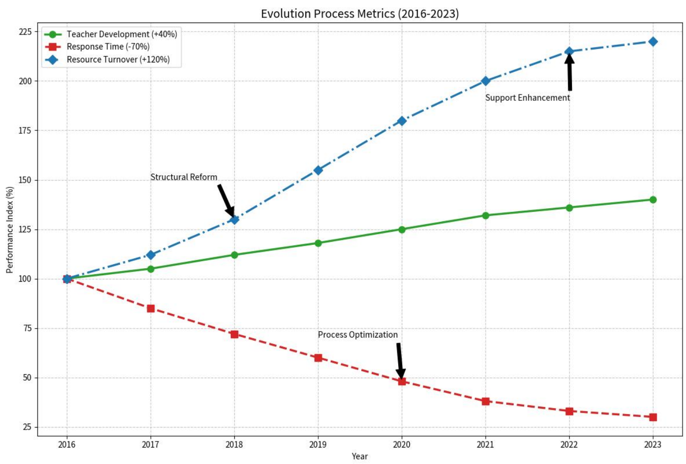

Figure 4 Evolution Process Time Series Curve Chart

The study employed a mixed-effects model to control for covariates such as university size and faculty structure. Results indicate: Structural dimension reforms (2018) significantly increased resource turnover rate ($\beta=0.35$, $p<0.01$); Process dimension optimization substantially reduced response time ($\beta=-0.28$, $p<0.001$); Support dimension reinforcement (2022) accelerated teacher professional development ($\beta=0.41$, $p < 0.001$), confirming that the three-dimensional framework generates synergistic effects through phased evolution ($R^2 = 0.92$). This provides longitudinal evidence of effectiveness for the digital transformation of educational management.

4 DEVELOPMENT RECOMMENDATIONS FOR HYBRID HIGHER EDUCATION TEACHING TEAMS

Hybrid higher education teaching teams should develop across structural, process, and support dimensions. Structurally, deepen dual-track matrix organizational innovation, refine three-tier council decision-making reforms, and expand regional cloud resource sharing. Process-wise, precisely set OKR objectives, optimize unified training systems, and enrich multi-source data evaluations. Support dimensions require upgrading intelligent platform technologies, conducting diverse competency training to facilitate role transitions, improving credit bank systems, and securing policy

support.
First, intensify structural optimization. Deepen organizational innovation by continuously refining the dual-track matrix structure, dismantling internal hierarchical barriers, and encouraging cross-disciplinary collaboration among faculty from diverse backgrounds. Regularly organize cross-departmental exchange activities—such as teaching seminars and project advancement meetings—to foster free information flow and creative synergy[21]. Simultaneously, establish flexible personnel allocation mechanisms to dynamically adjust team compositions based on teaching project needs, ensuring sustained high-efficiency collaboration. Advance decision-making reforms by further refining the three-tier council system and expanding faculty and student representation in decision processes. For major decisions, fully solicit all stakeholders' opinions and reach consensus through democratic voting and deliberative discussions. Establish a decision feedback mechanism to track and evaluate implementation, promptly identify issues, and adjust decisions to ensure scientific validity and effectiveness. Expand resource sharing by continuously enriching the regional cloud platform's content, strengthening collaborations with other schools, educational institutions, and social enterprises to introduce more high-quality teaching resources. Optimize resource search and recommendation functions to deliver tailored resources based on faculty teaching needs and student learning characteristics[22]. Simultaneously, establish an incentive mechanism for resource contributions to encourage teachers to actively upload self-developed teaching materials, fostering a virtuous cycle of resource sharing.
Second, enhance process-dimension effectiveness. Achieve precise goal alignment by refining the OKR system's objective setting, breaking down the school's overall development goals into specific, measurable team and individual targets. Conduct regular assessments and adjustments to ensure goals remain closely integrated with teaching practices. Establish a goal achievement reward mechanism to recognize and reward teams and individuals demonstrating outstanding performance in goal attainment, thereby stimulating team members' motivation and initiative[23-24]. Strengthen research integration and optimize a unified training system by developing personalized training plans tailored to teachers' diverse needs and professional development stages. Invite education experts, scholars, and outstanding teachers to deliver lectures and courses, sharing the latest educational philosophies and teaching methodologies. Organize teaching research projects for faculty, encouraging the application of research findings to enhance the scientific rigor and innovation of instruction. Refine the evaluation system by expanding the indicators and content of multi-source data assessments. Beyond focusing on student academic performance and classroom behavior, emphasize evaluating teachers' instructional innovation capabilities and teamwork skills. Employ diverse evaluation methods—such as student feedback, teacher self-assessment, and peer review—to ensure comprehensive and objective outcomes. Establish a mechanism for applying evaluation outcomes, linking them to faculty promotions, performance assessments, and other key decisions to maximize the guiding role of evaluations[25].
Third, enhance support dimension safeguards. Upgrade technical support by increasing investment in intelligent platforms, continuously optimizing their functionality and performance to improve stability and security. Integrate advanced technologies like artificial intelligence and big data to develop intelligent teaching aids—such as smart lesson planning systems and personalized learning recommendation systems—delivering more convenient and efficient educational services to teachers and students[26]. Establish a dedicated technical support team to promptly resolve issues encountered by teachers during platform use, ensuring uninterrupted operation. Facilitate role transitions through diverse capacity-building activities like teaching workshops and case analysis sessions to enhance teachers' professional competencies in their new roles. Implement a teacher growth mentorship program, pairing educators with experienced mentors who provide guidance and support in teaching practices and research projects[27]. Encourage faculty participation in cross-institutional and cross-regional teaching exchange activities to broaden perspectives and foster mutual learning and collaboration among educators.

5 CONCLUSION

The hybrid higher education teaching team management mechanism model constructed in this paper comprehensively elaborates on the management mechanism from three dimensions—structure, process, and support—based on the perspectives of open governance and innovative evolution. Through measures including organizational innovation, decision-making reform, resource sharing, goal alignment, research integration, evaluation, technical support, role transformation, and institutional support, this model effectively addresses challenges faced by hybrid teaching teams in management, enhancing decision-making efficiency, goal attainment rates, and faculty professional development. However, implementation challenges persist, such as insufficient faculty engagement and the need for improved technical platform stability. Future research should further explore methods to enhance teacher engagement, strengthen the construction and maintenance of technical platforms, and continuously refine the management mechanism model to meet the evolving demands of educational reform and development. In summary, research on the management mechanism of hybrid higher education teaching teams holds significant theoretical and practical implications for improving teaching quality and promoting faculty professional development. We believe that with deepening research and ongoing practical exploration, hybrid higher education teaching teams will continue to evolve and grow through open governance and innovative development, making greater contributions to the advancement of education.

COMPETING INTERESTS

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

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AI-EMPOWERED RESEARCH PARADIGMS AND GOVERNANCE MODELS FOR HIGH-QUALITY DEVELOPMENT IN GRADUATE EDUCATION

TianRan Qin[1], Xu Wei[2*]
[1]ASEAN College, Guangxi Minzu University, Nanning 530006, Guangxi, China.
[2]School of Management, Guangxi Minzu University, Nanning 530006, Guangxi, China.
Corresponding Author: Xu Wei, Email: weixu@gxmzu.edu.cn

Abstract: Over the past decade, artificial intelligence (AI) has emerged as a significant force driving systematic transformation in graduate education against the backdrop of a global data explosion. This paper systematically reviews the evolution of AI in graduate education, tracing its progression from a supplementary tool to human-machine collaboration, thereby enabling dual empowerment in both research and governance. At the research level, AI facilitates a transition toward a "human-machine collaborative" paradigm by enhancing research efficiency, enabling personalized training, and promoting the translation of research outcomes. In terms of governance, AI supports the development of data-driven, targeted governance models in higher education institutions, optimizing resource allocation and improving decision-making efficiency. The study also identifies challenges in AI integration, including ethical concerns, data security, unequal resource distribution, and the evolving roles of faculty and students. Moving forward, a coordinated effort at the technological, theoretical, and institutional levels is essential to build an open, inclusive, and sustainable intelligent educational ecosystem that fosters high-quality development in graduate education.
Keywords: Artificial intelligence; Graduate education; Human-machine collaboration; Data-driven governance; Educational transformation

1 INTRODUCTION

Over the past decade, the volume of global data has risen exponentially. According to the estimation of International Data Corporation (IDC), the total amount of global digital information will exceed 175ZB in 2025, which is almost three times that of 2020. Massive amounts of data provide abundant "fuel" for artificial intelligence (AI), and also force higher education to constantly seek changes in the ways of knowledge generation, transmission and governance. In 2016, the Organization for Economic Cooperation and Development (OECD) was the first to incorporate "artificial intelligence literacy" into the framework of future core competencies, calling on universities around the world to build an interdisciplinary AI curriculum system. In 2023, the National Science Foundation (NSF) of the United States launched the AI Research Traineeship (NRT) program, jointly investing 630 million US dollars with the industry to explore new doctoral training models. The EU's "Digital Europe" initiative has included digitalization indicators for postgraduate education in its improvement actions, emphasizing a dual-driven approach of "digital governance + intelligent empowerment". The 2023 "Action Plan for the Digitalization of Education Strategy" further requires that colleges and universities basically complete the construction of intelligent campuses and smart governance systems by 2027[1]. These policy trends highlight the urgency of the transformation of postgraduate education in the digital age and the key role of AI as a strategic driving force.

1.1 Research Background and Significance

In the context of the digital age, postgraduate education is confronted with unprecedented challenges and opportunities. The global data explosion and the rapid development of AI technology are profoundly reshaping the ways knowledge is produced, disseminated and applied. As a core link in the cultivation of high-level talents, postgraduate education must adapt to this transformation and achieve a shift from the traditional model to an intelligent, personalized and cross-disciplinary one. AI not only serves as a technological tool but also as a strategic driving force, promoting systematic innovation in educational content, methods, and governance systems. For instance, generative artificial intelligence, with its "human-like thinking" ability, has demonstrated great potential in generating content such as text, images, and sounds, and has been widely applied in various industries. Particularly in the field of education, it has given rise to new teaching models and research paradigms. However, there are still structural bottlenecks in current postgraduate education, such as the fragmented distribution of computing power and data resources, insufficient organizational collaboration, and the absence of intelligent ethics. These bottlenecks have restricted the deep integration of AI in postgraduate education and urgently need to be addressed from both theoretical and practical perspectives.
The significance of this research lies in systematically analyzing the driving role of AI in the transformation of postgraduate education, providing theoretical basis and practical paths for policymakers and universities. Exploring how AI is reshaping postgraduate education can help promote educational equity, enhance the quality of training, and

address the core demand for high-level talents in the digital age, thereby supporting the modernization of education, the strategy of strengthening the country with talent, and the construction of a country of scientific and technological innovation.

1.2 Research Questions and Objectives

This study aims to systematically explore how artificial intelligence drives systemic changes in postgraduate education. The core issue is: What are the internal mechanisms, practical paths, and key challenges faced by artificial intelligence empowering postgraduate education? Through an in-depth analysis of this issue, the research aims to construct a theoretical framework for understanding the integrated development of "artificial intelligence + postgraduate education", and to provide theoretical basis and path reference for the relevant practices of Chinese universities.

1.3 Research Methods and Approaches

This study mainly adopts the literature review method and qualitative analysis method. Through a systematic review and content analysis of relevant research literature, policy texts and typical cases at home and abroad, the evolution context, theoretical basis and practical model of artificial intelligence empowering postgraduate education are condensed. On this basis, through qualitative comparison and logical deduction, the internal mechanism, advantageous efficacy and potential risks are deeply analyzed, thereby forming systematic and multi-level research conclusions and development suggestions.

2 THE DEVELOPMENT PROCESS OF ARTIFICIAL INTELLIGENCE'S INVOLVEMENT IN POSTGRADUATE EDUCATION

2.1 The Evolutionary Context of Artificial Intelligence Applications in Education

The application of artificial intelligence in the field of education has undergone a profound transformation process from tool assistance to ecological integration. According to the generally recognized evolutionary framework in the international academic community, this process can be divided into four main stages: the computer-assisted instruction stage, the intelligent mentor system stage, the big data-driven stage, and the ecological integration stage. This evolutionary trajectory not only reflects the increase in technological complexity but also the systematic expansion of the depth of integration between artificial intelligence and education.

In the initial stage of the application of artificial intelligence in education, computer-assisted instruction (CAI) was the main form, positioning computers as teaching aids to achieve programmed teaching and basic multimedia presentation. The essence of technology at this stage is the application of computational intelligence. Machines mainly undertake information storage and computing functions, lacking the ability to perceive and understand the physical world. From the 1950s to the 1990s, CAI systems provided standardized learning content through preset programs [2]. Although they achieved a certain degree of teaching automation, their interactivity was limited and the degree of personalization was low, making it difficult to adapt to complex teaching demands.

Entering the 21st century, with breakthroughs in algorithms and improvements in computing power, the application of artificial intelligence in education has entered the stage of perceptual intelligence, and the intelligent mentor system has become a typical representative of this period [3]. Such systems obtain physical world signals through sensors and initially possess "visual" and "auditory" capabilities, being able to understand some intuitive physical information. The intelligent mentor system, based on student models, domain models and teaching models, provides adaptive learning path guidance and content recommendations by analyzing learning behavior data. The system at this stage to some extent simulates the personalized guidance ability of human teachers, significantly improving learning efficiency. However, it is still limited by the scale and quality of training data, making it difficult to achieve deep cognitive interaction.

In recent years, with the maturation of big data, the Internet of Things and cloud computing technologies, the impact of artificial intelligence on postgraduate education has gradually expanded from assisting local links to a comprehensive and systematic reshaping process. Its development trajectory can be summarized into three continuously deepening levels:

At the tool-assisted level, artificial intelligence mainly plays the role of an efficient "assistant". Typical applications include computer-assisted instruction and multimedia courseware. Its core function is to achieve digital display and programmatic transmission of teaching content [4]. At this stage, technological means have enabled the automated update of teaching tools, but have not yet had a fundamental impact on the educational model itself.

At the process optimization level, artificial intelligence has begun to penetrate into the core links of teaching and research. Represented by intelligent mentor systems and adaptive learning platforms, technology can dynamically adjust learning paths and content recommendations based on the knowledge foundation, learning progress and cognitive characteristics of postgraduate students, providing personalized learning support [5]. Meanwhile, in scientific research activities, artificial intelligence tools have been applied to literature screening and data analysis , helping postgraduate students improve their information processing efficiency and achieving an important transformation from knowledge transmission to ability cultivation.

At present, we are entering a stage of ecological integration and governance innovation. Its notable feature is the construction of a governance model based on all-domain data, which integrates multi-dimensional data such as teaching, research, management and services to achieve real-time monitoring and optimization of the entire process of postgraduate training. Managers can rely on data insights to warn of academic risks and optimize resource allocation [6]; Generative artificial intelligence tools, on the other hand, serve as "collaborative partners" for postgraduate students, deeply participating in knowledge innovation stages such as literature review, experimental design, and code development [7]. At this stage, artificial intelligence has transcended its instrumental nature and begun to systematically reshape the educational ecosystem, innovate governance models, and profoundly transform the way knowledge is produced.

2.2 Innovative Practices and Global Trends of Artificial Intelligence Empowering Postgraduate Education

Globally, the integration of artificial intelligence and postgraduate education is deepening continuously. Through policy guidance and system reconstruction, countries are actively promoting the strategic layout of "artificial intelligence + postgraduate education". Universities at home and abroad have successively carried out diverse explorations and formed development paths with their own characteristics.

2.2.1 Domestic practice trends

Chinese universities have gradually formed systematic explorations in empowering postgraduate education with artificial intelligence, presenting the following three main trends:

First, the governance model is trending towards all-domain perception and precise decision-making. Some universities have built an integrated data platform to achieve full-cycle tracking of postgraduate students' learning, research and growth processes [8]. Such systems not only provide support for management decisions but also achieve personalized guidance through multimodal interaction technology, initially building a new teaching governance ecosystem of "teacher-machine-student" collaboration.

Second, the training system focuses on system reconstruction and capacity expansion. Taking the artificial intelligence layout plan of Beijing Institute of Technology as an example, this framework emphasizes the construction of an adaptive smart education system through interdisciplinary collaboration, process optimization and institutional coordination, aiming to respond to the long-term demand for talent cultivation in the context of rapid technological iteration [9].

Third, the professional directions focus on cross-integration and industry-education collaboration. More and more universities are promoting the deep integration of artificial intelligence with traditional disciplines. For instance, they have launched micro-majors such as "AI+ Green Chemistry", using project-based systems and practical alliances as carriers to cultivate high-level talents with interdisciplinary capabilities and industrial perspectives. Some universities have also broadened the international horizons and innovative capabilities of postgraduate students by setting up virtual classrooms and promoting cross-border scientific research cooperation.

2.2.2 International development trends

Internationally, the application of artificial intelligence in postgraduate education presents a pattern where strategic planning and diversified exploration proceed simultaneously.

At the strategic level, some countries have promoted the integrated development of the postgraduate education system and artificial intelligence through special programs. For instance, the AI talent cultivation program launched by the National Science Foundation of the United States emphasizes the collaboration among industry, academia and research, while the "Digital Europe" initiative of the European Union incorporates the digital capabilities of postgraduate students into its assessment system, aiming to build a regional collaborative postgraduate education network.

At the practical level, universities are actively exploring the application of intelligent technologies in course teaching and scientific research training. For instance, introduce an AI teaching assistant system to provide students with real-time Q&A and learning support; In professional fields such as medicine, complex case diagnosis training is carried out by using simulated diagnosis and treatment environments to enhance the practical ability and professional judgment of postgraduate students [10].

In terms of technological evolution, artificial intelligence is expanding from cognitive models to multi-modal fusion, the collaboration between general and specialized systems, as well as embodied intelligence. These developments bring new possibilities to postgraduate education: multimodal technology is more in line with real learning scenarios, the interaction of large and small models enhances the applicability and efficiency of teaching systems, and the materialization of embodied intelligence provides new experimental platforms and methodological support for postgraduate students to participate in cutting-edge scientific research [11].

3 PRACTICAL CHALLENGES AND INTERNATIONAL EXPERIENCES IN POSTGRADUATE EDUCATION

3.1 The Current Development Status and Core Pain Points of Domestic Postgraduate Education

While the scale of postgraduate education in our country continues to expand, it is now confronted with a series of deep-seated structural contradictions and urgently needs to promote systemic changes through artificial intelligence technology. The current core predicament is mainly reflected in the following four dimensions:

At the level of resource allocation, high-quality educational resources exhibit significant characteristics of "fragmentation" and "isolation" [12]. High-level teaching staff, advanced experimental equipment and high-quality course resources are unevenly distributed among different universities and disciplines, making it difficult to achieve efficient sharing and collaborative utilization. This imbalance in resource allocation seriously restricts the improvement of the overall quality of postgraduate education.

At the level of training models, the phenomenon of homogenization is becoming increasingly prominent, making it difficult to meet the diversified demands for compound talents in the digital intelligence era. Influenced by traditional management paradigms, the current training system overly emphasizes standardization and patternization, forming an educational framework centered on stabilizing the transmission of disciplinary knowledge. The teaching content is overly focused on mature theories, and the evaluation criteria tend to be the single quantification of academic achievements. This training mechanism neglects the individual differences and development needs of postgraduate students, resulting in a significant insufficiency in the cultivation of innovation capabilities. Meanwhile, the evaluation system mostly relies on course grades and the subjective impression of supervisors, lacking a dynamic assessment mechanism for multi-dimensional capabilities such as research skills and innovation potential.

At the level of scientific research transformation, there is a significant disconnection between research achievements and industrial demands, and the knowledge transformation cycle is too long. Traditional scientific research training follows a "trial-and-error model", and postgraduate students are inefficient in literature retrieval, experimental design, data analysis and other links, spending a lot of time on repetitive work. Due to the disciplinary barriers and the imperfect mechanism of industry-university-research collaboration, many research achievements with potential application value are difficult to be industrialized and transformed [13].

At the management decision-making level, the extensive management style dominated by experience is difficult to meet the demands of precise governance. The postgraduate training process involves multiple links such as course teaching, scientific research training, and supervisor guidance. The massive amount of data generated has not been effectively integrated and analyzed, making it difficult for the management department to grasp key information such as training quality and resource utilization efficiency in real time, resulting in governance predicaments such as delayed decision-making and untimely intervention [14].

These interrelated structural contradictions jointly restrict the high-quality development of postgraduate education in our country. To solve these problems systematically, it is not only necessary to intervene at the technical level, but also to drive the overall reconstruction of the educational ecosystem through artificial intelligence, achieving all-round and systematic breakthroughs from resource allocation, the training process, scientific research innovation to management and governance.

3.2 Overview of the Application of Artificial Intelligence in Postgraduate Education Abroad

Top international universities have formed a multi-dimensional and systematic application ecosystem in empowering postgraduate education with artificial intelligence, presenting diversified development paths and distinct regional characteristics.

American universities are at the forefront globally in the field of AI-assisted scientific research. Many top universities have built intelligent research platforms to provide interdisciplinary experimental environments and research support systems for postgraduate students. These platforms integrate the full chain of resources from data collection, algorithm analysis to computing power support, and can assist postgraduate students in completing the entire research process from literature mining, hypothesis generation to experimental verification, significantly improving research efficiency [15].

European universities have demonstrated unique advantages in personalized learning path planning. By developing an intelligent academic analysis system, based on the academic background, research interests and learning behavior data of postgraduate students, a dynamic ability development profile is constructed to achieve precise customization of personalized training programs. These systems can identify students' weak points in knowledge and their potential for development, providing technical support for "teaching students in accordance with their aptitude". Meanwhile, a complete academic ability certification system records the academic achievements and skill development of postgraduate students throughout the process, providing reliable proof for their career development.

In terms of interdisciplinary training, the international community promotes the deep integration of artificial intelligence with different disciplines through special talent cultivation programs. These plans usually adopt a collaborative model of industry, academia and research. By establishing interdisciplinary mentor groups and jointly building laboratories, they cultivate students' cross-border thinking and complex problem-solving abilities. These explorations provide a new paradigm for the cultivation of compound talents.

At the regional collaboration level, some international organizations promote the sharing and mutual recognition of educational resources among universities by formulating unified standards and collaboration mechanisms. These measures have promoted cross-border and cross-cultural learning and exchanges, providing a broader development platform for postgraduate students.

It is worth noting that in the process of promoting the application of artificial intelligence in education, international universities particularly emphasize the coordinated development of ethical governance and technological innovation. By establishing a dedicated ethical review mechanism and formulating a regulatory system covering aspects such as data privacy, algorithmic fairness, and academic integrity, the responsible use of artificial intelligence technology in the field of education is ensured, which provides an important guarantee for the deep integration of artificial intelligence and postgraduate education.

4 THE THEORETICAL BASIS ON WHICH ARTIFICIAL INTELLIGENCE AFFECTS POSTGRADUATE EDUCATION

4.1 Theory of Smart Education

The theory of smart education provides a core theoretical support for artificial intelligence to empower postgraduate education [16]. This theory emphasizes the construction of a learning environment that is perception-adapted, seamlessly connected and intelligently interactive through intelligent technologies, thereby achieving a systematic innovation of the traditional education model. At the postgraduate education level, the theory of smart education is mainly reflected in two dimensions: the construction of an intelligent environment and the realization of personalized learning.

From the perspective of environmental construction, the theory of smart education advocates creating an intelligent ecosystem that organically integrates physical space and digital space. This concept has been fully reflected in the practices of many domestic universities. By integrating technologies such as the Internet of Things, big data, and artificial intelligence, an intelligent environment capable of real-time perception of learning status, dynamic optimization of resource allocation, and precise provision of support services is constructed, providing a solid foundation for the cultivation of postgraduate students' innovation capabilities. This environment not only breaks through the physical boundaries of traditional classrooms but also achieves the extension and expansion of educational resources in the dimensions of time and space.

In terms of personalized learning, the theory of smart education goes beyond the traditional "one-size-fits-all" training model and emphasizes providing customized educational services based on the individual characteristics and needs of learners. This theoretical orientation is specifically reflected in the learning process of the "learning - experimentation - practice" closed-loop system. Through AI-driven ability profiling technology, a multi-dimensional dynamic assessment of postgraduate students' knowledge structure, research skills, and innovation potential is conducted to construct an accurate individual ability map, thereby achieving personalized customization of training programs. This personalized learning mechanism effectively supports the cultivation of "domain-related skills" in the theory of creativity components and provides a personalized path for the development of postgraduate students' innovative potential.

The practical value of the theory of smart education in postgraduate education is particularly prominent. Through specific applications such as the intelligent mentor system, adaptive learning platform, and virtual research environment, it has achieved a transformation from group teaching to personalized cultivation. This transformation not only enhanced educational efficiency, but more importantly, respected and developed the individual differences among postgraduate students, creating favorable conditions for cultivating top-notch innovative talents.

4.2 Human-Machine Collaboration Theory

The human-machine collaboration theory provides a crucial theoretical perspective for understanding the role positioning of artificial intelligence in postgraduate education. This theory emphasizes the complementary integration of artificial intelligence and human intelligence, advocating the maximization of overall efficiency through the complementary advantages of humans and machines. Its core lies in enhancing human intelligence rather than replacing human roles.

In the context of postgraduate education, the theory of human-machine collaboration redefines the boundary of the relationship between AI and teachers and students. According to this theory, artificial intelligence systems should undertake repetitive and computationally intensive tasks such as knowledge transfer, skills training, and data management, while teachers focus on creative work such as academic guidance, thinking inspiration, and personality shaping [17]. This role division is fully reflected in the experimental and practical training links of the "learning - experimentation - practice" closed-loop system. In scientific research training, AI research assistants are responsible for fundamental tasks such as literature retrieval, experimental simulation, and data analysis, enabling postgraduate students to focus their limited cognitive resources on higher-level innovative thinking and research design, effectively enhancing the depth and efficiency of scientific research training.

The theory of human-machine collaboration has significant explanatory value for postgraduate students' scientific research and innovation. According to the creativity component theory, the innovation ability of postgraduate students is composed of three core elements: domain-related skills, creativity-related processes, and intrinsic motivation. Under this framework, artificial intelligence mainly supports the cultivation of innovation capabilities by enhancing domain-related skills (such as strengthening knowledge reserves through intelligent literature analysis) and optimizing creativity-related processes (such as reducing experimental costs through digital twin technology), while the stimulation and maintenance of intrinsic motivation still rely on the guidance of mentors and the influence of an academic environment. This division of labor between humans and machines ensures that technology enhances rather than weakens the subjectivity and creativity of postgraduate students.

It is worth in-depth exploration that the human-machine collaboration theory also points to a new type of "teacher-machine-student" ternary relationship structure. In this structure, teachers act as academic leaders, artificial intelligence as capability enhancers, and postgraduate students as active constructors, forming a mutually beneficial and interactive collaborative system. Multiple practices have shown that this ternary collaborative model can significantly enhance the research autonomy and innovation efficiency of postgraduate students, while ensuring the leading position of teachers in the talent cultivation process.

4.3 Theory of Digital Transformation in Education

The theory of digital transformation in education explains from a macro perspective the internal mechanism and development path of the transformation of postgraduate education driven by artificial intelligence. This theory emphasizes that digital technology is not merely a simple optimization tool for the educational process, but rather a systematic reconstruction of the overall educational ecosystem. Its core lies in driving education from the superficial application of technological tools to a deep transformation of educational paradigms [18].

This theory reveals that the intelligent transformation of postgraduate education usually presents phased development characteristics and generally goes through three key steps: From the initial process digitalization (i.e., transforming traditional educational processes into digital forms), it gradually transitions to the mid-term business dataization (optimizing business processes through data-driven approaches), and ultimately achieves paradigm intelligence (building a new form of education based on intelligent technologies). In this process, the "learning - experimentation - practice" closed-loop system formed is precisely the concrete manifestation of this theory at the practical level, marking a comprehensive upgrade of postgraduate education from digital management to intelligent innovation. This closed-loop system has achieved a structural transformation of the postgraduate training model from knowledge imparting to innovation ability empowerment by building an intelligent ecosystem that integrates teaching, research and innovation.

From the perspective of paradigm evolution, the theory of digital transformation in education profoundly explains how artificial intelligence can drive the transformation of postgraduate education from the "Taylorist" standardized model to the "intelligence-enhanced" personalized model. This transformation not only encompasses upgrades at the technical level, but also includes systematic innovations in educational concepts, organizational structures and evaluation mechanisms. By integrating the theory of creativity components, digital transformation has comprehensively enhanced the qualities of postgraduate students in terms of domain-related skills, creative thinking processes and intrinsic motivation by providing personalized learning paths, intelligent research support and precise innovation incubation, thereby systematically improving the quality and efficiency of innovative talent cultivation.

In conclusion, the theories of smart education, human-machine collaboration, and the digital transformation of education jointly construct a theoretical framework for understanding the integrated development of artificial intelligence and postgraduate education. These theories not only provide conceptual tools for analyzing the current situation, but also point out the direction for future development. Under this framework, the "learning - experimentation - practice" closed-loop system serves as the specific practical path, and the creativity component theory is used as the basis for effect evaluation, jointly laying a solid theoretical foundation for exploring a new paradigm of postgraduate education in the era of artificial intelligence.

5 THE DUAL ADVANTAGES OF ARTIFICIAL INTELLIGENCE EMPOWERING POSTGRADUATE EDUCATION: INNOVATION FROM RESEARCH PARADIGMS TO GOVERNANCE MODELS

5.1 Student Research Level: A Paradigm Leap From "Tool-Assisted" to "Human-Machine Collaboration"

At the scientific research level, artificial intelligence has driven a fundamental transformation from traditional tool-assisted to intelligent human-machine collaboration.

Firstly, in terms of intelligent efficiency enhancement of the scientific research process, artificial intelligence, as an "intelligent scientific research assistant", has permeated the entire scientific research chain [19]. The intelligent retrieval system based on natural language processing can accurately locate core materials from a vast amount of literature, significantly improving the efficiency of information acquisition. Intelligent algorithms can simulate different schemes and optimize paths during the experimental design stage, effectively enhancing the scientific nature of the research process and the utilization rate of equipment. In the data analysis stage, artificial intelligence tools can handle complex datasets, conduct deep pattern recognition and predictive analysis, significantly enhancing the efficiency and depth of scientific research work.

Secondly, in terms of personalized cultivation and innovation ability stimulation, the ability profiling system driven by artificial intelligence analyzes the behavioral data of postgraduate students in their studies, research and academic exchanges, builds a dynamic and multi-dimensional ability assessment model, and customizes personalized cultivation plans for them. Meanwhile, virtual simulation technology provides a safe simulation environment for high-risk and high-cost research, effectively promoting the cultivation of postgraduate students' innovative thinking and experimental abilities. Research shows that intelligent learning systems combined with theoretical guidance can significantly enhance postgraduate students' academic abilities in human-computer collaboration and increase their sense of self-efficacy and the application level of cognitive strategies.

Finally, in terms of the efficient transformation of academic achievements, artificial intelligence technology has significantly shortened the transformation cycle from research to application by building an intelligent matching system between scientific research results and industrial demands. Such systems promote a virtuous cycle of "research - application - feedback - re-research", and facilitate the effective transformation of academic research into practical value. At present, multiple disciplinary fields have begun to build research-level intelligent analysis platforms, supporting the full-process empowerment of academic research from literature review, theoretical construction to mechanism deduction, accelerating the digital transformation of disciplinary research paradigms [20].

5.2 Campus Governance Level: From "Experience-Based Decision-Making" to "Data-Driven" Precise Governance

At the campus governance level, artificial intelligence is driving the transformation of the university management system from relying on experience and intuition to a data-driven, precise governance model. This transformation is specifically reflected in the triple leap of the structural paradigm and the intelligent upgrade of the governance system.

At the structural paradigm level, artificial intelligence has driven three major changes in the governance system. The flattening transformation effectively simplifies management levels, shortens the decision-making chain and enhances the organizational response speed through intelligent question-answering systems and automated process processing technologies. Platform-based reconstruction integrates the originally scattered teaching, research, management and service systems into a unified open platform. Through standardized interfaces, it enables flexible resource invocation and scenario-based combination, promoting cross-departmental collaborative innovation. The intelligent evolution conducts real-time analysis of the full-dimensional data of campus operation through deep learning models, and combines intelligent operation and maintenance technologies to build a ternary collaborative governance architecture of "platform - algorithm - person" with adaptive capabilities [21], injecting continuous evolution capabilities into campus governance.

At the governance system level, the real-time governance system represented by the "Education Digital Cockpit" has become the core carrier for achieving precise governance. This system builds a unified data foundation with various business systems through the Internet of Things, achieving real-time aggregation and integration of multi-source data such as teaching, research, and management. Based on this, the intelligent decision-making dashboard visually presents key governance indicators, supporting managers to dynamically track core indicators such as educational quality and resource efficiency through natural language interaction, which greatly enhances the timeliness of decision-making.

More importantly, such systems have formed a complete governance closed-loop mechanism. Through the in-depth interaction between algorithm models and business processes, a continuous optimization cycle covering planning, execution, inspection, and improvement has been established, achieving a transformation in governance from post-event remediation to pre-event early warning and in-event intervention. This data-driven precise governance model not only significantly enhances the efficiency of resource allocation and administrative management effectiveness, but also provides guarantees for the continuous improvement of teaching quality and the individualized development of students through refined early warning and intervention mechanisms.

6 THE CONSTRUCTION PATH OF EMPOWERING POSTGRADUATE EDUCATION WITH ARTIFICIAL INTELLIGENCE: DUAL-WHEEL DRIVE OF THEORY AND SYSTEM

6.1 Theoretical Guidance: The Innovative Evolution from the Traditional Paradigm to the Intelligent Paradigm

At the theoretical construction level, the empowerment of postgraduate education by artificial intelligence requires a systematic transformation from the traditional paradigm to the intelligent paradigm. The core of this transformation lies in establishing a new educational theoretical framework based on three dimensions: data-driven, algorithm-enabled, and ethical regulations. This framework emphasizes that education is a continuous development process that achieves real-time feedback, dynamic iteration and value co-creation through intelligent technologies. It can effectively promote the efficient transformation of knowledge production from theoretical construction to practical application and facilitate the substantive implementation of scientific research achievements.

At the practical level, this theoretical framework achieves the in-depth integration and coordinated development of talent cultivation and scientific research innovation by constructing a complete closed-loop system of "learning - practice - innovation". This system, supported by the triple forces of intelligent assessment technology, simulation training platforms and innovation incubation mechanisms, realizes the organic connection and coordinated operation of all links, significantly enhancing the efficiency and quality of knowledge transformation. Meanwhile, this framework, by establishing a systematic and observable indicator system, provides a unified reference standard for the personalized practices of different universities, supports cross-institutional experience replication and continuous optimization and improvement, and forms a replicable practice model.

This theoretical innovation not only focuses on the application at the technical level, but also emphasizes the return to the essence of education, highlighting the refinement, personalization and efficiency of the educational process under the support of intelligent technology, laying a solid theoretical foundation for the overall improvement of the quality of postgraduate education.

6.2 System Construction: The Synergistic Development Path of Scientific Research and Governance

Under the guidance of theory, it is necessary to systematically construct a coordinated development path for scientific research innovation and campus governance, forming a virtuous cycle of mutual support and common development.

In terms of the construction of the scientific research system, the focus is on systematically building around three dimensions. First of all, a complete intelligent scientific research support system should be established, including a unified university-level scientific research platform and data infrastructure, to provide comprehensive technical empowerment and methodological guidance for postgraduate research activities. Secondly, it is necessary to deeply integrate artificial intelligence literacy and ethical education throughout the entire training program, establish a new evaluation mechanism based on dynamic ability assessment, and achieve a precise grasp of the growth process of postgraduate students. Finally, we should vigorously promote collaborative innovation between schools and enterprises. Through various forms such as jointly building practical platforms and joint laboratories, we should facilitate the in-depth integration and substantive cooperation of industry, academia and research.

In terms of the construction of the governance system, efforts should be made to promote the coordinated development of the three key links. The primary task is to build a unified data governance platform, completely break down information barriers, and establish a complete campus intelligent computing resource system to provide fundamental support for smart governance. Secondly, we should comprehensively promote the in-depth application of intelligent technologies in core business processes, establish a big data-based early warning intervention and resource optimization mechanism, and achieve precise management services. The ultimate goal is to cultivate an open, collaborative and trustworthy smart governance culture, establish an effective cross-departmental collaborative decision-making mechanism, ensure the explainability and controllability of intelligent systems, and form a governance pattern that emphasizes both technological empowerment and humanistic care.

7 MAIN CHALLENGES

7.1 Technical Ethics and Data Security

The integration of artificial intelligence into postgraduate education brings to the fore critical ethical and data security concerns. Key issues requiring urgent attention include ethical breaches—such as the spread of misinformation, disinformation, and copyright or intellectual property violations—as well as security and privacy risks like unauthorized data usage and inadequate data protection.

Within the university context, these challenges translate into multi-faceted security dilemmas. First, the data ecosystem has grown increasingly complex. Institutional data now comprises not only structured forms—such as student records, staff details, enrollment status, and academic results—but also unstructured types like instructional videos, surveillance footage, and archival documents, as well as temporal data reflecting learning behaviors and IoT-generated activities. The heterogeneous nature of these data types significantly complicates governance.

Second, a tension exists between data sharing and regulatory compliance. While large-scale educational datasets are essential for training advanced AI models, legal frameworks such as the Personal Information Protection Law impose strict requirements on the collection and use of sensitive information—including students' behavioral traces and classroom audio-visual data. This creates a persistent conflict between enabling efficient data utilization and ensuring robust privacy safeguards.

Lastly, algorithmic bias and opaque decision-making mechanisms risk leading to unfair assessments of graduate students. At the same time, the misuse of generative AI tools can severely undermine academic integrity. These risks are not isolated; they exhibit a cross-scale coupling effect, whereby issues originating at the technical level may propagate and impact the broader educational system.

7.2 Resource Allocation and the Digital Divide

The empowerment of postgraduate education by artificial intelligence is exacerbating the digital divide due to uneven resource distribution. The successful adoption of AI demands substantial resources and capabilities, including funding, staffing, leadership, strategic and operational robustness, as well as technology and data infrastructure—resources to which some institutions have easier access than others. This disparity manifests in several ways: a significant gap in AI infrastructure, technical support, and professional talent between large and small-scale universities; varying depths of application across disciplines, with science and engineering fields seeing more profound integration compared to the humanities and social sciences; and a considerable digital literacy gap between teachers and students, where students generally use AI more frequently. This imbalance is particularly surprising given that institutional strategies often prioritize teacher training over student development in AI-related resource allocation.

7.3 Shifting Roles of Teachers and Students

The deep application of AI is profoundly reshaping the roles and interaction patterns between teachers and students in postgraduate education, creating a series of adaptive challenges. From a complex systems perspective, the "application self-organization" of generative AI can lead to the alienation of educational subject relationships. This alienation is evident in three areas: the pressure on supervisors to transition from traditional knowledge authorities to "cognitive architects" and academic leaders who can effectively collaborate with AI systems; the risk of an imbalanced ability structure in postgraduates, where over-reliance on AI tools may erode critical thinking, independent problem-solving skills, and academic autonomy; and the challenge of reconstructing the teaching relationship, as the traditional "teacher-student" dyad is replaced by a tripartite "teacher-AI-student" collaborative structure, risking the weakening of interpersonal academic interaction by algorithmic mediation.

8 RESPONSE STRATEGIES

8.1 Strategies for Ensuring Technical Ethics and Data Security

To address the challenges outlined in Section 7.1.1, a multi-layered governance framework must be established. The primary task is to implement a "Privacy by Design" data governance framework, embedding data security and privacy principles throughout the entire system development lifecycle. This involves adopting technologies like data anonymization and differential privacy at the design stage, strictly adhering to the data minimization principle, and establishing a comprehensive data classification and management system.

Concurrently, a regular algorithm audit and ethical review mechanism must be institutionalized. Universities should establish interdisciplinary ethics committees—comprising experts in education, computer science, law, and ethics—to conduct regular bias detection and fairness evaluations of core educational AI models. This ensures transparency in the algorithmic decision-making process and the interpretability of outcomes. For instance, the "Educational Algorithm Audit Framework" developed by the University of Cambridge can serve as a model, demonstrating how regular reviews can identify and correct biases in admissions and evaluation processes.

Finally, to counter misinformation and copyright infringement, clear institutional policies on the use of generative AI should be formulated, alongside the promotion of AI literacy education that emphasizes academic integrity and the ethical use of AI tools.

8.2 Strategies for Balancing Resource Allocation and Bridging the Digital Divide

In response to the disparities highlighted in Section 7.1.2, strategies should focus on equitable resource distribution and inclusive capacity building. Firstly, funding models should encourage and support inter-university consortia for sharing AI infrastructure and computing resources, particularly to assist less-resourced institutions.

Secondly, to address disciplinary imbalances, universities should launch targeted funding programs to stimulate interdisciplinary and humanities-specific AI application projects, developing bespoke tools and methodologies for these fields.

Finally, regarding the digital literacy gap, AI training programs must be comprehensively designed for both faculty and students. This involves moving beyond technical training to include critical pedagogy on AI's ethical and social implications for teachers, and for students, integrating modules on responsible AI use, critical evaluation of AI outputs, and the development of AI-complementary skills (e.g., critical thinking, creativity) into the core curriculum.

8.3 Strategies for Facilitating Role Transformation and Capacity Building

To navigate the role shifts described in Section 7.1.3, systematic support and clear guidelines are essential. For faculty, universities should establish dedicated professional development programs to help supervisors transition into their new roles as "cognitive architects." This includes training on co-teaching with AI, designing AI-enhanced research projects, and providing mentorship in an AI-rich environment.

For postgraduate students, the curriculum must be redesigned to strengthen meta-cognitive and critical thinking skills, ensuring these capabilities are prioritized alongside technical proficiency. Assignments should be structured to encourage the use of AI as a tool for exploration rather than a source of answers.

Furthermore, to foster healthy "teacher-AI-student" dynamics, institutions should develop and disseminate best practice guidelines for tripartite collaboration. This includes creating spaces for reflection on the changing nature of academic interaction and implementing measures to ensure that meaningful human dialogue and mentorship remain at the core of the postgraduate education experience.8 Conclusions and Future Prospects

This article systematically explores the theoretical construction and practical path of deeply integrating artificial intelligence into postgraduate education. Research shows that artificial intelligence is driving a profound paradigm leap in the postgraduate education experience from "tool-assisted" to "human-machine collaboration". By building a data-driven governance model and a closed loop of "learning - experimentation - practice" in training, artificial intelligence has demonstrated significant advantages in the two core levels of scientific research innovation and campus governance: on the one hand, it has reshaped the scientific research paradigm through intelligent efficiency enhancement, personalized training, and accelerated transformation of research results; On the other hand, it has promoted the transformation of university management from experience-based decision-making to precise governance through the governance reform of flattening, platformization and intelligence. The framework constructed by the research, which integrates the theories of smart education, human-machine collaboration and digital transformation, provides a strong theoretical support for understanding this systemic change.

However, this process is also accompanied by multiple challenges such as technological ethics, data privacy, uneven resource distribution, and the reconfiguration of the roles of teachers and students, which urgently need to be systematically addressed through technological governance, institutional innovation, and quality improvement.

Looking ahead, the integration of artificial intelligence and postgraduate education will deepen in three dimensions: At the technical level, the progress of multimodal large models and embodied intelligence will create a more immersive and adaptive scientific research training environment, promoting the leap from "digital twin" to "digital native"; At the theoretical level, it is necessary to further construct an interdisciplinary framework that can profoundly explain the cognitive mechanism of human-machine collaboration, the ethics of intelligent teaching, and the calculation of educational value, in order to guide the increasingly complex "teacher-machine-student" trinity interactive relationship. At the practical level, the core task lies in building an open, shared and continuously evolving smart education ecosystem, promoting the formation of a fairly accessible intelligent teaching and research platform and a deeply collaborative industry-education integration network.

Ultimately, the value orientation of artificial intelligence empowering postgraduate education lies in building a new model of smart education that is more inclusive, adaptable and innovative. We should always adhere to the principle of "people-oriented and intelligence for good", and while actively leveraging technological empowerment, remain true to our original aspiration of nurturing talents, ensuring that artificial intelligence truly serves to enhance educational quality, promote academic innovation and cultivate high-level talents capable of leading the future. China's exploration should be committed to absorbing global experience while building an independent knowledge system and practical path with Chinese characteristics and in line with Chinese needs, contributing Chinese wisdom to the development of global intelligent education.

COMPETING INTERESTS

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

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AUTHOR BIOGRAPHY

Tianran Qin (2000-), male, born in Nanning, Guangxi, with a bachelor's degree; currently a graduate student at the College of ASEAN Studies, Guangxi Minzu University;

Xu Wei (1994-), male, born in Huanghua, Hebei, who holds a Ph.D. in Law, is a lecturer and master's supervisor at the School of Management, Guangxi Minzu University.

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QUANTITATIVE ANALYSIS METHOD FOR SAFETY ACCIDENT CAUSES IN UNIVERSITY LABORATORIES

Qin Liu[1], ZeMin Qi[1*], Ke Liu[2], HongBing Li[1]
[1]Aba Teachers College, Wenchuan 623002, Sichuan, China.
[2]Sichuan Normal University, Chengdu 610101, Sichuan, China.
Corresponding Author: ZeMin Qi, Email: zmin918@sina.com.cn

Abstract: Recently, safety accident in university laboratories occurs frequently, and it's necessary to dig into its causes which provide scientific basis for precise management of university laboratories. First, the safety accident causes are identified with qualitative method. Then, quantitative analysis of DEMATEL-ISM-MICMAC method is combined with grey number, and hierarchical structure model is constructed to clarify the causal hierarchy and identify its attribute and characteristics. Finally, the grey DEMATEL-ISM-MICMAC method combined with 24 Model is applied to analyze "4.5" Explosion Death Accident of China University of Mining and Technology. The results show: (1) the factors such as the weak supervision of the education administrative department are the deep objective causes; (2) illegal operation, defects in the safety management system, and insufficient attention to laboratory safety rules and regulations are the key subjective causes; (3) the type of safety inspection, inadequate safety protection measures and other factors are secondary causes of the accident. The analysis results are consistent with the report on "4.5" Explosion Death Accident of China University of Mining and Technology, which shows that the 24Model-Grey DEMATEL-ISM-MICMAC method is reliable in the identification, quantitative characterization and attribute feature identification of the cause of safety accidents in university laboratories, and the proposed method is highly practical, providing a decision-making basis for the refined safety management of university laboratories and the scientific formulation of emergency plans.
Keywords: 24 Model; Grey system theory; Decision Making Trail and Evaluation Laboratory (DEMATEL); Interpretive Structural Modeling (ISM); Matrix Impacts Cross-reference Multiplication Applied to Classification (MICMAC) method

1 INTRODUCTION

The laboratory is an important place for colleges and universities to undertake scientific research innovation and talent cultivation[1]. With the high-quality promotion of the strategy of rejuvenating the country through science and education, the construction of university laboratories has developed rapidly. Safety accidents in university laboratories have occurred from time to time, causing huge losses to state-owned property and casualties, which have had a significant negative impact on the reputation of the schools and the image of teachers and students, and therefore have received high attention from society. With the characteristics of complex personnel types, high mobility and uneven safety- quality of personnel participation, and the reality of the increasing scientific research and teaching tasks, the safety management of university laboratories has become cumbersome[2]. Therefore, it is of great significance to accurately identify the causes of safety accidents in university laboratories, accurately depict their internal connections, and identify the characteristics of the cause attributes, so that it can accurately prevent and control the safety risks in university laboratories, scientifically formulate emergency measures for safety accidents in university laboratories, and ensure the safety of the lives and property of teachers and students in colleges and universities.

2 RESEARCH STATUS

The safety mechanism and management of university laboratories have received widespread attention. Using the safety information flow (SIF) accident cause model, Yang et al. analyzed the explosion accident in a university laboratory in 2018[3]. The research results show that laboratory safety information is a key variable in ensuring system security. In Gao's research, the STAMP model was used to analyze the laboratory explosion accidents[4]. And it turns out that identifying control defects in laboratory safety in universities can improve the effectiveness of laboratory safety management in a targeted manner. On account of work experience in the university laboratory, Wu et al. focused on the laboratory safety education system in "double first-class" universities and provided practical basis for the safety management of university laboratories[5]. By summarizing and analyzing the current situation of laboratory safety management in local universities, Lin found out the shortcoming of laboratory safety management in terms of laws and regulations, site planning and informatization level, and put forward corresponding safety measures[6]. By applying HFACS model, Yang et al. found out nineteen types of safety accident causes in university laboratories and dug into the one of human error behavior, which gives enlightenment on the safety management of university laboratories[7]. Later, combing with the actual situation of university laboratories, Yang et al. applied the FDA accident cause mode in their research[8]. They put emphasis on three aspects, the skill level of laboratory personnel, the practice of university laboratory management and the supervision of the education management departments and noticed the importance of each one in preventing the safety accidents in university laboratories. By employing 24 Model, Wang et al. analyzed the whole process of safety accident evolution in university laboratories and proposed a laboratory safety risk control plan[9]. Similarly, given some enlightenment from the 24 Model, Guo et al. divided the safety accident causes in university laboratories into several aspects and then analyzed the evolution mechanism of laboratory safety accident causes[10]. At last, the analysis model of hazardous chemical laboratories in universities and colleges was conducted. In Xu et al.'s research, 46 cases of safety accident in university laboratories were collected and analyzed with the 24 Model[11]. From their research results, the unsafe human behavior and the aging equipment are the main accidents causes. In Fu et al.'s research, the 24-accident model was applied to systematically analyze the direct accidents causes in university laboratories based on 107 accident cases from 2001 to 2016[12]. And the result shows that the process of using experimental reagent materials is prone to be wrong. The above research indicates that accident cause models are effective methods for studying university laboratories safety, and the 24 Model with systematic and modular characteristics is widely favored. Based on this, a series of semi-quantitative methods are proposed. For example, based on cheese model, Moray et al. explored the significance of chemical spillage in the university laboratory safety[13]. The research results indicate that the amount of chemical spillage is not an indicator for summative assessment, and the focus of laboratory safety should be on organizational or site factors. Li et al. applied the Apriori algorithm into the analysis of the influencing factors of laboratory accidents and the relationship among different ones and found out the key to controlling laboratory safety accidents[14]. In lines with association rules, An et al. analyzed safety accident causes in laboratories from four aspects, people, object, environment and management, which provides feasible strategies for improving safety laboratory management[15]. However, the importance and usage of these factors are still unknow, and that may bring difficulties to the precise management and accident prevention of university laboratories.

The combined model of DEMATEL and ISM is a method for quantitatively characterizing the relative importance and roles in influencing factors in complex systems, which is widely applied in industries such as ancient architecture and hazardous chemical transportation. By using the Delphi method, DEMATEL and ISM, Zhang et al. identified and analyzed the 18 certain fire-causing elements in ancient building fire accidents[16]. The results show that the fire accidents in ancient buildings results from neighboring reasons, transitional reasons, and essential reasons. Based on the analysis of 1041 cases of hazardous chemicals tank truck transportation accidents, Zheng et al.'s research, applied with DEMATEL and ISM method, shows that wrong operation, tank and safety accessory faults are the direct key causes of accidents[17]. Using DEMATEL and ISM method, Tu and Wang made an effort to study the blunt effect of anti-riot kinetic energy bomb[18]. They brought forward that impact acceleration and impact displacement are the critical factors affecting the effect. Looking through relevant literature, Zhao et al. analyzed 33 influencing factors of entrepreneurship among university scholars and students with DEMATEL and ISM method[19]. They found out that there are 11 key influencing factors such as academic level and achievements, educational background. Adopting the 24 Model-D-ISM method, Zhou et al. made a quantitative analysis of the impact relationship between the causes of laboratory safety accidents and put forward that the lack of safety management supervision and responsibility system are the root causes of safety accidents[20].

However, one of the limitations of all these methods is that the scores of the mutual influence degree are given by expert which leads to a high degree of subjectivity. At the same time, it is difficult to accurately quantify uncertain scenarios where some information is known and some unknown. Therefore, it is necessary to find an objective method to accurately characterize the degree of mutual influence between factors. And the grey numbers in the Grey System Theory can effectively avoid this problem. For example, using sustainable laboratory evaluation method based on improved Pythagorean fuzzy linguistic set, Zhu et al. conducted case analysis and verified the effectiveness and stability of this method in handling the uncertainty of laboratory evaluation information[21]. And this research provides new technical support for laboratory safety management. Based on the fuzzy comprehensive evaluation with analytic hierarchy process, Ren analyzed the relations among 24 laboratory safety accident causes in a quantitative way[22]. And the objectivity of evaluation results is improved which provides with more objective prevention and control suggestions for laboratory safety management. However, there are still shortcomings in the above research, such as the inability to characterize the attribute characteristics of factors.

To sum up, many scholars have conducted in-depth qualitative analysis of the accident causes of laboratory safety by using different accident cause models and they have achieved significant results. However, none of them have accurately characterized the attribute characteristics of the safety accident causes of university laboratories. Moreover, few scholars have conducted in-depth quantitative analysis on the safety accidents causes in university laboratories, and there is even fewer research on the logical relationship and attribute characteristics of the safety accidents causes in university laboratories. Based on this, this research uses the 24 Model structure and its accident cause identification procedure to identify and select the safety accident causes in university laboratories from three levels: external factors, organizational factors, and personal factors accurately and systematically. Moreover, grey numbers are introduced, and the grey DEMATEL-ISM method is constructed to quantitatively characterize the interaction relationship between the safety accident causes in university laboratories, and the MICMAC method is adopted to identify the attribute characteristics of the safety accident causes in university laboratories. The integrated 24 Model Grey DEMATEL-ISM-MICMAC method is used to deeply analyze the "4.5" Explosion Death Accident of China University of Mining and Technology, and the research results are compared with the investigation report on the causes, which verifies the reliability of the integrated 24 Model Grey DEMATEL-ISM-MICMAC method in the quantitative analysis of the safety accident causes in university laboratories.

The research innovations are as follows: (1) The grey number is introduced to accurately quantify uncertain scenarios in which some information is known and some unknown in university laboratory safety accidents. And that achieves precise and quantitative characterization of the relationship between the safety accident causes in university laboratories. Based on the quantitative relationship among accident causes, an accurate hierarchical structure model of accident causes is constructed to visually describe the complex relationship between the causes. And it intuitively presents the root causes, transition causes, and nearby causes of safety accidents in university laboratories. (2) With the 24 Model, the causal factors of safety accidents in university laboratories are dug out, and the MICMAC method is used to calculate the driving forces and dependence of each factor in university laboratory safety accidents. Based on this, a Cartesian coordinate is established to identify the attribute characteristics of the safety accident causes in university laboratories. And the accident causal factors including autonomous, dependent, associative, and independent elements are identified, providing a theoretical basis for the safety refinement management of university laboratories.

3 RELEVANT METHODS AND PRINCIPLES

3.1 24 Model

Fu et al. launched the first version of the 24 Model in 2005. In it, they introduce a solution to diagnose organizational safety management in a quantitative way. 24 Model is a modern accident cause model[23]. After more than a decade of promotion and development, it has been widely used in various fields such as aviation accident, coal mine gas explosion accidents, traffic safety accidents[24-26]. And its structural framework is shown in Figure 1. This model divides the causes of behavioral outcomes into three aspects: personal factors, organizational factors, and external factors. Personal factors cover two stages: disposable behavior and state of matter, and social convention; Organizational factors cover two stages: operational behavior and guiding behavior; External factors refer to external supervision, natural environment and so on. With the characteristics of modularity and clarity, this model can accurately and systematically identify the safety accident causes. Based on this, putting it into laboratory safety accidents can obtain the identification procedure for the safety accident causes in university laboratories. And the identification procedure for laboratory safety accidents based on 24 Model is shown in Figure 2.

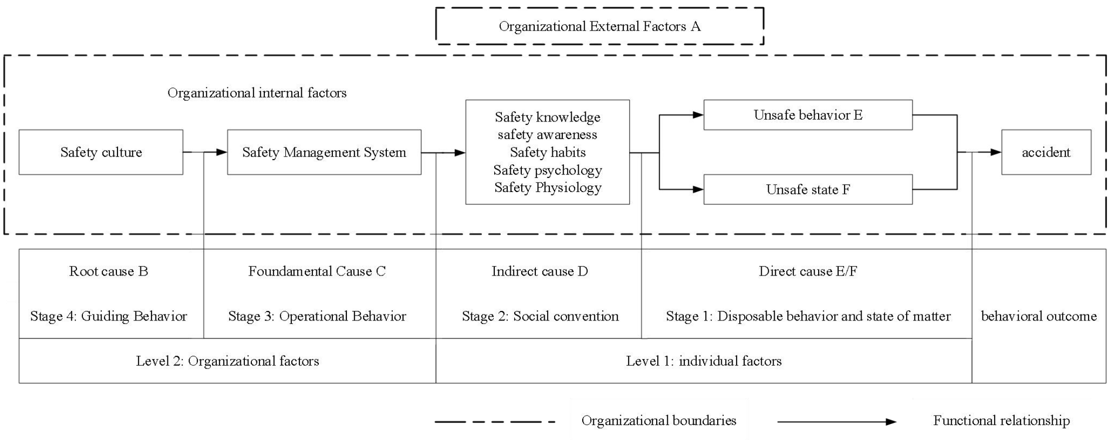

Figure 1 Structural Framework of 24 Model

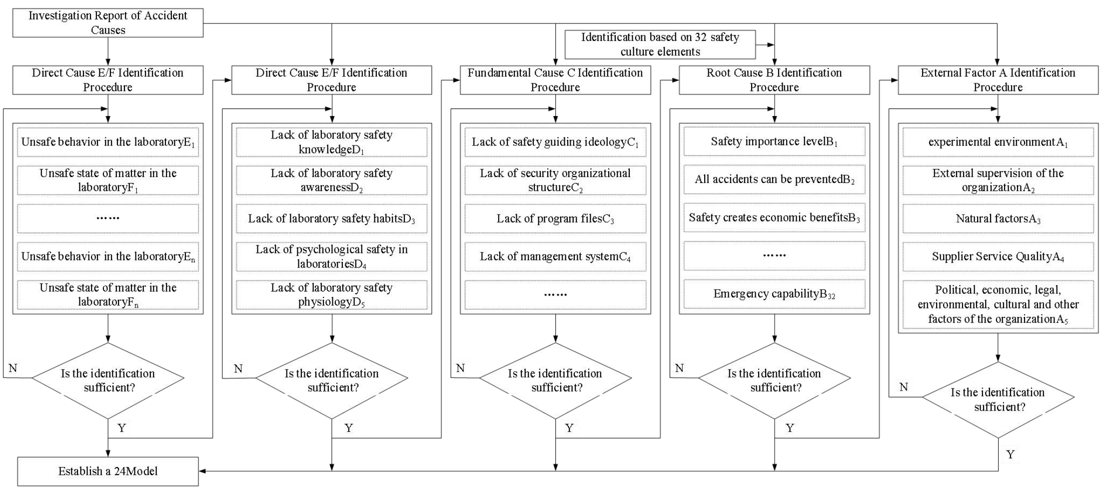

Figure 2 Chart of Accident Cause Identification Procedure Based on 24 Model

3.2 Grey DEMATEL-ISM-MICMAC Method

The traditional ISM method is based on the computer concept of Boolean matrix, and it divides the various elements in the system into two aspects: 1 represents direct relationships and 0 represents no direct relationships. Based on expert judgment, the DEMATEL method is used to describe the relationship between various factors, and its results highly rely on expert opinions. And the DEMATEL-ISM method is constructed integrating the DEMATEL method with the ISM method, which combines the advantages of both methods. However, there are still certain limitations, making it difficult to accurately quantify uncertain scenarios where some information is known and some unknown. Based on the Grey System Theory, grey numbers are introduced, and the Grey DEMATEL-ISM method is integrated to depict the relationship more accurately between factors causing safety accidents in university laboratories. And it, to some extent, reduces the subjectivity of quantitative analysis. Based on this method, the quantitative analysis results are divided into hierarchical structures. Finally, the MICMAC method, which can be used to analyze the attribute characteristics of accident causes, integrates with the Grey DEMATEL-ISM method[27]. And the Grey DEMATEL-ISM-MICMAC method is constructed to deeply explore the attribute characteristics of safety accident causes in university laboratories. The calculation steps of the Grey DEMATEL-ISM-MICMAC method are as follows.

1)Establish accident cause set A, $\mathrm{A} = \{\mathrm{A}_1, \mathrm{A}_2, \cdots, \mathrm{A}_i\}$

2)Determine the original impact relationship matrix between two factors B^m

m experts are invited to score the strength of the relationship between each cause according to the five-level grey language scale (see Table 1). And the scorings are converted into grey numbers to construct a grey impact relationship matrix.

Table 1 Five-level Grey Language Scale

Grey language	Scoring	Grey number
No impact	0	0
Weak impact	1	(0, 0.25]
Low impact	2	(0.25, 0.5]
High impact	3	(0.5, 0.75]
Extremely high impact	4	(0.75, 1]

3) Whitenization of grey number

① Standardize the upper and lower limits of the grey number through equation (1).

$$\begin{gathered}\bar{\otimes}\,\bar{\mathrm{u}}_{ij}^m = (\bar{\otimes}\,\mathrm{u}_{ij}^m - \min\,\bar{\otimes}\,\mathrm{u}_{ij}^m)\ /\,\Delta_{\min}^{\max}\\ \underline{\otimes}\,\bar{\mathrm{u}}_{ij}^m = (\underline{\otimes}\,\mathrm{u}_{ij}^m - \min\,\underline{\otimes}\,\mathrm{u}_{ij}^m)\ /\,\Delta_{\min}^{\max}\\ \Delta_{\min}^{\max} = \max\bar{\otimes}\,\mathrm{u}_{ij}^m - \min\,\underline{\otimes}\,\mathrm{u}_{ij}^m\end{gathered} \tag{1}$$

In the formula: m represents the number of experts; $\bar{\otimes}\,\mathrm{u}_{ij}^m$ and $\underline{\otimes}\,\mathrm{u}_{ij}^m$ are the upper and lower limits of grey numbers; $\bar{\otimes}\,\bar{\mathrm{u}}_{ij}^m$ and $\underline{\otimes}\,\bar{\mathrm{u}}_{ij}^m$ are the standard values for the upper and lower limits of the grey number; $\Delta_{\min}^{\max}$ is the difference between the maximum upper limit and the minimum lower limit of the gray number.

② Calculate the standardized whitening value y_{ij}^m through equation (2).

$$y_{ij}^m = \frac{\underline{\otimes}\,\bar{\mathrm{u}}_{ij}^m(1 - \underline{\otimes}\,\bar{\mathrm{u}}_{ij}^m) + (\bar{\otimes}\,\bar{\mathrm{u}}_{ij}^m \times \bar{\otimes}\,\bar{\mathrm{u}}_{ij}^m)}{(1 - \underline{\otimes}\,\bar{\mathrm{u}}_{ij}^m + \bar{\otimes}\,\bar{\mathrm{u}}_{ij}^m)} \tag{2}$$

③ Calculate the final whitening value b_{ij}^m through equation (3).

$$b_{ij}^m = \min\,\underline{\otimes}\,\mathrm{u}_{ij}^m + \mathrm{y}_{ij}^m \bullet \Delta_{\min}^{\max} \tag{3}$$

4) Calculate the weighted whitening grey influence relationship matrix B through equation (4)

$$b_{ij} = w_1 b_{ij}^1 + w_2 b_{ij}^2 + \cdots + w_m b_{ij}^m \tag{4}$$

In the formula: W_m is the weight and $\sum_{m=1}^{n} w_m = 1$.

5) Normalize the weighted whitening grey impact relationship matrix B through equation (5) to obtain the standardized impact relationship matrix V; Establish comprehensive impact relationship matrix T through equation (6).

$$v_{ij} = \frac{b_{ij}}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} b_{ij}} \tag{5}$$

$$\mathrm{T} = \mathrm{V}\left(E - \mathrm{V}\right)^{-1} \tag{6}$$

In the formula, E and V are identity matrix in the same order.

6) Calculate the overall impact relationship matrix H through equation (7); Then calculate the mean and standard deviation of all elements in the comprehensive impact relationship matrix T, and the threshold value is obtained by summing them; Calculate the reachable matrix $\mathrm{K} = (k_{ij})$ through equation (8).

$$\mathrm{H} = \mathrm{E} + \mathrm{T} \tag{7}$$

$$k_{ij} = \begin{cases} 1 & h_{ij} \ge \lambda(i, j = 1, 2, \cdots, n) \\ 0 & h_{ij} < \lambda(i, j = 1, 2, \cdots, n) \end{cases} \tag{8}$$

7) Calculate the reachable set L_i and antecedent set S_i of each cause through equations (9) and (10).

$$L_i = \{a_j | a_j \in \mathrm{A}, k_{ij} \ne 0\} \; j = 1, 2, \cdots, n \tag{9}$$

$$S_i = \{a_i | a_i \in \mathrm{A}, k_{ij} \ne 0\} \; i = 1, 2, \cdots, n \tag{10}$$

Each cause is verified to see if it meets $L_i = L_i \cap \mathrm{S}_i \; (i = 1, 2, \cdots, n)$. If meets, the cause belongs to the first layer, and then the corresponding row and column are removed from the reachable matrix K; This verification process is repeated until all contributing factors have been assigned and a hierarchical structure model is constructed.

8) Calculate the driving forces DL_i and dependence DS_i of each factor through equations (11) and (12); Then, the causal factors are identified as autonomous, dependent, associative, and independent elements based on numerical values. Among them, the driving force and dependence of autonomous elements are relatively low; the driving force of dependent elements is relatively low, but the dependence is relatively high; the driving force and dependence of associative elements are relatively high; and the driving force of independent elements is relatively high but the dependence is relatively low.

$$DL_i = \sum_{j=1}^{n} k_{ij} \; i = 1, 2, \cdots, n \tag{11}$$

$$DS_i = \sum_{i=1}^{n} k_{ij} \; j = 1, 2, \cdots, n \tag{12}$$

4 EXAMPLE ANALYSIS

4.1 Accident Overview

An explosion accident occurred about 12:40 on April 5, 2015, at the Laboratory A315 of the School of Chemical Engineering, China University of Mining and Technology, because the person in charge configured and stored 17% methane in violation of regulations and the laboratory personnel improperly operated during the relevant experiments. This accident caused one casualty, four injuries, and a direct economic loss of about 2 million yuan. The “4.5” explosion accident of China University of Mining and Technology (“4.5” accident for short) is a very typical chemical related laboratory explosion accident, and it is also one of the most serious university laboratories methane gas explosion accidents. It fully exposes the loopholes in the safety production and management of education administration departments and schools and colleges, which is highly representative, warning and learning significance to others. In view of this, the “4.5” accident is chosen as an example to conduct a thorough analysis of its safety accident causes.

4.2 Identification of Accident Causes Based on 24 Model

24 causes of the “4.5” mining accident based on the 24 Model is accurately identified with reference to the Report on “4.5” Explosion Death Accident of China University of Mining and Technology and the Notice of Laboratory Safety Inspection in Higher Education Institutions (28) issued by General Office of the Ministry of Education[28-29]. Specifically, it mainly includes: 2 external factors, $\mathrm{A}_1 \sim \mathrm{A}_2$, 7 root causes, $B_1 \sim B_7$, 4 fundamental causes, $C_1 \sim C_4$, 6 indirect causes, $D_1 \sim D_6$, and 5 direct causes, $E_1 \sim E_3$, $F_1 \sim F_2$. And it is as follows in Figure 3.

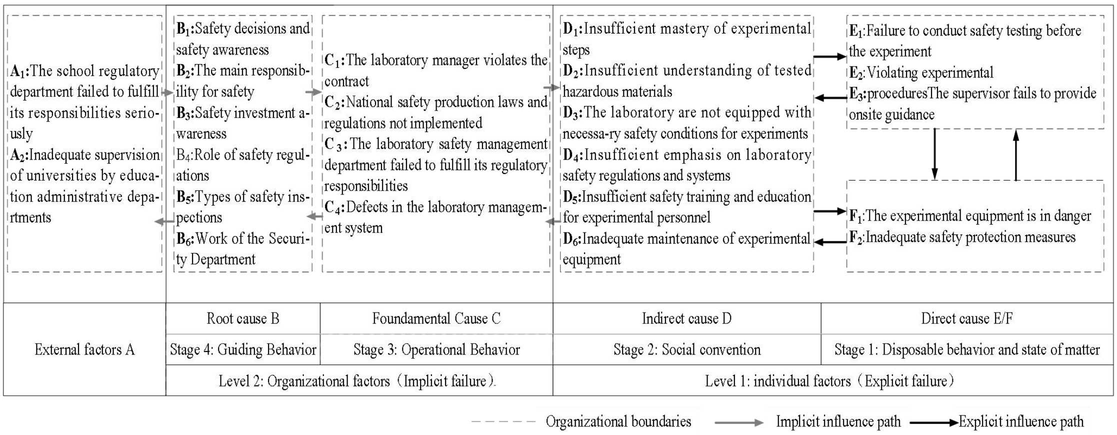

Figure 3 Chart of Cause Identification of "4.5" Accident Based on the 24 Model

3.3 Quantitative Analysis of the Safety Accident Causes in Laboratories Based on the Grey DEMATEL-ISM-MICMAC Method

1)Firstly, experts and scholars engaged in research on the safety management of university laboratories are invited to evaluate the impact degree between various causes, and their opinions afe set as equally important, that is, $w_i = \dfrac{1}{m}\ (i = 1, 2, 3, \cdots, \mathrm{m})$. Then, the evaluation scores of each expert are converted into grey numbers through Table 1, and the weighted whitening grey influence matrix B is calculated according to equations (1) to (4). Finally, the standardized impact relationship matrix V and the comprehensive impact relationship matrix T are calculated according to equations (5) and (6).

2) The mean and standard deviation of the comprehensive impact relationship matrix T are calculated. And the threshold $\lambda = 0.0538$ is obtained by summing them. The reachable matrix K is established based on equations (7) and (8). And a hierarchical structure model is established based on equations (9) and (10). The results are shown in Figure 4.

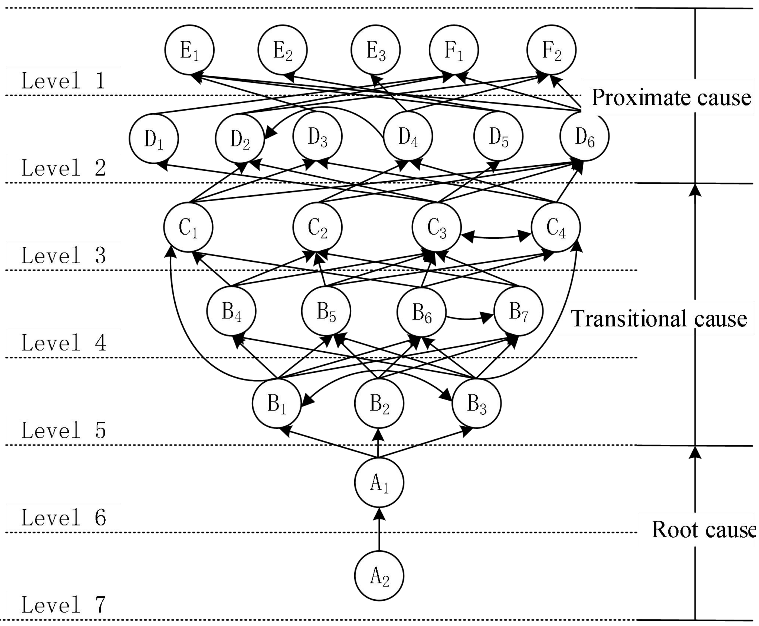

Figure 4 Hierarchical Structure Model of the Cause of "4.5" Accident

3) The driving force and dependence of each cause is calculated according to equations (11) and (12), and Cartesian coordinate is established with the driving force as the horizontal axis, the dependence as the vertical axis, and the mean as the central axis. The results are shown in Figure 5.

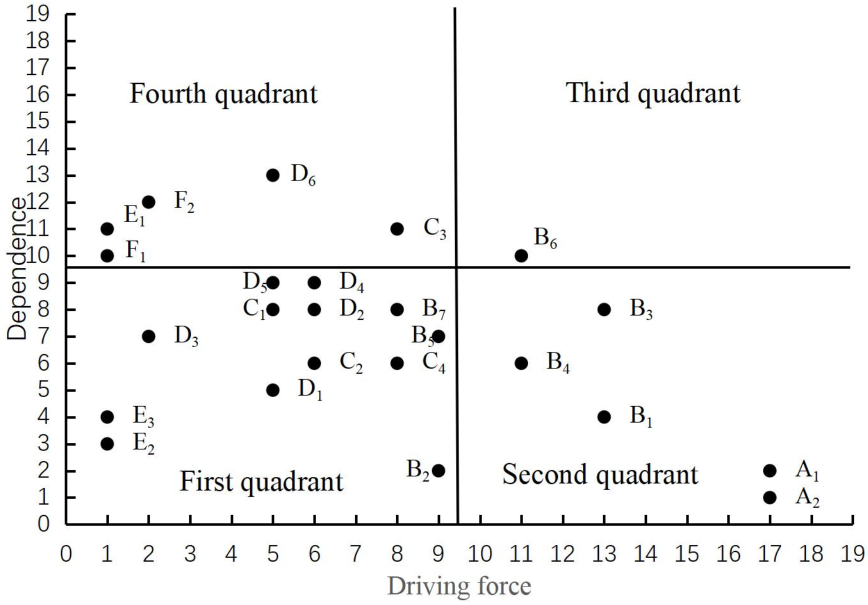

Figure 5 Diagram of MICMAC Identification Results of “4.5” Accident Cause

3.4 Result Analysis

3.4.1 Cause identification analysis of “4.5” accident based on 24 model

The 24 Model is used to identify the causes of laboratory safety accidents accurately and comprehensively in universities, and it clearly identifies the different safety accident causes of university laboratories at different stages. From the analysis in Figure 3, it can be seen that the relationship between the causes of safety accidents in university laboratories is extremely complex. This complex relationship is not only manifested in the interaction between external causes and organizational causes, but also in the interaction between organizational causes and individual causes, as well as the interaction between internal factors of organizational causes and individual causes. Among them, there are implicit influence paths of interaction between external cause A and guiding behavior cause B, between guiding behavior cause B and operational behavior cause C, and between operational behavior cause C and social conventional cause D. And there is an explicit influence path of interaction among social conventional cause D, unsafe behavior cause E, and unsafe state cause F. This indicates that among the causes of laboratory safety accidents in universities, regardless of which stage of the cause has a negative impact, it will directly or indirectly affect others. This lays a solid theoretical analysis foundation for further research, with quantitative analysis, on the interrelationships between the various causes of safety accidents in university laboratories.

3.4.2 Analysis of hierarchical structure model

From the analysis in Figure 4, it can be seen that the 24 causes of the “4.5” accident is divided into 7 levels. Among them, the nearby causes of the “4.5” accident are in the 1st to 2nd layers, including 11 factors including E_1, E_2, E_3, F_1, F_2, D_1, D_2, D_3, D_4, D_5, and D_6. These causal factors are the direct causes and explicit macroscopic manifestations of the “4.5” accident. The transition causes of the “4.5” accident is located on the 3rd to 5th layers, including 11 factors, B_1, B_2, B_3, B_4, B_5, B_6, B_7, C_1, C_2, C_3, and C_4. These factors affect each other and serve as a bridge between the root causes and the nearby causes. They are the indirect causes of the “4.5” accident in the entire laboratory safety accident. The root causes of the “4.5” accident is in the 6th to 7th layers, including two factors, A_1 and A_2. And these two factors can directly affect the transition causes, which in turn has an indirect impact on the nearby causes and are the fundamental causes of the “4.5” accident. Through in-depth analysis of the hierarchical structure model, the complex interaction between the causes of laboratory safety accidents is discovered. This relationship is manifested not only between the same levels and adjacent levels, but also between cross level interactions. Accurately controlling the root causes and transition causes of laboratory safety accidents is the key to preventing their coupling effect and causing accidents.

3.4.3 MICMAC analysis of accident causes

As shown in Figure 5, the 24 causes of the “4.5” accident are identified as autonomous, independent, associative and dependent elements, located in the first, second, third, and fourth quadrants of the Cartesian coordinate respectively.

The autonomous elements located in the first quadrant include a total of 13 items, including B_2, B_5, B_7, C_1, C_2, C_4, D_1, D_2, D_3, D_4, D_5, E_2, and E_3. The driving force and dependence of these elements are relatively low, but in laboratory safety accidents, they serve as a key point and are regarded as the focus of accident prevention. At present, with the continuous development of the market economy, it is very common to see the phenomenon of cooperation between university laboratories and enterprises. However, in pursuit of maximizing profits, cooperative enterprises are likely to reduce safety investment and even engage in illegal operations. Therefore, there are deficiencies and inadequate supervision in the laboratory management system, which may lead to risks such as contract violations. So, the autonomous element in the accident causes should be given special attention. Colleges and universities should make an effort. For example, they should establish a comprehensive laboratory management system and strengthen their supervision. National laws and regulations, and operating procedures should be strictly implemented. It is recommended to include the leaders' safety training effectiveness and lesson plan quality of the laboratory management in the year-end performance evaluation and use the training lesson plan and activities of the laboratory as the basis for professional title evaluation. The treatment of laboratory leaders should be properly improved to promote their implementation of safety training. Safety knowledge training and regulatory education for laboratory personnel should be strengthened, which aims to enhance safety awareness. Students who have received safety training and passed the assessment will be granted the right to enter and exit the laboratory. Students who have failed will not be eligible to provide opening reports, thesis defense, or regular graduation. A laboratory safety knowledge competition could be held and students for outstanding performance are rewarded[30]. Relevant laboratory safety emergency plans should be improved, and regular drills conducted. Cooperative enterprises and universities should establish a strong awareness of the safety production red line, strengthen the investment on the awareness of safety for teachers, students, and employees, which could improve their safety emergency skills and awareness.

The independent elements located in the second quadrant include 5 items: A_1, A_2, B_1, B_3, and B_4. This type of factor has a high driving force and a low dependence, and it mainly causes accident by influencing other causes. The education administrative department should learn from the lesson of the "4.5" accident to strengthen the supervision of university laboratories. Measures to establish a university laboratory big data supervision platform could be established, which includes but is not limited to VR images, experimental equipment, main uses, main principals, management methods, maintenance measures and other information of each laboratory. And on-site assessment and inspection should be carried out periodically. VR images, assessment results and other information should be updates and uploaded on the platform, which are the measures to stop and rectify university laboratories with high security risks. Safety laws and regulations should be vigorously promoted, and their role should be implemented in the management system of university laboratories. Safety summary meetings for university laboratories could be regularly held and new hidden dangers should be discussed in a timely manner to figure out the rectification measures, which is a way to strengthen safety awareness. Spot checks on the safety knowledge reserves and emergency skills could be regularly conducted within university teachers and students to verify the implementation and effectiveness of laboratory safety training. The above measures can enhance the influence of education administrative departments on other causes and in the end reduce laboratory safety risks.

The associative elements locate in the third quadrant is B_6 with both high driving force and dependence. The type of safety inspection has a significant influence and control over other causes, and the effective implementation of relevant laws and regulations is the main driving force for reducing hazards and preventing and controlling accidents.

Therefore, relevant departments should improve their own regulatory and inspection systems, pay timely attention to laboratory accidents both at home and abroad, study and assess new safety issues in university laboratories in the new era, and revise and improve relevant safety inspection laws and regulations. And the reason is that strict implementation is an effective way to curb accidents at the root.

The dependent elements located in the fourth quadrant include C_3, D_6, E_1, F_1 and F_2. These elements have a low driving force and a high degree of dependence. They are subordinate to operational behavior, one-off behavior, physical state and social convention, which need to be solved by other factors.

5 CONCLUSION

(1) 24 causes of the "4.5" accident analyzed with the 24Model were accurately identified. The Grey DEMATEL-ISM method was used to quantitatively analyze the impact between the causes of the "4.5" accident, which clarifies the logical relationships in the accident causes, and a 7-level hierarchical structure model of the causes of the "4.5" accident was constructed. The MICMAC method was used to identify the attribute characteristics of the cause of the "4.5", and specific causal factors of the four categories, autonomous, independent, associative, and dependent factors of the "4.5" accident were excavated. All those methods have fully verified the practicality of the 24 Model Grey DEMATEL-ISM-MICMAC method in analyzing the causes of safety accidents in university laboratories.

(2) The joint efforts from cooperative education administrative departments, universities, cooperative enterprises, and other aspects are required to prevent and control the safety accidents in university laboratories. The education administrative department should establish the concept of safety working, strengthen the supervision and inspection of university laboratories, as well as actively improve laws and regulations on safety inspection, which curbs accidents from an external perspective. Cooperative enterprises should strengthen their own safety management and investment and improve personnel's safety awareness and ability. Universities should carefully study and actively implement laws and regulations on safety working, strengthen the safety inspection and management of hazardous materials in university laboratories, establish and improve a system for identifying safety hazards, as well as strengthen safety education and training for laboratory personnel, which could reduce risk levels from an organizational level.

COMPETING INTERESTS

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CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Qin Liu: Conceptualization, Method, Writing – original draft. Ke Liu and Zemin Qi: Data curation, Formal analysis, Writing – review & editing. Hongbing Li: Visualization, Investigation, Validation.

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EXPLORING THE APPLICATION OF GENERATIVE ARTIFICIAL INTELLIGENCE IN UNIVERSITY FRENCH TEACHING

XiaoTing Zhao*, LinLin Fang
School of Humanities, Beijing University of Posts and Telecommunications, Beijing 102206, China.
Correpsonding Author: XiaoTing Zhao, Email: zhaoxiaotingfr@163.com

Abstract: This paper focuses on the teaching of French at the university level and explores the application of generative artificial intelligence (GAI) in various aspects of pedagogy, including classroom design, the creation of learning resources, grammar instruction, and interactive learning support. Using three representative platforms—ChatGPT (United States), Kimi (China), and Le Chat (France)—as case studies, the research systematically compares their models of application, advantages, and limitations in the context of university French instruction. A teaching experiment was conducted in the course "Public French as a Second Foreign Language" at a certain university. The experiment was supplemented by questionnaire surveys and statistical analysis via SPSS to compare the performance of students who used GAI platforms and those who did not in listening, speaking, reading, and writing. Results show that students who used generative AI exhibited significant improvements in both language proficiency and learning motivation. However, challenges persist in areas such as cultural depth, accuracy of generated content, and the need for teacher guidance. Based on these findings, this paper proposes strategies such as optimizing instructional design, enhancing teachers' technological competence, and strengthening data privacy protection. It aims to provide evidence-based references and innovative approaches for reforming and improving university French teaching, thereby cultivating more competitive French language talents.
Keywords: Generative artificial intelligence; University French teaching; Application comparison; Teaching reform

1 INTRODUCTION

Against the backdrop of globalization and deepening digitalization, foreign language proficiency has become an essential component of higher education talent cultivation. As one of the six official languages of the United Nations, French holds an irreplaceable role in diplomacy, academic research, international cooperation, and cultural exchange. However, the current system of French language teaching in Chinese universities—especially for French as a second foreign language (L2)—faces multiple challenges. On one hand, instructional hours are limited, with most students only taking a few courses during their sophomore or junior years. On the other hand, there is a shortage of qualified teachers, making it difficult to meet the growing demand for cross-cultural communication and applied language training. Moreover, many students lack sufficient motivation, interest, and autonomy in learning, which leads to unsatisfactory outcomes. The question of how to improve students' linguistic competence and intercultural communication skills under limited teaching conditions has become a pressing issue[1].

In recent years, the rapid development of artificial intelligence (AI) has opened new possibilities for language education reform. Generative Artificial Intelligence (GAI), in particular, with its powerful capabilities in natural language processing and text generation, can simulate authentic communication scenarios, produce personalized learning materials, and provide instant feedback, thereby compensating for the shortcomings of traditional pedagogical approaches. The emergence of large language model–based platforms such as ChatGPT, Kimi, and Le Chat has brought new technological support to higher foreign language education. Existing studies show that GAI has been applied in several key aspects of language learning: (1) generating comprehensible input to enhance learners' understanding; (2) promoting language output through interactive simulations; and (3) providing instant feedback to correct errors, thereby improving learning effectiveness.

However, most existing research has focused on English, producing a rich body of findings, while studies on smaller languages such as French remain relatively scarce. Many of these studies are limited to theoretical discussions or case analyses, lacking systematic empirical validation[2]. Furthermore, platforms developed in different countries exhibit noticeable variations in corpus selection, language style, and cultural embedding. Whether these differences affect the effectiveness of French language teaching at the university level remains underexplored.

More importantly, the application of GAI has transcended the scope of classroom practice to become a matter of educational policy and national strategy. For instance, France's 2024 AI Committee Report explicitly emphasized the integration of AI into education and included dedicated projects for digital and intelligent education under the "France 2030" national strategic plan. Similarly, the Chinese Ministry of Education's 2024 policy guidance called for the exploration of new "AI + Foreign Language" models in higher education to enhance students' cross-cultural communication and autonomous learning capabilities[3]. These developments suggest that countries worldwide regard the integration of generative AI into education as a crucial pathway toward modernizing higher education.

Based on this background, this study takes the "Public French as a Second Foreign Language" course at a Chinese university as its research site and selects three representative GAI platforms—ChatGPT (United States), Kimi (China), and Le Chat (France)—for comparative analysis. Through teaching experiments, questionnaires, and statistical methods, the study aims to answer the following questions:
1. Can generative artificial intelligence effectively improve university students' French learning outcomes?
2. What similarities and differences exist among the three platforms in their application to French teaching?
3. What challenges and coping strategies do teachers and students encounter when using these tools?

2 LITERATURE REVIEW

2.1 Technological Evolution: From General Large Language Models to Education-Oriented Models

The development of generative artificial intelligence is closely tied to the progress of large language models (LLMs). From the release of GPT-3 in 2020 to GPT-4 in 2023 and GPT-4o in 2025, models have made remarkable advances in parameter scale, reasoning capability, and multimodal processing. Studies have demonstrated that innovations such as instruction tuning, reinforcement learning from human feedback (RLHF), and retrieval-augmented generation (RAG) have significantly improved the stability and efficiency of LLMs in educational settings.
Beyond OpenAI's GPT series, numerous localized models have emerged worldwide. In China, for instance, platforms such as Kimi, ERNIE Bot, and Tongyi Qianwen emphasize multilingual support and adaptation for Chinese learners; in France, Le Chat and Mistral AI are built on native French corpora, reinforcing deep linguistic and cultural integration. These technological advances not only enhance the quality of language generation but also expand the possibilities for personalized and intelligent foreign language education.
In the field of language education, a transition is taking place from the use of general-purpose models to education-specific ones. Some research teams have attempted to fine-tune LLMs for educational purposes, developing AI systems tailored to foreign language learning[4]. For example, Chinese scholars have constructed a French essay evaluation system based on ChatGPT that provides multidimensional feedback at the syntactic, lexical, and discourse levels. Similarly, the French education sector is experimenting with Le Chat–based teaching platforms for classroom interaction and intercultural communication training. These explorations indicate that generative AI in language education is evolving from a supportive tool to an integrated pedagogical system.

2.2 Educational Applications: Second Language Acquisition Theory and Generative AI

Within the theoretical framework of second language acquisition (SLA), generative AI demonstrates distinctive pedagogical advantages. According to Krashen's Input Hypothesis, language acquisition depends on the availability of comprehensible input. Generative AI can automatically generate reading materials and grammatical examples that align with learners' proficiency levels, providing controlled and personalized input.
Long's Interaction Hypothesis posits that language learning is facilitated through negotiation of meaning in communicative exchanges. AI-powered conversational systems can identify learners' linguistic challenges in real time and suggest corrections or alternative phrasing, enabling progress through meaningful interaction[5]. For example, ChatGPT's dialogue functions simulate everyday conversational contexts, Le Chat embeds French cultural elements in exchanges, and Kimi offers bilingual Chinese–French explanations to lower comprehension barriers. Empirical research supports these observations: Dupont's study in French universities found that students using Le Chat improved significantly in fluency and cultural understanding, while Smith's research showed that ChatGPT enhanced students' lexical diversity and textual coherence in writing. These findings provide theoretical grounding for the empirical analysis of this study.

2.3 Advantages and Limitations of Generative AI in Foreign Language Teaching

Generative AI offers numerous advantages in foreign language education:
1. Personalized Learning Paths: AI can tailor learning tasks and feedback to each student's level and needs, overcoming the limitations of one-size-fits-all instruction.
2. Multilingual Support: AI platforms typically support multiple languages, facilitating cross-linguistic learning—an especially valuable feature for students studying a second foreign language.
3. Increased Motivation: The interactive and engaging nature of AI enhances student interest and motivation.
4. Reduced Teacher Workload: AI can assist teachers in generating lesson plans, quizzes, and multimedia materials, allowing more time for in-class interaction and personalized guidance.
However, several limitations remain:
1. Accuracy Issues: AI-generated content sometimes contains grammatical or factual errors that require teacher verification.
2. Lack of Cultural Depth: Many platforms struggle to convey the nuanced cultural contexts of target languages.
3. Overdependence on AI: Excessive reliance on AI tools may weaken students' autonomy and critical thinking.
4. Privacy and Ethical Risks: Data security and academic integrity remain concerns when students use online AI platforms.

2.4 Research Progress and Directions for Expansion

Existing studies on the application of generative AI in language education have achieved notable progress, particularly in high-resource languages such as English. However, research on smaller languages like French remains limited. Most current works are confined to theoretical exploration or individual case studies, lacking large-scale quantitative validation and cross-cultural comparative analysis. Furthermore, prior research often focuses on a single AI platform, leaving cross-platform differences underexplored.

2.5 International and Policy Context

At the macro level, the integration of generative AI into education has become a global policy priority. In 2024, the French Ministry of Education established the Artificial Intelligence in Education Committee, which called for the responsible use of AI in language teaching and highlighted its potential for lesser-taught languages[6]. The "France 2030" national strategic plan also listed digital education and AI innovation as key investment areas, encouraging universities to explore integrated "AI + Language Education" models. Likewise, China's Ministry of Education issued policy guidelines in 2024 urging universities to apply AI in higher education and develop new AI-driven approaches for second foreign language teaching to address teacher shortages and low learner engagement[7]. These international and policy contexts underscore the strategic significance of applying generative AI to university-level French instruction.

Based on the preceding review, this study aims to build upon existing findings by conducting a cross-platform empirical investigation of ChatGPT, Kimi, and Le Chat, comparing their effectiveness and differences in university French education and analyzing their respective advantages, limitations, and areas for improvement in specific instructional settings.

3 RESEARCH METHODS

3.1 Research Participants and Group Design

The research participants consisted of 158 first- and second-year undergraduate students enrolled in the "Public French (Second Foreign Language)" course during the 2023–2024 and 2024–2025 academic years at a comprehensive university. To ensure scientific validity and comparability, an experimental design with both an experimental group and a control group was adopted. The two groups showed no significant differences in gender or academic background[8]. The experimental group (n = 40) systematically used generative AI platforms—ChatGPT, Kimi, and Le Chat—throughout the course, while the control group (n = 40) continued with the traditional instructional model (teacher lectures plus textbook-based exercises).

3.2 Experimental Design

The instructional experiment followed a three-stage structure encompassing pre-class, in-class, and post-class learning activities.

3.2.1 Pre-class stage

Teachers used the three AI platforms to generate grammar explanations, listening exercises, reading comprehension materials, and writing samples. ChatGPT excelled at producing diverse resources efficiently; Kimi was best suited for generating grammar materials with Chinese explanations[9]; Le Chat specialized in producing culturally embedded content such as news summaries or excerpts from French literature. Teachers filtered and integrated the AI-generated resources to provide differentiated learning tasks for the experimental group.

3.2.2 In-class stage

Students used the AI platforms in several ways during class:

- Dialogue simulation: Students engaged in oral practice with ChatGPT or Le Chat, simulating authentic contexts such as shopping, booking tickets, or job interviews.
- Grammar instruction: Teachers demonstrated how ChatGPT and Kimi explained a given grammar point differently, prompting students to compare and evaluate the explanations.
- Cultural enrichment: Using Le Chat, teachers generated short texts on French history, geography, or customs to foster group discussions and enhance cultural awareness.

3.2.3 Post-class stage

Students completed two types of assignments:

- Writing tasks: Students wrote short essays of 80–100 words (e.g., "My Vacation") and used ChatGPT or Kimi for feedback and revision.
- Self-study tasks: Students used Le Chat to explore French literary works, thereby cultivating cross-cultural reading competence.

3.3 Data Collection

To ensure comprehensive and reliable findings, both quantitative and qualitative data were collected.

- Language proficiency pre- and post-tests: Standardized formative and summative French assessments measured improvements in listening, speaking, reading, and writing skills.
- Questionnaire survey: A five-point Likert-scale questionnaire was designed, covering four dimensions—learning resources, interactivity, language generation quality, and overall satisfaction. The questionnaire contained 20 items, with key indicators including "richness of learning resources," "smoothness of interactive experience," "accuracy of generated content," and "enhancement of learning motivation."
- Interviews and classroom observations: After the experiment, semi-structured interviews were conducted with 10 students and 3 teachers to gather subjective feedback and experiences.

3.4 Data Analysis

Quantitative data were analyzed using SPSS 29.0 with the following procedures:
- Independent sample t-tests to compare performance differences between the experimental and control groups.
- Effect size (Cohen's d) to measure the magnitude of observed differences.
- Reliability and validity analysis of the questionnaire, yielding a Cronbach's α coefficient of 0.86 (indicating high internal consistency) and a KMO value of 0.79 (suitable for factor analysis).

Qualitative data were analyzed through thematic analysis summarizing recurring patterns in teachers' and students' experiences with the three AI platforms during the teaching process.

4 COMPARATIVE ANALYSIS OF THE THREE PLATFORMS IN FRENCH TEACHING

4.1 ChatGPT

ChatGPT, developed by OpenAI and launched in November 2022, is an AI-based conversational platform built on the GPT-3.5 architecture and trained on extensive multilingual text corpora. It supports conversation, translation, content generation, and even code debugging, becoming the fastest application in history to reach 100 million users. Its application in French language teaching can be summarized as follows.

4.1.1 Learning resource generation

ChatGPT can rapidly produce French exercises, reading passages, and grammar explanations at various difficulty levels. For instance, when teaching the imperative or subjunctive mood, a teacher may input "Generate 10 French sentences using the subjunctive mood," and ChatGPT will instantly produce examples across diverse contexts, often accompanied by explanations. Compared with manual preparation, this greatly reduces teachers' workload and preparation time[10].

4.1.2 Interactive simulation

ChatGPT's dialogue feature provides students with a near-authentic conversational environment. When practicing speaking, learners can simulate real-life contexts such as ordering food, asking for directions, or job interviews. The AI provides immediate corrective feedback, allowing students to identify and correct grammatical or lexical errors in real time.

4.1.3 Writing support

In writing instruction, students use ChatGPT to receive guidance on paragraph structure, logical coherence, and lexical variety. Smith (2023) found that students who employed ChatGPT in writing tasks demonstrated significant improvements in vocabulary diversity and textual cohesion.

4.1.4 Strengths and limitations

ChatGPT's primary advantages lie in the breadth of its linguistic resources, the fluency of its interactions, and its strong writing support. Trained on massive multilingual corpora, it generates diverse materials encompassing grammar, reading, and writing. Its swift response enables real-time alternative phrasing and corrective feedback, enhancing communicative efficiency[11]. In writing support, ChatGPT helps students improve organization, vocabulary choice, and coherence, thus elevating essay quality. However, limitations include occasional misuse of advanced grammar, superficial treatment of cultural context, and limited coherence in extended dialogues, sometimes leading to logical inconsistencies.

4.2 Kimi

Kimi is a Chinese generative AI platform focused on multilingual dialogue and content generation. Trained on extensive multilingual datasets, it performs well in cross-linguistic understanding and text production. Its integration with Chinese educational systems provides convenience for French learners in China. One of its design goals is to lower the cognitive barriers students face when using foreign-language tools.

4.2.1 Cross-linguistic explanation

When generating grammar explanations and exercises, Kimi frequently includes Chinese explanations. For example, in explaining the imperfect tense (imparfait), it not only provides French examples but also parallel Chinese interpretations. This is particularly valuable for learners of French as a second foreign language, enabling them to form clear interlingual connections.

4.2.2 Reduced cognitive load

Students often struggle with abstract grammatical concepts such as the subjunctive mood. Kimi simplifies explanations with concise bilingual annotations, reducing comprehension difficulty and alleviating learning anxiety.

4.2.3 Writing and translation support

In translation exercises, students can input a Chinese text, and Kimi generates the corresponding French translation with grammatical and lexical explanations. For instance, “I hope he can come tomorrow” is translated as “J’espère qu’il pourra venir demain,” followed by an explanation of modal and mood usage.

4.2.4 Strengths and limitations

Kimi’s strengths lie in its accessibility for Chinese learners. By providing Chinese explanations, it helps beginners quickly establish interlanguage correspondences and reduces cognitive load. Its detailed feedback in translation and writing assists comprehension of grammatical and lexical reasoning. However, Kimi’s accuracy declines with advanced grammar or literary texts. It lacks cultural depth, and its generated tasks are relatively uniform, with little focus on intercultural communication.

4.3 Le Chat

Le Chat is a French generative AI platform developed by Mistral AI and released in February 2024. Based on the Mistral Small and Mistral Large models, it relies primarily on French literary, journalistic, and educational corpora. Its distinctive features are cultural embeddedness and linguistic authenticity.

4.3.1 Cultural contextualization

When explaining grammar, Le Chat often references examples from French literature or news. For instance, in discussing relative clauses, it may quote sentences from Victor Hugo or Albert Camus. This approach helps students grasp grammatical structures within authentic cultural contexts.

4.3.2 Cross-cultural communication training

During conversational practice, Le Chat offers native-like expressions and culturally appropriate politeness formulas. For example, when asked to “simulate a café order dialogue in Paris,” it generates context-rich dialogues featuring authentic idiomatic expressions, which greatly benefit the development of intercultural competence.

4.3.3 Teacher support tool

Teachers can use Le Chat to generate short introductions to French society, history, or customs, enriching classroom content and enhancing cultural awareness.

4.3.4 Strengths and limitations

Le Chat’s major strengths are its linguistic authenticity and cultural integration. Drawing from native French corpora, it produces natural expressions aligned with real usage. Its contextualized grammar explanations, often linked to literature or current events, help students internalize language in meaningful contexts. It also enables teachers to efficiently generate culturally immersive materials. However, Le Chat has limited international reach and slower information updates. Its interface supports fewer languages, and some social or topical information may be outdated. Additionally, its support for academic writing is less comprehensive than that of ChatGPT.

4.4 Summary

In summary, the three platforms each exhibit distinct pedagogical advantages. ChatGPT excels in resource generation and writing support. Kimi is particularly suitable for beginners due to its bilingual explanations and reduced cognitive demands. Le Chat stands out for its strong cultural contextualization and authentic language expression. Teachers should flexibly integrate these platforms according to course objectives and learner proficiency levels. Combining their strengths can maximize teaching effectiveness and offer students a more comprehensive, engaging, and culturally enriched learning experience.

5 CHALLENGES IN APPLYING GENERATIVE ARTIFICIAL INTELLIGENCE TO UNIVERSITY FRENCH TEACHING

Although generative artificial intelligence demonstrates clear advantages in French language teaching, its implementation in practice faces multiple challenges. These challenges arise from technical, pedagogical, student-related, and ethical dimensions.

5.1 Technical Challenges

The accuracy of AI-generated content remains one of the most prominent technical issues. While platforms such as ChatGPT can quickly produce large volumes of text, they may still generate errors in advanced grammatical structures or highly specialized topics. For instance, when producing examples that contrast the subjunctive and conditional moods, AI systems may occasionally confuse voice or mood, which, if unchecked, could mislead students.

Another concern is the lag in knowledge updates. Because large language models rely on pre-trained corpora, their content may become outdated if the models are not refreshed regularly. For example, when addressing recent French social issues, the information generated by some platforms lags behind real-world developments.

In addition, platform stability and internet accessibility can influence teaching effectiveness. Some universities in China face unstable connections to overseas servers, limiting the use of ChatGPT, while domestic platforms such as Kimi, though more stable, still lack certain advanced functionalities.

5.2 Teacher-Related Challenges

Teachers' technical literacy and acceptance of AI tools play a crucial role in determining the effectiveness of GAI-assisted instruction. Some teachers remain skeptical, fearing that AI might weaken their classroom authority or instructional autonomy. Moreover, teachers who are unfamiliar with AI capabilities may misuse it as an "answer generator" rather than an "instructional assistant," preventing full pedagogical integration.

Another issue lies in the challenge of instructional design. Teachers must determine how to incorporate AI into limited class time without letting it overshadow human interaction. Achieving an appropriate balance between human and machine collaboration remains a pressing challenge. Some students directly submit AI-generated assignments without personal input, undermining their cognitive engagement and complicating evaluation processes. Additionally, several French instructors have expressed that "the pace of technological innovation far exceeds that of pedagogical adaptation," which limits their ability to integrate AI effectively even when they are willing to experiment. The questions of "how to use" and "when to use" AI thus remain key uncertainties for educators.

5.3 Student-Related Challenges

Students also face challenges when using generative AI tools. The most notable is overreliance. Some students depend entirely on AI-generated texts for writing tasks, neglecting independent thinking and creative expression. Over time, such dependency can erode their linguistic and critical abilities.

Learning anxiety presents another issue. While AI provides personalized feedback, some students feel pressured by the "ideal answers" produced by the system, fearing mistakes or constant comparison with AI's standard responses. This anxiety can reduce their confidence and willingness to communicate. In some cases, students develop excessive trust in AI outputs, assuming its suggestions are always correct, which discourages self-expression and hinders the internalization of language skills. Furthermore, digital inequality deserves attention: students with limited access to reliable devices or internet connections are disadvantaged in AI-assisted learning environments.

5.4 Ethical and Institutional Challenges

The integration of generative AI into education raises ethical concerns related to academic integrity and data privacy. Some students submit AI-generated essays or assignments without proper acknowledgment, violating principles of academic honesty. Moreover, the personal data and learning records entered into AI systems may be at risk of exposure or misuse.

Institutionally, most universities have yet to establish clear policies to regulate AI use in education. On one hand, strict prohibition could hinder technological innovation; on the other, a lack of regulation may lead to irresponsible use. Establishing clear ethical frameworks and operational guidelines is therefore essential to ensure responsible and sustainable adoption of AI in university-level French teaching.

6 DATA RESULTS AND ANALYSIS

6.1 Comparison of Student Performance

This study compared the learning outcomes of students who used generative AI platforms with those who did not, focusing on their performance in listening, speaking, reading, and writing. The results demonstrated that the introduction of generative AI significantly enhanced students' overall language proficiency.

Table 1 Comparison of French Learning Outcomes between Students with and without Generative AI Use (N = 158)

Learning Indicator	Without Generative AI (M ± SD) (M±SD)	With Generative AI (M±SD)	t value	p value
Listening Comprehension	72.5 ± 8.4	81.3 ± 7.2	3.12	0.003
Oral Expression	68.9 ± 7.9	79.7 ± 6.9	4.05	<0.001
Reading Comprehension	76.4 ± 8.2	85.6 ± 7.1	3.76	0.001
Writing Ability	65.2 ± 7.5	76.8 ± 7.4	4.22	<0.001
Overall Score	70.7 ± 6.8	80.6 ± 6.5	4.65	<0.001

As shown in Table 1, students in the experimental group outperformed the control group in all four dimensions of language competence. The most significant improvements appeared in writing ability and oral expression ($p < 0.001$), indicating that generative AI was particularly effective in enhancing students' productive skills. All Cohen's d values exceeded 0.8, signifying large effect sizes.

6.2 Student Satisfaction Survey

Table 2 Student Satisfaction with Different Generative AI Platforms (M ± SD)

Platform	Learning Resources	Interactivity	Language Generation Quality	Overall Satisfaction
ChatGPT	4.2 ± 0.6	4.0 ± 0.7	3.9 ± 0.8	4.0 ± 0.6
Kimi	3.8 ± 0.7	3.6 ± 0.8	3.7 ± 0.7	3.7 ± 0.7
Le Chat	4.1 ± 0.5	3.9 ± 0.6	4.5 ± 0.5	4.2 ± 0.5

Survey results revealed that students expressed generally high satisfaction with all three platforms, see Table 2. Le Chat scored highest in the authenticity and cultural relevance of language generation, ChatGPT was most favored for its diversity and richness of learning resources, and Kimi received positive feedback for its bilingual support and operational convenience. Overall, Le Chat achieved the highest ratings for language quality, ChatGPT excelled in resource generation, and Kimi performed well in learner accessibility though with room for improvement in interactivity.

6.3 Interviews and Classroom Observations

Qualitative findings from interviews and classroom observations corroborated the quantitative results. Students widely agreed that ChatGPT enhanced their writing competence, Kimi was particularly beneficial for beginners, and Le Chat improved their understanding of French culture. Several students reported that AI-generated feedback boosted their confidence. One student commented: "I used to feel discouraged about writing, but with ChatGPT's suggestions and encouragement, I am now more willing to express myself." These insights suggest that AI tools not only improve linguistic skills but also positively influence learners' psychological engagement and self-efficacy.

6.4 Teacher and Student Satisfaction

The survey data showed that teachers and students both recognized the distinct advantages of the three platforms. Le Chat was rated highest for cultural relevance and authenticity; ChatGPT was valued for the richness of its resources; and Kimi was appreciated for its clear Chinese–French explanations suited to local learners. Many students reported that "Le Chat made them feel that what they learned was truly connected to French society," while others referred to Kimi as a "starter's companion." Teachers acknowledged that AI-assisted teaching significantly reduced their preparation workload, though they emphasized the continued need for teacher-led lesson design and classroom control.

7 IMPLICATIONS

The findings of this study correspond with and extend existing domestic and international research. Smith (2023) demonstrated that ChatGPT effectively enhances vocabulary diversity and textual coherence in foreign language writing instruction. This is consistent with the significant improvement in writing scores observed among students in the experimental group of this study. Similarly, Dupont (2023) found that Le Chat played a unique role in improving students' cultural understanding in French universities, and the present study further supports this conclusion through questionnaire and interview evidence. Unlike previous studies that primarily focused on English or a single platform, this research conducted a cross-platform comparison among ChatGPT, Kimi, and Le Chat, thereby providing new empirical evidence for the application of generative AI across multiple languages and cultural contexts.

The study's findings also provide theoretical implications for second language acquisition (SLA). Results indicate that students using AI platforms achieved particularly notable improvements in both input and output abilities, aligning closely with Krashen's Input Hypothesis, Swain's Output Hypothesis, and Long's Interaction Hypothesis. Generative AI not only provides learners with controlled and level-appropriate comprehensible input but also creates opportunities for authentic communicative output and immediate feedback during interaction. This continuous "input–output–interaction" cycle fosters meaning negotiation and linguistic refinement, positioning AI as an active and multifaceted facilitator within the SLA process.

From a pedagogical perspective, the integration of generative AI introduces both opportunities and challenges for teachers and students. Teachers' roles are shifting from knowledge transmitters to learning facilitators and resource integrators. This transition requires educators to develop higher levels of digital literacy and instructional design competence to effectively employ AI as a supportive teaching tool. Meanwhile, AI offers students more personalized and flexible learning pathways but simultaneously places greater demands on their autonomy and critical thinking. Overreliance on AI-generated responses may hinder independent thought and creativity. Thus, achieving a balanced and ethical "human–AI collaboration" becomes a key concern for sustainable educational practice.

Notably, several institutions have already begun experimenting with such hybrid teaching models. At Sciences Po Paris, instructors have integrated Le Chat with traditional textbooks, resulting in higher student participation and improved comprehension of cultural context. Similarly, Harbin Institute of Technology in China introduced Kimi in second foreign language courses, where teachers observed more solid grammatical mastery but also noted cases of "translation dependence." In Bordeaux, a group of educators jointly released a teaching guideline emphasizing that "AI should serve human learning rather than replace it." These international practices collectively underscore that human–AI collaboration represents the central direction for the future of foreign language education.

Furthermore, this study highlights the need to address emerging challenges in the ethical and institutional dimensions of AI integration. Strengthening frameworks for academic integrity, data privacy, and educational equity is essential for the responsible use of AI in higher education. The observed cultural and linguistic differences among various platforms also suggest that blended or multi-platform approaches may offer the most comprehensive learning experience. By leveraging the complementary strengths of different AI systems, educators can provide students with more diverse, authentic, and culturally enriched opportunities for language learning.

Nevertheless, this research has certain limitations. The experimental sample size was relatively small and limited to a single institution, which restricts the generalizability of the findings. Additionally, the study duration covered only one semester, making it insufficient to assess the long-term impact of AI use on language acquisition. Subjective bias may also exist in questionnaire and interview responses. Future research should therefore expand the sample size, extend the observation period, and incorporate more diverse data collection methods to validate and refine the present findings. Despite these limitations, the results provide valuable insights for understanding the pedagogical potential and boundaries of generative AI in university-level French instruction.

8 CONCLUSION

Through empirical investigation, this study confirms that the application of generative artificial intelligence in university French teaching produces measurable and positive effects. However, several limitations must be acknowledged. First, the sample size was relatively small, encompassing only students from one university, which limits the generalizability of the results. Second, the research period was short, covering only one semester, making it difficult to assess the long-term effects of AI use on language acquisition. Third, questionnaire and interview data may carry subjective bias, as self-reported feedback cannot always reflect objective learning outcomes. These limitations indicate that future studies should adopt larger, longitudinal, and multi-institutional designs, incorporating diverse forms of data collection to validate and deepen the findings presented here.

The comparative analysis of the three platforms—ChatGPT, Kimi, and Le Chat—demonstrates that each possesses distinctive pedagogical advantages. ChatGPT performs best in generating learning resources and providing writing assistance; Kimi is most suitable for beginners, offering bilingual support and reducing cognitive barriers; and Le Chat excels in integrating authentic cultural and linguistic contexts. Despite these advantages, the implementation of generative AI in French teaching continues to face challenges at multiple levels, including technology, teacher readiness, learner autonomy, and educational ethics.

Future research and practice should explore multi-platform integration, intercultural competence development, and the establishment of ethical and regulatory frameworks for AI use in education. Generative artificial intelligence should not be regarded as a replacement for traditional teaching but rather as an extension and enhancement of it. Only through effective teacher guidance, pedagogical design, and institutional safeguards can AI's potential be fully realized to support intelligent, personalized, and internationalized French language education.

Ultimately, the integration of generative AI into higher education marks a transformative stage in foreign language pedagogy. By combining technological innovation with human-centered instruction, universities can foster a new model of language education that emphasizes efficiency, creativity, and cultural understanding. Such an approach will contribute to cultivating high-quality French language professionals equipped with global vision, intercultural communication competence, and innovative thinking—attributes essential for success in an increasingly interconnected world.

COMPETING INTERESTS

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INTERDISCIPLINARY INTEGRATION CULTIVATION MODE OF ENVIRONMENTAL DESIGN MAJOR IN THE CONTEXT OF RURAL REVITALIZATION

HaiYu Li[1], Dan Li[2], MoFei Chi[1*]
[1]Xi'an University of Architecture and Technology Huaqing College, Xi'an 710000, Shaanxi, China.
[2]Xi'an Institute of Archaeology, Xi'an 710000, Shaanxi, China.
Corresponding Author: MoFei Chi, Email: 735834806@qq.com

Abstract: Rural Revitalization is an important part of the national strategy in the new era. Environmental Design serves as the core technical support for improving rural living environments, reshaping industrial spaces, and passing down local culture. The quality of talent training directly affects the scientific nature and sustainability of rural construction. At present, there is a shortage of high-quality compound talents, and the single-discipline training model cannot handle the complex problems of rural areas. This has become a key bottleneck that limits industry services. This article is based on Complex Systems Theory and Constructivist Learning Theory. By analyzing the needs of Rural Revitalization and the existing shortcomings in training, it proposes a modular matrix cultivation mode of "problem-oriented, interdisciplinary core, multi-scene practice, and diverse evaluation". It focuses on key aspects such as training objectives, core competencies, curriculum system, teaching mode, and evaluation mechanism. It systematically explains the theoretical foundation, core structure, implementation path, and support mechanisms. The results show that this mode can effectively improve students' comprehensive ability to solve complex rural problems. It provides solutions and ideas for the transformation and upgrading of university Environmental Design majors. It helps cultivate compound innovative talents who "understand rural areas, know design, are good at coordination, can implement, and know operation". The innovation of this research lies in building a theoretical model for interdisciplinary integration cultivation of Environmental Design oriented to Rural Revitalization. It proposes an implementation path that combines a modular matrix curriculum system with progressive practical teaching. It emphasizes the construction of a school-local collaborative education community. It has strong theoretical value and practical guidance significance.
Keywords: Rural revitalization; Environmental design talent; Interdisciplinary cultivation; Modular matrix cultivation mode; Curriculum system; Core competencies; Practical teaching

1 INTRODUCTION

The deep and comprehensive promotion of the Rural Revitalization strategy has shaped the path of rural development in China. It puts forward diverse demands in areas such as improving rural living environments, reshaping industrial spaces, and creating cultural scenes. Environmental Design is the core technical support for shaping rural physical space forms and passing down regional cultural genes. The quality of its talent training directly relates to the effectiveness and sustainability of rural construction. The rural environmental system has compound attributes of nature, society, economy, and culture. It involves multiple dimensions such as ecological protection, cultural inheritance, industrial development, and social governance. Therefore, Environmental Design talents need not only solid professional design skills but also interdisciplinary knowledge perspectives, systems thinking abilities, and comprehensive practical abilities. However, current Environmental Design professional education in China shows significant mismatch: the knowledge structure is single and rigid, the curriculum system still focuses on traditional aesthetic training and space form design, and lacks systematic integration of related knowledge such as rural ecology, agricultural production, and local culture; there is a serious disconnect between theory and practice, teaching content is misaligned with real rural needs, and students often know design but not rural areas, can draw but hard to implement, and have weak overall design; interdisciplinary collaboration ability is weak, the training process is limited to a closed loop within design discipline, failing to effectively link key disciplines for rural development such as agronomy, ecology, and sociology, making it difficult for students to handle complex rural system problems.
Although domestic and international research has paid attention to the necessity of design education reform and interdisciplinary integration, there is still a significant gap in systematic and localized interdisciplinary integration cultivation mode research for the Rural Revitalization strategy. Existing explorations mostly stay at the macro-concept level or partial course adjustments, lacking systematic reconstruction of key aspects such as training objectives, core competencies, and curriculum systems. In the broad context of Rural Revitalization, Environmental Design practice research mostly focuses on specific projects or technical methods, with insufficient systematic research on education mode reform for talent support systems; Environmental Design education reform research involves concepts such as interdisciplinary integration and local service, but research specifically exploring interdisciplinary integration cultivation modes oriented to Rural Revitalization is rare and lacks operational plans. Developed countries have experience in community design and participatory design, but direct transplantation faces challenges from differences in

culture and social governance systems[1-3].

Therefore, building a new paradigm for interdisciplinary cultivation of Environmental Design talents that fits China's Rural Revitalization needs is not only the key to solving the current disconnect between design education and practice but also an inevitable requirement to serve major national strategic needs. This article stands on the complex needs of Rural Revitalization, systematically analyzes the ability demands and training shortcomings of Environmental Design talents, and explores the theoretical foundation, core structure, and implementation path of interdisciplinary integration cultivation mode. It provides systematic solutions and preliminary plans for the reform of Environmental Design professional education.

2 ABILITY DEMANDS AND CULTIVATION CHALLENGES FOR ENVIRONMENTAL DESIGN TALENTS DRIVEN BY RURAL REVITALIZATION

2.1 Deconstruction of Ability Demands Driven by the Five Major Tasks of Rural Revitalization

The five major tasks of the Rural Revitalization strategy—"thriving industries, livable ecology, civilized rural styles, effective governance, and affluent life"—form an organic whole. They put forward multi-dimensional and compound ability demands on Environmental Design talents[4]. Under the guidance of thriving industries, environmental designers need to have industrial space design and integration planning abilities. They should understand the laws of rural industry integration and turn the needs of industries such as agricultural production, agricultural product processing, and rural tourism into specific space carriers, such as agricultural landscape layout, characteristic homestay design, and rural tourism service point planning. Under the guidance of livable ecology, they need to master ecological priority design and comprehensive technical integration abilities suited to local conditions. They should use ecological principles to assess environmental carrying capacity, adopt local materials and ecological restoration technologies such as rainwater-flood management and biodiversity protection to create harmonious living environments, achieving unity between improving rural landscape styles and ensuring ecological functions. Under the guidance of civilized rural styles, they need to have cultural sensitivity and regional inheritance literacy. They should deeply explore regional genes such as traditional villages, ancient architecture, and folk customs, and use design methods such as protective renovation and cultural scene creation to revitalize the spiritual home of rural areas, avoiding homogenized designs of "one thousand villages with the same face". Under the guidance of effective governance, they need to have social collaboration and community participation abilities. They should shift from "top-down" design thinking to become collaborators and enablers in rural environmental governance, organize and guide villagers to participate in the design process, coordinate the demands of multiple interest parties, and promote co-building, co-governance, and sharing of rural environments. Under the guidance of affluent life, they need to have comprehensive benefit improvement and operation planning abilities. They should consider environmental benefits, social benefits, and economic benefits together, incorporate considerations such as cost control and industrial operation in design, and ensure the economic feasibility and sustainability of design plans.

2.2 Diagnosis of Shortcomings in the Current Environmental Design Professional Talent Cultivation Mode

Facing the complex demands of Rural Revitalization, the current Environmental Design professional talent cultivation mode has many structural shortcomings. First, the training objectives are vague in positioning, mostly following urban design standards and ignoring the local characteristics of rural areas, failing to clarify the differentiated training direction of "serving rural areas", leading to weak student cognition of rural social culture, ecological environment, and industrial laws. Second, the knowledge system is single and closed. Course settings focus on core design courses such as design principles, expression techniques, and space form design, lacking organic integration with key disciplines for rural development such as agricultural landscape and industrial layout in agronomy, environmental carrying capacity assessment in ecology, community creation in sociology, and industrial planning in economics. Students find it hard to form a knowledge framework for systematically solving complex rural problems. Third, teaching methods are disconnected from practice. Classroom teaching focuses on theoretical lectures and virtual topics, lacking long-term localized practice links. Students' cognition of rural areas stays at "superficial survey" level, failing to deeply understand the real needs of rural residents, leading to design plans that are "all talk no action" and hard to implement. Fourth, the faculty structure is single, with most teachers from design backgrounds, lacking interdisciplinary teaching abilities and rural practice experience, making it difficult to guide students in integrating multi-disciplinary knowledge to solve real problems. Fifth, the evaluation system is one-sided and rigid, focusing on aesthetic expression and drawing standards of design plans, ignoring the assessment of students' interdisciplinary knowledge integration abilities, problem-solving abilities, and other comprehensive competencies, unable to fully measure training quality. These shortcomings together lead to Environmental Design talents who cannot adapt to the actual needs of Rural Revitalization. When participating in rural construction projects, they often feel powerless due to limited knowledge structure and insufficient practice experience.

3 THEORETICAL FOUNDATION AND CONSTRUCTION IDEAS FOR THE INTERDISCIPLINARY INTEGRATION CULTIVATION MODE OF ENVIRONMENTAL DESIGN MAJOR

3.1 Theoretical Foundation

The construction of the interdisciplinary integration cultivation mode for Environmental Design major in the context of Rural Revitalization needs to rely on multi-disciplinary theoretical support to form a systematic theoretical framework. Complex Systems Theory views rural areas as dynamic composite systems where nature, society, economy, and culture interact. It emphasizes the connections and wholeness between systems, requiring the cultivation mode to break single-discipline thinking and guide students to analyze rural environmental problems from a systems perspective, forming holistic dynamic design thinking. Constructivist Learning Theory holds that knowledge is constructed by learners through active exploration and collaborative interaction in real contexts, rather than passive acceptance. This provides methodological guidance for interdisciplinary course design, that is, using real rural problem contexts to motivate students to autonomously integrate multi-disciplinary knowledge. Project-Based Learning (PBL) theory drives with real projects, guiding students to conduct interdisciplinary collaboration around problems, achieving knowledge integration and ability improvement in the process of solving problems, fitting the demand for practical talents in Rural Revitalization. Collaborative Education Theory emphasizes breaking barriers between disciplines, universities, and localities, integrating resources from government, universities, rural areas, enterprises, and others to form educational synergy. It provides theoretical basis for interdisciplinary faculty construction and practice platform building[5]. Local Knowledge Theory emphasizes respecting rural local wisdom and traditional experience, opposing "elite" design thinking. It requires the cultivation mode to incorporate rural surveys and villager interviews, guiding students to shift from "external designers" to "local learners", improving the suitability and locality of design plans.

3.2 Overall Construction Ideas

Based on the above theoretical foundation and analysis of Rural Revitalization needs, this research proposes the overall construction ideas for a modular and matrix cultivation mode of "problem-oriented, interdisciplinary core, multi-scene practice, and diverse evaluation"[6]. "Problem-oriented" starts from real environmental problems in Rural Revitalization practice, such as traditional village revitalization, ecological restoration, and community creation. It decomposes complex problems into specific topics, such as material selection in farmhouse renovation and villager demand coordination in public space design, guiding students to integrate multi-disciplinary knowledge with problems as clues. "Interdisciplinary core" is based on Environmental Design professional abilities, dynamically integrating core concepts and methods from related disciplines such as agronomy, ecology, sociology, and management to form an open multi-dimensional knowledge system. For example, in the topic of "rural ecological restoration design", it needs to integrate knowledge modules such as "biodiversity protection" in ecology, "local plant application" in agronomy, and "landscape creation" in Environmental Design. "Multi-scene practice" builds progressive practice scenes in classrooms, campuses, rural areas, enterprises, and others, strengthening students' immersive experience and localized learning through case studies, field investigations, village-based projects, and other links, gradually improving practice abilities from "cognition, skills, comprehensive". "Diverse evaluation" breaks the traditional single evaluation mode, building a comprehensive evaluation system with multi-party participation and multi-dimensional consideration of knowledge mastery, ability improvement, competency development, and social contribution, emphasizing the locality, feasibility, and social value of design plans. This idea organically integrates elements such as training objectives, core competencies, curriculum system, teaching mode, practice platform, and evaluation mechanism, forming a talent cultivation system with clear objectives, clear structure, and efficient operation[7].

4 CORE STRUCTURE AND IMPLEMENTATION PATH OF THE INTERDISCIPLINARY INTEGRATION TALENT CULTIVATION MODE FOR ENVIRONMENTAL DESIGN MAJOR

4.1 Core Structure

4.1.1 Training objective positioning

The interdisciplinary integration talent cultivation objective for Environmental Design major serving Rural Revitalization should focus on compound specialized talents who "understand rural areas, know design, are good at coordination, can implement, and know operation". Specifically, they master the basic theory and skills of Environmental Design profession, have systems thinking, interdisciplinary integration, and lifelong learning abilities, are familiar with rural social culture, ecological environment, and industrial development laws, and can independently engage in design, research, and management work in areas such as rural living environment improvement, cultural heritage protection, ecological restoration, and industrial space planning. This objective emphasizes not only professional abilities in Environmental Design but also differentiated competencies such as rural cognition, interdisciplinary collaboration, and practical implementation, forming a significant distinction from urban design talent cultivation.

4.1.2 Core competency system construction

Around the training objectives, build a system of six major core competencies. In terms of systems thinking and complex problem-solving competency, students are required to use systems theory methods to analyze the causes and connections of rural environmental problems, such as the impact of "industrial hollowing out" on village styles, and propose sustainable solutions that balance ecology, culture, and economy; cultural sensitivity and local inheritance competency emphasizes respecting rural cultural diversity, excavating local knowledge through field investigations and oral history records, and turning it into design language; ecological ethics and green design competency requires mastering ecological design principles, being familiar with local material characteristics and ecological restoration technologies, and avoiding "high-input, high-consumption" design plans; social collaboration and community participation competency cultivates students' organizational coordination abilities, enabling them to effectively guide villagers in participating in the design process and balance various interest demands; local technology application and practice innovation competency encourages students to integrate modern appropriate technologies such as low-cost energy-saving technologies on the basis of traditional crafts such as wooden structures and stone masonry, improving the operability of design plans; industrial integration and operation planning competency requires students to understand the logic of rural characteristic industries, incorporate industrial planning, cost control, and operation management considerations in design, ensuring the economic sustainability of design results.

4.1.3 Curriculum system reconstruction: modular matrix design

To adapt to the demand for compound Environmental Design talents in the Rural Revitalization strategy, this research breaks the shackles of traditional linear curriculum structure and builds a modular and matrix curriculum system of "professional foundation module + interdisciplinary crossover module + rural practice module + personalized development module". This system takes students' different grades and cultivation stages as the vertical axis, and the four major course modules as the horizontal axis. Through cross-penetration of module courses in each stage, it achieves spiral upward of knowledge and abilities. The professional foundation module focuses on three major directions: "rural living environment design", "rural cultural heritage and place creation", and "rural industrial space planning". They respectively integrate core knowledge such as space planning, local technology, microclimate design; cultural heritage protection, social design, community participation; and industrial planning, experience economy, sustainable tourism design, forming clear directional course clusters; the interdisciplinary crossover module relies on cross-college elective courses and workshops, adopting a mode of "thematic lectures + interdisciplinary workshops + case discussions". For example, the "rural community creation" workshop is co-taught by mentors from sociology, Environmental Design, and rural practice, guiding interdisciplinary collaboration; the rural practice module implements progressive teaching, with lower grades conducting rural cognition internships and traditional village surveys, middle grades doing environmental mapping and local material experiments, and higher grades participating in village-based projects and rural-themed graduation designs, supported by courses such as "Rural Environmental Design Practice" and "Rural Workshops"; the personalized development module sets elective courses in digital technologies and characteristic cultures such as rural digital twin design and intangible cultural heritage inheritance to meet personalized development needs.

Adopt diversified collaborative education teaching modes to promote integration of "teaching, learning, and doing". Project-Based Learning (PBL) uses real rural projects such as public space renovation in a certain village as carriers, organizing interdisciplinary learning groups including students from Environmental Design, ecology, sociology, and others. It simulates the full process from survey, planning, design, construction, to feedback. Teachers only act as guides, and students independently complete problem analysis, scheme design, multi-party coordination, and other links. Participatory workshop teaching invites villager representatives, rural craftsmen, government officials, enterprise mentors, and other parties around specific themes such as "village entrance square design" to conduct design co-creation through seminars, brainstorming, model building, and other ways, guiding students to understand diverse rural demands. The school-local dual-mentor system assigns each student a school professional mentor for theoretical and design method guidance and a rural practice mentor such as a senior rural designer for local knowledge and practical skill guidance. Dual mentors jointly participate in topic guidance and result evaluation. Case teaching and scenario simulation analyzes excellent rural design cases such as ancient village revitalization in Songyang, Zhejiang, and Echigo-Tsumari Art Triennale in Japan, combined with VR/AR virtual simulation technology to restore rural scenes, improving teaching intuitiveness. Flipped classroom and blended learning combine online resources such as rural survey databases and interdisciplinary MOOCs with offline interactions such as group discussions and design reviews, guiding students to learn theoretical knowledge autonomously before class, and focusing on problem-solving and ability improvement in class.

4.1.4 Practice platform construction and evaluation mechanism optimization

Build a "school-local collaborative education community" practice platform: cooperate with local governments to jointly build rural practice teaching bases, providing real project resources and localized practice scenes; set up rural design workstations/institutes as bases for teachers and students' village-based practice, result transformation, and long-term tracking services; integrate school resources to build interdisciplinary labs such as rural ecological design lab and local material research center, providing technical support; establish school-enterprise cooperation platforms with rural construction enterprises and cultural tourism companies, introducing real industry projects and mentor resources; use internet technology to build virtual learning communities, sharing rural survey data, design cases, interdisciplinary courses, and other resources to achieve remote collaboration and knowledge sharing[8]. In terms of evaluation mechanism, establish a multi-dimensional comprehensive evaluation system: diversified evaluation subjects, absorbing villager representatives, practice mentors, enterprise experts, etc., to participate, avoiding limitations of single teacher evaluation; multi-dimensional evaluation content, focusing on knowledge integration ability (interdisciplinary knowledge application), problem-solving ability (targetedness of design plans), competency development (cultural respect, social responsibility), and social contribution (villager satisfaction, project implementation effect); diversified evaluation methods, process evaluation through learning portfolios recording students' full-process growth trajectory from rural surveys, scheme conception, to result display, summative evaluation using design defenses, result exhibitions, village-based work reports, etc., and social value evaluation introducing quantitative indicators such as community satisfaction surveys and project economic benefit analysis; contextualized evaluation standards, emphasizing rural design characteristics such as locality (whether it fits rural culture), suitability (whether it matches rural economic level), and sustainability (whether it is easy for later maintenance), rather than pure aesthetic expression[9].

4.2 Implementation Path and Support Mechanisms

The implementation path adopts a "pilot first, gradual promotion" strategy. Select grades or classes with certain conditions for pilot operation, optimize the cultivation plan through student feedback, teacher discussions, and practice tests, and promote it to the whole college after maturity. Progressive cultivation in stages: lower grades (cognition and foundation stage) focus on professional foundation learning and rural cognition, initially establishing rural cognition framework through courses such as "Introduction to Rural Environmental Design" and "Traditional Village Survey"; middle grades (integration and skills stage) deeply learn interdisciplinary crossover module courses, conduct small and medium rural design topic practices such as farmhouse renovation design and village entrance landscape improvement, strengthening professional skills and interdisciplinary collaboration abilities; higher grades (comprehensive and innovation stage) participate in real rural construction projects such as village-based design and Rural Revitalization demonstration village planning, completing rural-themed graduation designs, achieving a "from theory to practice" closed loop. Projects drive courses, and courses serve projects, turning local government and enterprise Rural Revitalization projects such as "cultural-tourism integration space design" in a certain village into teaching content. Students work in groups to complete design plans and connect to actual construction, achieving "integration of teaching, learning, and doing".

Support mechanisms need multi-dimensional collaboration: in organizational support, establish a talent cultivation guidance committee composed of university leaders, department heads, interdisciplinary teachers, local government representatives, and enterprise mentors to coordinate cultivation plan formulation, resource integration, and quality monitoring; in faculty support, implement "school faculty interdisciplinary training plan" to send design teachers to agronomy, sociology, and other departments for further study, "external expert flexible introduction plan" to hire rural planners, ecologists, village cadres, etc., as part-time mentors, and regularly organize interdisciplinary teaching seminars and rural practice ability training; in resource integration support, break department barriers to achieve school resource sharing such as courses, labs, and research projects, seek local government policy support such as practice base construction subsidies and project docking priority, expand school-enterprise cooperation resources such as enterprise scholarships and internship positions, and set up special funds to support interdisciplinary course construction, rural practice subsidies, etc.; in institutional support, innovate interdisciplinary elective and credit recognition systems to allow students to take rural-related courses across departments and count them into total credits, establish teacher teaching reform reward mechanisms to include interdisciplinary teaching and rural practice guidance in assessment and excellence evaluation indicators, and student practice achievement incentive mechanisms to prioritize excellent rural design plans for competitions and docking implementation projects, and implement routine teaching quality monitoring to regularly assess cultivation effects and dynamically adjust plans through student feedback, peer review, and social evaluation.

5 CONCLUSION

The comprehensive promotion of the Rural Revitalization strategy puts forward compound demands on Environmental Design talents for "understand rural areas, know design, are good at coordination, can implement, and know operation". The current single-discipline cultivation mode cannot meet this demand. This article is based on Complex Systems Theory, Constructivist Learning Theory, and others, building a modular matrix cultivation mode of "problem-oriented, interdisciplinary core, multi-scene practice, and diverse evaluation". It systematically explains its theoretical foundation, core structure, implementation path, and support mechanisms. This mode clarifies the cultivation objectives serving Rural Revitalization, builds a system of six major core competencies, reconstructs modular matrix courses, innovates diversified collaborative teaching modes, builds school-local collaborative practice platforms, and optimizes multi-dimensional comprehensive evaluation mechanisms, forming a set of logical, specific, and operable interdisciplinary integration talent cultivation plan for Environmental Design major.

The innovative value of the research lies in: for the first time, systematically building a theoretical model for interdisciplinary integration cultivation of Environmental Design oriented to Rural Revitalization, breaking the limitations of traditional design education's "single-discipline closed loop"; proposing specific paths combining "modular matrix curriculum system" and "progressive practical teaching", solving the problem of how to systematically embed interdisciplinary knowledge into the cultivation process; emphasizing the construction of "school-local collaborative education community", promoting synergy among universities, governments, rural communities, and enterprises to form educational forces, improving the practical feasibility of the cultivation mode. The implementation of this mode helps improve students' comprehensive design abilities, systems thinking abilities, and practice innovation abilities to solve complex rural problems, providing systematic solutions for the transformation and upgrading of university Environmental Design majors, and injecting continuous intellectual support into the comprehensive promotion of the Rural Revitalization strategy.

Future research can further deepen the application of digital technologies such as rural environmental gene databases and digital twin design platforms in interdisciplinary cultivation to improve teaching intuitiveness and interactivity; explore adaptive promotion strategies for this mode in different types and levels of universities, forming differentiated implementation paths; conduct long-term tracking evaluations of the mode implementation effects such as graduate career development and rural project implementation effects, and continuously optimize the cultivation system; deepen the long-term mechanism for "university-rural" collaborative development, explore sustainable business models for design services in Rural Revitalization and talent return mechanisms, and promote the true formation of endogenous development power in rural areas.

COMPETING INTERESTS

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

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AI EMPOWERS COLLEGE STUDENTS' CAREER PLANNING EDUCATION: MODEL CONSTRUCTION, PRACTICAL DILEMMAS AND OPTIMIZATION PATHS

JunDi Chen
Nanning Normal University, Nanning 530001, Guangxi, China.
Corresponding Email: 18974389@qq.com

Abstract: On the one hand, the traditional education mode of career planning in colleges and universities faces the difficulties of outdated static, lack of individuality and disconnection from reality; On the other hand, with the rapid development of artificial intelligence technology, AI technology, with its unique advantages in data mining, intelligent analysis and personalized guidance, provides historic opportunities for the innovation of college students' career education. Therefore, this paper aims to systematically explore the innovative career planning education model of college students through AI empowerment, and analyze the main problems existing in the current career planning education in colleges and universities. On this basis, a new AI-empowered education model consisting of five modules: "accurate portrait, personalized planning, immersive experience, scientific decision-making, and dynamic adjustment of the whole process" is built. Then, it deeply analyzes the practical risks and challenges of this model in data leakage, algorithm bias, technology dependence, weakening of teachers' role, etc., and puts forward corresponding optimization paths, in order to provide theoretical reference and practical guidance for promoting the transformation of career planning education in colleges and universities to digital, intelligent, humanized and scientific directions.
Keywords: Artificial intelligence; Empowerment; Career planning education

1 INTRODUCTION

A career is a sequence of work experiences that maintains a person's development and continuity [1]. Career planning education for college students is an inevitable requirement to empower students' lifelong development and happiness, improve the quality of national higher education talent training and serve the national talent strategy. However, for a long time, the career education of college students in colleges and universities in China has mostly stayed at the traditional mode level of "centralized training, unified indoctrination and single form". This mode is a systematic and standardized framework, and it is difficult to cope with the rapid iteration of the professional world in the digital age. and the diversified needs of individual development. Its drawbacks are mainly as follows: it does not meet students' individual needs, is seriously out of touch with the changes of talent market demand, focuses on graduation job seeking results, rather than training students' long-term career adaptation and development, and lacks continuous attention to the whole process of students' university stage. At the same time, AI artificial intelligence technologies represented by big data, machine learning, natural language processing, computer vision, reinforcement learning, knowledge graphs, etc. have been deeply integrated into career planning education. The large AI model has created conditions for college students' career planning education that teaches students in accordance with their aptitude [2]. Through AI technology, it can accurately depict each student's "career portrait" and provide "one-on-one" accurate guidance for growth path guidance. Therefore, it is of great theoretical value and urgent practical significance to systematically study the innovative mode, practical dilemma and optimization path of AI-empowered career planning education in colleges and universities.

First, the main problems existing in current career planning education in colleges and universities

The "diseases" of the current career education system are mainly reflected in the following aspects:

(1) It can't meet the individual needs of students. Traditional career planning education for college students mainly relies on book knowledge transfer and face-to-face classroom teaching. The teaching form is relatively single [3], and the curriculum content and activity forms converge. However, each student's interests, abilities, values and family backgrounds vary widely, and counselors and career tutors cannot conduct in-depth "one-on-one" accurate analysis and guidance to hundreds of students.

(2) Knowledge is out of touch with the dynamic market. Due to the emergence of new occupations and the demise of old occupations, skill requirements are updated rapidly. Many career textbooks and curriculum contents in colleges and universities have remained unchanged for many years, and teachers' knowledge reserve lags far behind the market forefront. The information students get is often "past tense", and the old knowledge can no longer effectively guide their future-oriented decision-making.

(3) The professor's theory lacks practical test. At present, career education focuses too much on theoretical explanation, policy interpretation and skill teaching, which is "armchair strategist" and fails to achieve the effect of "unity of knowledge and action". Students lack real or simulated practical experience, which leads to their cognition of career staying on the surface. There is no opportunity for trial and error and correction, and it is difficult to form a profound

professional identity and feasible action plan.

(4) Career education lacks full-process attention. Career planning is a continuous and developing educational closed loop that runs through students' freshman year to senior year, involving professional study, second classroom practice and other links. As a matter of fact, some colleges and universities have compressed career education into "freshman education" in freshman and "employment guidance" in senior stage, showing the characteristics of "fragmentation" and "emergency", and lacking attention to college students for four years.

2 INNOVATIVE MODEL OF AI-EMPOWERED CAREER PLANNING EDUCATION

In view of the above-mentioned dilemmas in career planning education, AI technology can systematically build a new empowerment model from the following five dimensions.

2.1 Digital Intelligence Dimension-Big Data Empowers "Accurate Career Portrait"

Big data is the premise and foundation of AI empowerment. The AI system generates a dynamic personal portrait for each student by analyzing massive student evaluation data, professional learning and second classroom activity trajectories, interests and preferences, abilities and skills and other data. The AI system uses traditional career assessment tools such as MBTI personality test and Holland Career Interest Scale to calculate the "accurate portrait" of students' careers. For example, the system can more accurately infer students' potential areas of interest and generate reports by analyzing their course selection preferences, learning situation and second classroom activities on the MOOC platform. Finally, teachers in career education have also correspondingly transformed from being dominant figures into guides [4], teachers can provide personalized guidance, guide students to connect from vague self-knowledge to accurate career navigation, and realize the accurate matching of personal career planning and personal value.

2.2 Personalized Dimension-Personalized Career Planning Driven by Generative AI

This is the core of AI empowerment. On the basis of accurate "career portraits" and through large language models, generative AI can act as a "never-tired personalized career consultant" to provide students with personalized guidance. Students can have in-depth conversations with AI consultants through language instructions, asking questions such as "I am interested in chemistry and computers. What fields can I work?"In order to become a qualified physical education teacher, how should four years in college be planned?"And other questions. AI consultants can integrate massive career data, employment recruitment information, industry reports and curriculum resources to generate a fully personalized and phased "University Four-Year Career Development Action Plan" for students. The program not only includes course elective suggestions, skill learning paths, certificate acquisition plans, internship schedules, but also recommends relevant associations, competitions and tutor resources, so as to realize personalized and refined career planning guidance from "one person, one policy" [5].

2.3 Experiential Dimension-Virtual Technology Supports Immersive Professional Scene Experience

In order to solve the problem of disconnected practice in career planning education, virtual reality (VR), metaverse and other technologies are used to break the constraints of time, space and cost and reshape the highly simulated "career experience scene". Students can immersively play specific professional roles in a virtual professional scene to complete playing tasks. For example, law students can simulate the activities of judges and lawyers in moot courts;Normal students can simulate teachers in class. In this highly simulated and repeatable immersive experience environment, the AI simulation system can conduct dynamic evaluation and provide consultation based on the performance of the tester. Students participating in the experiment can gain practical experience by deeply tempering their skills and adaptability.

2.4 Decision-Making Dimension: Intelligent Information Provides Scientific Decision-Making for Career Planning and Prediction

AI can collect, analyze and summarize global recruitment information, industry trends, policies and regulations, and cutting-edge technology reports through natural language processing technology, forming a structured "job market knowledge map". When students want to inquire about a certain occupation, the system will extract the description information of the occupation from massive information according to the characteristics and needs of students, including traditional and future development forecast information. This enables students to borrow the inquired information to make more strategic and scientific career orientation and career position selection, and avoid "blind people touching elephants" decisions.

2.5 Dynamic Dimension-Data Tracking Provides Dynamic Adjustment Mechanism

AI empowerment breaks the static and one-time phased limitations of traditional career planning education. Through visual data methods such as words, tables and maps, the system continuously tracks students' ability growth, interest evolution and real-time changes in market positions, clearly shows students and tutors their growth and development trajectory and goal achievement degree, and forms a dynamically updated personal and professional double portrait, thus achieving dynamic adjustment and optimization, and forming a closed loop of continuous improvement of "perception-decision-feedback".

3 RISKS AND CHALLENGES FACED BY THE AI EMPOWERMENT MODEL

Technology-empowered career planning education is not omnipotent, and the hidden risks behind it must be highly valued and dealt with carefully.

3.1 There are Potential Security Risks in Data Information

Constructing "career portrait" involves a large number of students' personal sensitive and private data. Planning platforms and evaluation tools need to collect detailed personal data of users to make comprehensive predictions. This information often includes students' identity information, educational background, academic experience, social activities, skills, hobbies and personality characteristics. If these highly sensitive data are leaked, there may be serious threats such as fraud and identity theft, which will expose students' career core information to risks. Therefore, colleges and universities must establish a strict data confidentiality system and take security measures to maintain user data.

3.2 Excessive Technical Dependence Leads to the Lack of Humanistic Care

On the one hand, career planning relies too much on cold algorithms and data, which may lead to the "alienation" of education, reduce students to data tools, and weaken students' independent decision-making and creativity, critical thinking, courage to face complexity, empathy, leadership and other core competencies unique to human beings. On the other hand, AI cannot and should not replace teachers' functions of humanistic care full of temperature and wisdom inspiration full of life experience.

3.3 Algorithmic Bias Brings Fairness Crisis

AI models have problems with historical training and bias. All citizens have equal employment opportunities [6], if the training data itself contains gender, race, region and other biases inherent in human society, the AI system may replicate or even amplify these biases. For example, it thinks that boys prefer science and engineering occupations and girls prefer civilian occupations, which will virtually copy social stereotypes, thus recommending discriminatory career advice to students. Therefore, career planning education must introduce manual intervention and critical examination to ensure that technology serves the all-round and free development of people, and reduce or eliminate the unfairness caused by this prejudice.

3.4 Teachers have Ability Panic and Technical Anxiety

Under the AI empowerment model, AI may replace teachers or reduce the number of teachers needed, causing teachers to feel panic about their abilities and technical anxiety. It is necessary to conduct large-scale and effective training for existing teachers so that they can actively embrace IA technology, be good at collaborating with AI, achieve human-machine collaboration, and play a greater role in career planning education guidance.

4 OPTIMIZATION STRATEGY OF CAREER PLANNING EDUCATION PATH

In order to cope with the above risk challenges and promote the forward development of AI-empowered career education, efforts need to be made in the following aspects:

4.1 Build a Trinity Governance System of "Technology-System-Humanities"

Strengthen research and development in technology, provide a more scientific and intelligent system for career planning, enhance, optimize and reshape students' career development, and at the same time, better protect the security and privacy protection of data information in technology. In terms of system, establish and improve campus AI application ethical security review, data privacy protection, application specifications, intellectual property protection, literacy training system, etc., so as to achieve equal emphasis on promoting innovation and preventing risks. In terms of humanities, we always insist that technology is the skeleton and humanities are the soul, adhere to "student-centered", emphasize the tool attributes of AI, design must have temperature, application must have boundaries, and aim to cultivate students' autonomy and adaptability. It reflects that campus life is warmer, more inclusive, respects and supports each unique life individual of students, so that they can develop comprehensively and freely.

4.2 Promote the Two-Way Guidance Model of "Man-Machine Collaboration"

Clarify the boundaries of responsibilities between AI and teachers, and the two work together to educate people. AI is responsible for processing massive amounts of information, conducting preliminary screening, providing data analysis and making standardization recommendations;AI empowerment does not replace teachers. Teachers should be the conductors of the "human-machine collaboration" symphony. They can use the "computing power" and "information power" of AI to liberate themselves, focus on in-depth counseling, emotional support, value guidance and coping with complex cases, so that teachers can truly return to the role of "human soul engineers". Therefore, AI and teachers complement each other and can form a greater synergy.

4.3 Strengthen the Integration of Teacher and Student Training and Curriculum System

Provide systematic AI literacy training for career instructors to help teachers consciously accept the AI system, be good at using AI tools to improve work efficiency and quality, and better guide students to formulate career plans. At the same time, the AI career platform is deeply embedded in the educational administration system and courses, and students are taught IA principles and usage technologies through courses, so as to cultivate students' basic literacy and critical thinking, master AI usage skills for all students to keep up with the times, and help their own career development.

4.4 Promote Open Cooperation and Promote Inclusive Sharing of High-Quality Resources

Encourage the government, universities, enterprises and scientific research institutions to strengthen cooperation, build and share career databases and algorithm models, integrate and analyze open industry data, job requirements and college resources, generate dynamic career maps and skill reports, and present them fairly to all students. Reduce the development cost of individual schools and departments, thus breaking down information barriers. Different schools in different regions can take open classes and internship opportunities to share information. College students are individuals with self-awareness, and schools should promote and encourage personalized education [7]. With the continuous maturity of general artificial intelligence technology, future career education assistants provide students with personalized recommendation engines and personalized guidance for different students' needs. Finally, the AI-empowered education model promotes the sharing of high-quality resources, so that students can get personalized and high-quality career guidance and find a unique path to realize the value of life.

5 CONCLUSION

AI empowers college students' career planning education, which is a profound paradigm revolution. Through accurate portraits, personalized planning, immersive experience, scientific decision-making, and dynamic adjustment of the whole process, it effectively solves the shortcomings of the traditional model of "one size fits all", static, and fragmented. However, AI technology is a double-edged sword. While embracing the efficiency and accuracy brought by AI, we must be alert to its potential data risks, algorithm bias and lack of humanities. The ultimate goal of career counseling is consistent with the purpose of quality-oriented education, which is to achieve all-round development of individuals [8]. The future development direction of career planning education must be to build a new educational ecology based on the all-round development of people and "man-machine collaboration". Therefore, we must make full use of AI as a powerful weapon of the times and cultivate a new generation of young people who can control the future.

COMPETING INTERESTS

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

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