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THE OPTIMIZATION PATH OF HEALTH CARE VOCATIONAL EDUCATION UNDER THE COLLABORATIVE INNOVATION OF INDUSTRY, ACADEMIA AND RESEARCH

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Abstract: With the intensifying aging population in China, the demand for health care service professionals has surged, highlighting the significant gap between supply and demand. Vocational education is regarded as the primary channel for cultivating technical talents in the health care sector. However, challenges such as structural mismatches between education and industry needs, insufficient practical training, and low enterprise participation persist. This study takes Xinyang City in Henan Province as a case to explore the optimization path of health care vocational education through industry-academia-research collaborative innovation. The research integrates collaborative innovation theory and the German "dual system" vocational model as theoretical frameworks. It analyzes the local government's initiatives—such as the construction of the Leishan Jiangu vocational education park and industry-education integration platforms—and identifies key problems like weak coordination mechanisms, limited enterprise engagement, and insufficient “dual-qualified” teaching staff. Based on domestic and international best practices, the study proposes targeted strategies: strengthening collaborative governance mechanisms, enhancing enterprise participation, optimizing curricula and practical teaching systems, and improving policy support. These measures aim to align vocational education with health care industry demands, thus cultivating high-quality talents and supporting sustainable development in the context of population aging.
Keywords: Vocational education; Health care; Industry-Academia-Research collaboration; Aging population; Talent training; Xinyang

1 INTRODUCTION

The intensification of population aging has put forward urgent requirements for the supply of talents for health care (healthy elderly care) services. According to statistics, by the end of 2024, the number of elderly people aged 60 and above in my country has reached 310.31 million, accounting for 22.0% of the total population, of which 220.23 million are 65 years old and above, accounting for 15.6%. The elderly population is large and growing rapidly. It is estimated that around 2035, the proportion of the population over 60 years old will reach 30%, and the elderly population will exceed 400 million. Along with this, there is a surge in demand for health care services such as medical and nursing care, rehabilitation and nursing. However, there is currently a serious shortage of professional talents in the health care field. For example, according to a survey, my country's demand for elderly care workers is more than 6 million, but the actual number of practitioners is only about 500,000, and the talent gap is significant. This contradiction between supply and demand directly affects the quality of elderly care services and medical and health security, and has become a livelihood issue that needs to be solved urgently.

Vocational education is regarded as the main channel for cultivating technical and skilled talents in health care services. However, for a long time [1], there has been a structural and quality mismatch between the education supply side and the industry demand side. The talents cultivated by vocational colleges are difficult to fully meet the actual needs of the industry, and a "two-faced" phenomenon has emerged. In order to solve the structural contradiction between talent supply and demand, the government attach great importance to deepening the integration of industry and education and school-enterprise cooperation, and have elevated it to a national strategy. The "National Vocational Education Reform Implementation Plan" (2019) and the newly revised "Vocational Education Law" (2022) and other policies clearly require the improvement of the modern vocational education system integrating industry and education, encourage enterprises to deeply participate in collaborative education, and encourage enterprises to run schools through tax and fee concessions [2]. Especially in the field of health care, the Ministry of Education, the National Health Commission and other departments will deploy in 2025 to accelerate the training of medical and nursing talents, promote vocational colleges to set up undergraduate majors in health care services, require at least 50% of the courses to be practical training, and encourage in-depth cooperation between schools and enterprises to carry out teaching in conjunction with nursing homes and hospitals. These measures show that taking industry-university-research collaborative innovation as a starting point to promote the organic connection between the vocational education chain and the health care industry chain has become the only way to improve the quality of health care talent training and cope with the challenges of aging.

This paper takes Xinyang City, Henan Province as a case study, focusing on the optimization path of health care vocational education under the background of collaborative innovation among industries, schools and scientific research.

Xinyang City is a populous city with an aging rate higher than the national average. In 2020, the population aged 60 and above accounted for 19.27%. By the end of 2023, the number of people aged 65 and above will exceed 1.015 million [3], accounting for about 16.8% of the permanent population. The local health care industry has an urgent need for development, but there are still shortcomings in the supply of vocational education, such as insufficient layout of nursing-related majors and weak practical teaching. In recent years, Xinyang City has attached great importance to vocational education reform, and has taken industry-education integration as an important breakthrough in the development of vocational education. It has invested in the construction of the "Leishan Jiangu" industry-education integration vocational education park, and plans to integrate health care vacation bases and research bases into it, promoting the coordinated development of "health care + research + tourism". Xinyang Vocational and Technical College and other colleges and universities are also actively exploring school-enterprise cooperation models, such as co-building industrial colleges with nursing institutions and implementing the "1+1+1" talent training model, which has significantly improved the practical ability of graduates [4]. In this context, it is of great theoretical value and practical significance to study how to further optimize the path of health-care vocational education through collaborative innovation between industry, academia and research.

2 LITERATURE REVIEW

Current status of research on industry-education integration and health-care vocational education: Domestic scholars have discussed the issue of industry-education integration in vocational education. Chen Nianyou and other scholars pointed out that industry-education integration is a deep cooperation between vocational education and industry, and its essence lies in the collaborative education of vocational colleges and industry enterprises to improve the quality of talent training. Industry-education integration is regarded as a fundamental way to solve the contradiction between the supply side of talents and the demand side of industries, which is conducive to improving the adaptability of vocational education. In recent years, research has focused on the institutional mechanism, operation mode and policy effect of industry-education integration. For example, some studies have sorted out the evolution of China's industry-education integration policy and believed that it is necessary to improve the long-term mechanism of school-enterprise cooperation and eliminate the interest barriers between schools and enterprises. In the field of health-care vocational education, with the implementation of the "Healthy China" strategy, relevant research has gradually increased. Wang Hui and others analyzed the strategic opportunities and problems faced by the training of health-care tourism talents in higher vocational colleges, and proposed to seize the window period of rapid development of the health-care industry to improve the talent training plan. Ke Jie and others focused on the current status of health care professional construction in Hainan, pointing out that the current level is mainly junior colleges [5], and the undergraduate level is in urgent need of development, and the quality of technical and skilled personnel training needs to be improved in the integration of industry, academia and research. Lin Yuting and others conducted a special study on the integration of industry, academia and research in Hainan's health care vocational education, sorted out the problems of disconnection between education and industry needs, insufficient enterprise participation, and lack of practical training resources, and proposed strategies such as strengthening school-enterprise cooperation, optimizing curriculum settings, and promoting scientific research transformation. Overall, domestic literature emphasizes that deepening the integration of industry and education is the key to improving the quality of health care vocational education, and health care talents that meet industry needs should be cultivated through collaborative innovation mechanisms.

Research on collaborative innovation and dual system model: "Industry-university-research collaborative innovation" as an advanced form of industry-education integration has also attracted attention. Wang Haijun and others explained in journals such as technology and economy that collaborative innovation emphasizes the complementary advantages and resource sharing of innovation subjects such as universities, scientific research institutions, and enterprises, and build an interest-aligned partnership to jointly carry out innovation activities. This concept originates from the "Triple Helix" theory. Etzkowitz and Leydesdorff proposed that the collaborative interaction of universities, industries, and governments can generate continuous innovation momentum [6]. Research on vocational education from the perspective of collaborative innovation shows that school-enterprise-research collaboration can accelerate the transformation of scientific and technological achievements into teaching content and enhance the ability of vocational education to serve industrial development. Abroad, Germany's "dual system" vocational education model has been widely studied for its successful experience. The "dual system" refers to the combination of practical training in enterprises and theoretical learning in schools, and is jointly cultivated by enterprises and vocational schools. It is a highly effective model for cultivating skilled talents. Research points out that Germany has about 350 nationally recognized occupational standards, which are jointly formulated and implemented by the government and industry in accordance with the law to ensure that the training standards are consistent with job requirements. As the main body of training, enterprises bear about 2/3 of the training costs (equivalent to 15,300 euros per student per year) and regard the training of apprentices as the best way to obtain skilled workers. Apprentices acquire skills and socialization abilities that meet market needs by learning in real scenarios, thereby greatly improving their employment competitiveness. This model has been successfully operated for a long time and is considered an important factor in maintaining the competitiveness of Germany's manufacturing industry. Some domestic scholars have summarized the inspiration of the "dual system" for my country's vocational education in the following aspects: strengthening the training model of combining work and study, improving legal protection, increasing the enthusiasm of enterprises to participate, and changing social concepts. In summary, Chinese and foreign literature provides reference for this study: deepening the collaborative innovation of industry, academia and research is the general trend, and typical model experience (such as Guiyang Health Vocational College and Germany's dual system) can provide useful ideas for the reform of health vocational education.

3 THEORETICAL BASIS

This study is based on the collaborative innovation theory and school-enterprise cooperation theory. First, the collaborative innovation theory of industry, academia and research explains the internal mechanism of collaborative education of multiple subjects. The collaborative innovation theory believes that different subjects can form an innovative force of "1+1>2" through resource sharing and complementary advantages [7]. Specifically, in the cooperation between industry, academia and research, enterprises, universities and scientific research institutions establish a collaborative partnership based on aligned interests, and carry out innovation activities in accordance with the principle of "cooperative research and development, sharing of results, and sharing of risks" to achieve technological breakthroughs and joint training of talents. This theory emphasizes the importance of interest ties and goal orientation, and provides guidance for building a long-term cooperation mechanism between schools, enterprises and research institutes in the field of vocational education. Secondly, school-enterprise cooperation and dual education theory are important supporting theories for vocational education. Modern vocational education theory emphasizes experiential learning and work process orientation, requiring teaching content to connect with actual positions to achieve alternating integration of learning and work. The German "dual system" model is based on this theory, which gives equal weight to school education and enterprise training. On the one hand, schools provide systematic knowledge and basic skills training [8]; on the other hand, enterprises provide practical training in real situations, and the two complement each other. The dual education theory emphasizes legal and institutional guarantees, and ensures the stable operation of cooperation by clarifying the responsibilities and interests of all parties. In the context of my country, the new "Vocational Education Law" clearly states that vocational colleges should focus on the integration of production and education, school-enterprise cooperation, and provide incentives for enterprises that are deeply involved. This provides a legal basis for the implementation of "dual" education at the practical level. In short, the collaborative innovation theory and the dual education concept together constitute the theoretical framework for analyzing the problem in this article: the former focuses on the macro multi-subject collaborative mechanism, and the latter focuses on the micro talent training model. The combination of the two is helpful to explore the optimization path of health care vocational education from the two levels of institutional mechanisms and practical paths.

4 ANALYSIS OF THE CURRENT SITUATION OF PRACTICE IN XINYANG CITY

Xinyang City is located in the southern part of Henan Province. It is a populous city and an old district. The aging situation is severe. The data of the seventh census shows that in 2020, the proportion of people over 65 years old in Xinyang is 15.20%, which is higher than the national average; by the end of 2023, the number of people over 65 years old in the city will exceed 1.015 million, accounting for 16.8% of the permanent population. At the same time, Xinyang's health care industry has a certain foundation. Xinyang is famous for its ecological livability, has good traditional Chinese medicine and hot spring health care resources, and is building a health care industry cluster featuring elderly care, health preservation, and rehabilitation nursing. However, there is a shortage of local health care service professionals, and grassroots medical and elderly care institutions are facing a "labor shortage", while many graduates from vocational colleges have difficulty finding jobs, which reflects the mismatch between talent training and industrial needs.

The Xinyang Municipal Municipal Government attach great importance to the connection between vocational education and industrial needs, and regard "grasping vocational education is grasping development and people's livelihood" as a consensus. In recent years, a series of policy documents have been issued to increase financial investment and promote the reform of vocational education integration. The municipal government has listed the construction of "Xinyang Vocational Education New City (Leishan Jiangu)" as a key project, integrating land and financial resources to create a highland for industry-education integration. Leishan Jiangu Industry-Education Integration Vocational Education Park takes the integrated development of "health care + research and study + tourism" as its concept, plans to build a health care resort base, a research and study practice base, etc., and integrates health care industry elements into the vocational education park, aiming to achieve the simultaneous layout of the education chain and the health care industry chain. In addition, Xinyang is actively striving to become a national pilot city for industry-education integration. In March 2024, it established the "Xinyang High-tech Zone Municipal Industry-Education Consortium", which will work together with the government, schools, industries, and enterprises to establish professional committees such as industrial development, school-enterprise cooperation, and technological innovation to explore the closed-loop mechanism of "demand co-research - resource co-construction - results sharing".

Local vocational colleges represented by Xinyang Vocational and Technical College have made useful explorations in the training of medical and health care talents in recent years. Vocational schools closely connect with the needs of local health care industry upgrades and dynamically adjust their professional structures. In the past three years, new health-related majors such as elderly care and management, medicinal diet therapy, etc. have been established, and some redundant old majors have been eliminated, so that the matching degree between majors and regional industries has reached 92%. The school has also been recognized as the first batch of Henan Province's healthy elderly care education and training bases and elderly care service talent training bases, and undertakes the provincial civil affairs industry elderly care skills competition and other tasks, and the status of the regional health care talent training center has been gradually established. The school actively expands cooperation with health care institutions. For example, it co-established the "Health Care Industry College" with Xinyang Shengde Nursing Center and implemented the "1+1+1" talent training model, that is, one year of on-campus learning, one year of corporate internship, and one year of post-job training, focusing on the integration of theory and practice. This model allows students to hone their skills in the real environment of nursing institutions, greatly improving the practical ability and employment willingness of graduates, and more and more graduates stay in the local elderly care service industry for development. For example, the school, the Municipal People's Hospital and the Shanghai Jiaotong University School of Medicine team jointly established the "Dabie Mountain Aging Research Institute" to explore the "industry-university-research-medicine" collaborative innovation model, carry out geriatric medicine and health care service research, and provide the latest scientific research support for teaching. This is a beneficial attempt by universities, hospitals and scientific research institutions to jointly educate people.

At present, Xinyang Vocational College has established cooperative relations with more than 290 enterprises, of which 251 are listed as off-campus internship bases, and 35 industry-education integration training bases have been built to achieve full coverage of professional cooperation such as health care. The school and enterprises have jointly developed 47 courses, compiled 14 textbooks, sent thousands of teachers to each other for training, and promoted training forms such as order classes and named classes, initially forming a virtuous cycle of "enrollment is recruitment, admission to school is admission to the enterprise, and graduation is employment". For example, in cooperation with a nursing enterprise, a "customized class" was opened, and students signed contracts to become prospective employees while in school. The course content was customized according to job requirements, and they could start work after graduation, which greatly improved the fit between talent training and job requirements. These measures have significantly improved the quality and quantity of Xinyang's health care talent training. Overall, Xinyang City has made positive progress in policy guarantees, school-enterprise cooperation platforms, and industrial college construction, but there is still room for expansion in deepening collaborative innovation and improving the level of talent training.

5 EXISTING PROBLEMS

Although Xinyang City has achieved certain results in the integration of industry, academia and research in health and wellness vocational education, there are still many shortcomings and challenges. These problems are universal to a certain extent, which restricts the improvement of the quality of health and wellness talent training and needs to be analyzed in depth:

The system and mechanism are not sound, and the synergy is insufficient. At present, the cooperation between schools, enterprises and research is mostly carried out in the form of projects or agreements, lacking a stable and long-term synergy mechanism. Schools and enterprises often operate independently, and due to the absence of effective mechanisms for interest and risk sharing, it remains difficult to establish a stable and long-term cooperation framework. For example, some cooperation remains at the level of short-term internship bases or order classes, lacking in-depth equity cooperation or joint school-running mechanisms. Once the external environment changes, the cooperative relationship is prone to loosening. In addition, there is a lack of a platform for overall coordination among multiple subjects, and it is difficult to efficiently integrate resources between governments, colleges and universities, industry organizations, and scientific research institutions, and the synergy of collaborative innovation has not yet been fully stimulated.

The degree of enterprise participation is not high, and the connection between schools and enterprises is not tight. Although the government has introduced incentive policies for industry-education integration enterprises, it has limited appeal to local small and medium-sized health and wellness enterprises. Some health care enterprises are not very enthusiastic about participating in vocational education, believing that the investment is slow to take effect and the cost is high, so they lack motivation. This has led to the fact that school-enterprise cooperation is mainly concentrated in a few demonstration enterprises, with a narrow coverage. The boundaries of rights and responsibilities between enterprises and schools in talent training are not clear enough. Enterprises play more of a role of "cooperating to provide internship places" and are not deeply involved in the teaching process. In Xinyang, there are limited large-scale health care institutions in the local area. Enterprises participate in school-running mainly to provide training bases. There are no cases of enterprises investing in co-building vocational colleges or leading professional construction, and a stable, deeply integrated partnership between schools and enterprises has not yet been fully established.

The connection between majors and needs is not tight, and the course content and practical teaching need to be optimized. On the one hand, the setting and level of health care majors need to be improved. At present, most health care-related majors in Xinyang are set up at the higher vocational and secondary vocational levels, and undergraduate talent training has not yet been carried out, which is insufficient in meeting the needs of high-end positions in the health care industry. On the other hand, the curriculum system is not closely connected with the cutting-edge needs of the industry. Some college courses still focus on theoretical teaching, and the content of courses such as elderly care and new Chinese medicine rehabilitation is updated slowly, and the latest technologies and specifications have not been absorbed in a timely manner. For example, emerging cross-cutting contents such as smart elderly care and rehabilitation engineering are not covered enough in the curriculum. The more prominent problem is the weak practical teaching. Although some internship bases have been established, due to the limitations of venues, equipment and management, students' practical opportunities and practice time are still insufficient, making it difficult to truly achieve the purpose of training skills. Some practical trainings are reduced to simulation exercises and are out of touch with real nursing situations. The practical teaching guidance force is also insufficient. The number of corporate mentors is limited and it is difficult to invest energy in the long term, which affects the effectiveness of practical teaching.

"Dual-qualified" teachers and scientific research support are relatively weak. Health and wellness vocational education requires a "dual-qualified" team of teachers who understand professional theories and have practical experience. However, in reality, such teachers are scarce: medical nursing teachers mostly come from academic colleges and lack front-line elderly care experience; and part-time teachers with industry backgrounds often lack teaching ability and find it difficult to systematically undertake courses. The mechanism for full-time teachers to go deep into enterprises for training is not sound, and the improvement of practical ability is limited. In addition, vocational colleges have weak scientific research capabilities and it is difficult to transform scientific research results into teaching content. At present, the cooperation between industry, academia and research institutes is mostly at the level of employment and training. There are not many R&D platforms jointly built by schools and enterprises, and the channels for teachers and students to participate in enterprise technological innovation are limited. This makes it difficult to integrate new technologies and processes into the teaching content in a timely manner, and talent training cannot fully meet the needs of industrial upgrading.

Talent training level and regional talent retention problem. The health care industry needs not only a large number of front-line nursing staff, but also high-level compound talents such as medical, management, and social workers. At present, Xinyang vocational colleges are mainly at the junior college level, and there is a lack of talent training at the undergraduate level and above. The "ceiling" of health care talents in the region is relatively low, and high-end talents mostly flow to developed areas. There is also a phenomenon of loss of local outstanding graduates, and they are not willing to stay in grassroots nursing institutions for development. This is related to salary and benefits, and also reflects that the local health care career development channel is not smooth, the talent promotion space is limited, and it is impossible to attract and retain high-quality talents, thus forming a vicious cycle of "talent outflow and job vacancies".

6 COUNTERMEASURES AND SUGGESTIONS

Focusing on the above-mentioned problems, this study proposes the following path suggestions for optimizing health care vocational education:

(1) Improve the industry-university-research collaboration mechanism and establish a stable and long-term cooperation framework.Strengthen top-level design to promote effective alignment between colleges, enterprises, and research institutions. It is recommended that the government take the lead in forming an industry-university-research collaboration council or alliance, responsible for drafting a long-term cooperation charter to guide joint actions. Joint projects should be established in key areas such as talent cultivation and technological innovation, enabling all parties to share the outcomes and jointly bear the investment risks.For instance, the "school-enterprise joint venture" model may be explored, in which enterprises contribute capital and equipment while schools provide venues and teaching staff, with resource allocation and benefit-sharing mechanisms linked to the operational performance of the institution. This model fosters an interest-aligned and mutually supportive partnership between schools and enterprises.In addition, collaborative innovation platforms—such as health and wellness technology research centers and skill master studios—should be established. Regular coordination meetings can be held to align talent training objectives with industry development needs. Through institutionalized mechanisms, sustained and effective multi-stakeholder collaboration can be achieved.

(2) Strengthen the role of enterprises as the main body and encourage in-depth participation in school-enterprise cooperation. Actively implement the recognition and preferential policies for enterprises integrating industry and education, and give priority to enterprises participating in school operation in terms of tax reduction and exemption, financial subsidies, and financial credit. Establish evaluation indicators for enterprise participation in vocational education, and include the number of practical training positions provided by enterprises, the number of times they participate in course development, and the number of graduates received in the evaluation of corporate social responsibility to enhance the enthusiasm of enterprise participation. Encourage large-scale health care institutions to organize or participate in the organization of vocational schools, such as establishing health care vocational training centers, senior citizen universities, or cooperating with universities to set up "enterprise order classes", and enterprises will participate in the whole process of enrollment, teaching and assessment. Promote the training model of "enrollment is recruitment, and admission to school is admission to enterprise". Give priority support to deep cooperation enterprises in terms of land use, credit, etc., to form a win-win situation of "enterprises get talents, schools get resources, and students get skills".

(3) Optimize the professional and curriculum settings and enhance the adaptability of talent training. Adjust the professional layout according to the development trend of the health care industry, actively develop health care service vocational undergraduate education on the basis of higher vocational education, and cultivate high-level skilled talents in management, rehabilitation, and nursing. Establish a dynamically updated curriculum system and closely follow the new standards and technologies in cutting-edge fields such as medical and nursing integration and smart health care. Invite industry experts and excellent front-line nurses to participate in the compilation of textbooks and the formulation of curriculum standards to ensure that the teaching content keeps up with actual needs. Promote modular curriculum reform, decompose job skills into learning modules, and facilitate students' personalized improvement. Increase the

proportion of practical courses and strictly implement the requirement of no less than 50% of practical teaching hours. Expand the practical training conditions inside and outside the school, build a nursing practice center and rehabilitation training room with real-life simulation, and regularly update the equipment to be close to the clinical and nursing sites. Implement the work-study alternation training system, such as setting up a concentrated practice semester every academic year, so that students can stay in hospitals and nursing institutions for long-term internships and improve their skills in a real environment. Through the dual optimization of courses and practical links, the ability and quality of graduates will be more in line with the requirements of health care positions.

(4) Strengthen the construction of a "dual-qualified" teaching staff and improve the ability to integrate teaching and practice. Implement special plans to build a team of teachers with both theoretical level and practical experience. First, promote the teacher enterprise practice system, and stipulate that teachers of health care majors in vocational colleges must have a certain amount of time to work or practice in hospitals and nursing homes every 2-3 years to update their industry experience. Give teachers treatment guarantees and subsidies during their enterprise practice to relieve their worries. Secondly, recruit professional talents with rich experience in health care practice from the society as full-time and part-time teachers, especially introducing industry masters and inheritors of intangible cultural heritage medicine in the fields of nursing, rehabilitation, and traditional Chinese medicine. Schools can set up "industry professor" positions or studios, flexibly introduce hospital head nurses, rehabilitation therapists, etc. as mentors, undertake practical training guidance and course teaching. Secondly, schools and enterprises jointly build teacher training bases, regularly hold training courses on new knowledge and new technologies in health care, and improve the professional level of teachers. Schools and enterprise masters establish a "dual mentor system", teachers learn practical skills from enterprise mentors, and enterprise masters learn teaching methods from teachers, so as to achieve mutual employment and mutual training. Through these measures, teachers can understand both educational laws and industry practices, so as to better guide students in teaching.

(5) Improve policy support and guarantees to create a good development environment. Government departments should introduce supporting policies to provide support for the integration of industry, academia and research in health care vocational education. First, funding guarantee: set up special funds to support vocational colleges and health care enterprises and institutions to jointly build training bases, research and development centers, etc., and provide financial support for the development of industry-university-research collaborative projects. Second, talent policy: give preference to the employment of graduates from health care vocational colleges, such as grassroots employment subsidies and career development promotion channels, to attract more outstanding talents to engage in elderly care services. Public institutions are encouraged to recruit graduates of health care majors with advanced skills certificates to enhance their career attractiveness. Third, evaluation and incentives: The results of industry-education integration will be included in the quality assessment indicators of vocational colleges, and colleges with remarkable results will be commended and given additional resources. A benchmark demonstration mechanism will be established to select outstanding industry-education integration cooperation projects, outstanding teachers and corporate mentors, and create an atmosphere of support for industry-university-research integration in the whole society. Fourth, legal guarantees: Accelerate local legislation, such as formulating the "Regulations on Promoting Industry-Education Integration in Xinyang City", clarifying the rights and responsibilities and incentives of each subject, and guaranteeing the implementation of the collaborative education mechanism from a legal perspective. Through policy synergy, escort the reform of health care vocational education.

In summary, optimizing health care vocational education requires multiple measures. Only by improving the collaborative mechanism, stimulating corporate motivation, connecting with the industry to optimize teaching, building a dual-teacher team and improving policy guarantees can a strong synergy of industry-university-research collaborative innovation be formed, the quality of talent training can be continuously improved, and the talent needs for high-quality development of the health care industry can be met.

7 CONCLUSION

In the era of collaborative innovation between industry, academia and research, health and wellness vocational education has ushered in an opportunity period and a challenge period for quality development. Taking Xinyang City as an example, this paper finds through empirical analysis that the local area has made certain progress in promoting industry-education integration and school-enterprise cooperation, such as building a health and wellness industry-education park, co-building an industrial college, and carrying out medical-education collaboration. However, there are still prominent problems such as an imperfect coordination mechanism, weak enterprise participation, and misalignment between teaching supply and industry demand. These problems are common across the country and restrict the quality and scale of health and wellness skilled talent training.

In order to solve the above problems, this paper draws on the typical experience of Guiyang Health and Wellness Vocational University and the German dual system model. The case of Guiyang Health and Wellness Vocational University shows that vocational colleges must adhere to the characteristics of running schools and deepen the integration of industry and education in order to cultivate high-quality technical and skilled talents in order to connect with the emerging health and wellness industry. Its innovative measures such as the "Four Hundred Projects" and "Three Integrations and Four Chains" are worth learning. The German dual system emphasizes the deep collaboration between schools and enterprises and the combination of work and study under legal protection, providing us with a mature paradigm. Based on comprehensive analysis, this paper proposes optimization path suggestions from the aspects of collaborative mechanism construction, enterprise main role, curriculum practice reform, teacher team construction and policy support, striving to be targeted and operational.

Strengthening the collaborative innovation of industry, academia and research is of great significance to the high-quality development of health care vocational education. On the one hand, it will effectively bridge the gap between education supply and industry demand, cultivate sufficient, well-structured and high-quality health care service talents, and alleviate the current talent shortage dilemma under the background of aging. On the other hand, it will help promote the transformation and upgrading of vocational education itself, improve the school-running level and social service capabilities through collaborative innovation, and achieve a benign interaction and win-win development between vocational education and health care industry. Especially for old areas like Xinyang, the collaborative innovation health care vocational education model can not only serve the local people's livelihood, but also cultivate new growth points for the regional economy.

It should be pointed out that the collaborative innovation of industry, academia and research is a systematic project, involving changes in policies, concepts and systems, and it cannot be achieved overnight. In practice, it should be carried out step by step according to local realities, and experience should be summarized and strategies adjusted in a timely manner. For example, we should first establish several pilot school-enterprise-research alliances, and gradually promote them through pilot projects; we should focus on cultivating typical examples and give play to the benchmark effect. In the process of promotion, the government, colleges, enterprises, and scientific research institutions should update their concepts and work closely together to truly form a joint force for collaborative education. Only in this way can we explore a path to optimize health and wellness vocational education with local characteristics.

In short, under the background of population aging and the Healthy China strategy, health and wellness vocational education has great potential. Through collaborative innovation between industry, academia, and research, we are expected to build a new ecology of vocational education with deep integration of industry and education, continuously improve the fit between talent training and industrial development, and provide a steady stream of high-quality skilled talents for the elderly cause and health and wellness industry. This is not only the due meaning of vocational education serving national strategies and local development, but also the only way to achieve its own high-quality development. The practice and exploration of Xinyang City provide us with a vivid example. Looking to the future, with the improvement of relevant policies and the deepening of efforts of all parties, collaborative innovation between industry, academia, and research will surely promote health and wellness vocational education to a new level on a larger scale and at a higher level, and achieve the goal of high-quality development. The health care talent training system established on this basis will provide solid talent guarantee and intellectual support for actively responding to the challenges of aging and improving people's health and well-being.

COMPETING INTERESTS

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

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MULTI-DIMENSIONAL EVALUATION FRAMEWORK FOR TEACHING QUALITY IN MANAGEMENT-ENGINEERING INTERDISCIPLINARY PROGRAMS UNDER THE 'DOUBLE NEW' INITIATIVE

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Abstract: Against the backdrop of the 'New Engineering + New Liberal Arts' initiative, universities are placing increasing emphasis on cultivating interdisciplinary talents. In this context, the construction of a robust teaching quality evaluation system for interdisciplinary programs integrating management and engineering has become particularly crucial. This study analyzes the current challenges in the evaluation of such programs, including limited diversity of evaluation subjects and methods, incomplete indicator systems, and weak mechanisms for feedback and improvement. To address these issues, a framework for a multi-dimensional, improvement-oriented evaluation system with broad stakeholder participation is proposed. The framework emphasizes the involvement of multiple stakeholders, the development of a comprehensive indicator system that reflects the characteristics of management–engineering integration, and the enhancement of scientific rigor and inclusiveness in evaluation. Moreover, the study focuses on optimizing the operational mechanism by standardizing procedures and strengthening data management. By establishing a systematic feedback loop and a process of continuous improvement, the framework enables closed-loop management of teaching quality and dynamic optimization of program development. This research provides a theoretical foundation and practical reference for building a scientific, reasonable, and highly operable teaching quality evaluation system.
Keywords: New Engineering; New Liberal Arts; Management–engineering Interdisciplinary programs; Teaching quality; Evaluation system

1 INTRODUCTION

The Ministry of Education of China, in its Opinions on Deepening Undergraduate Education and Teaching Reform to Fully Enhance the Quality of Talent Cultivation, emphasizes the need to improve the internal teaching quality evaluation systems in universities and to establish a full-process, multi-dimensional evaluation and assurance system for higher education quality [1]. Under the construction of the 'Double New' initiative—namely, New Engineering and New Liberal Arts—interdisciplinary talent cultivation has become a major trend in higher education. A growing number of interdisciplinary programs have emerged, among which management–engineering interdisciplinary programs are particularly prominent. These programs address the increasing demand for cultivating compound talents [2]. Integrating knowledge systems from management science and engineering technology, such programs emphasize the development of systems thinking, decision-making capabilities, and engineering practice skills. They are designed to tackle complex coordination problems between management and technology, and play a key role in supporting the digitalization and intelligent transformation of industries [3].

In recent years, to enhance the adaptability and forward-looking nature of talent cultivation, universities have continuously promoted curriculum reform and pedagogical innovation. Initiatives such as ideological and political education embedded in courses, project-based learning, and practice-oriented teaching have been strengthened. However, the evaluation systems for teaching quality remain fragmented and lag behind these reforms [4, 5]. In 2021, the Central Committee of the Communist Party of China and the State Council issued the Overall Plan for Deepening the Reform of Education Evaluation in the New Era, which explicitly called for overcoming entrenched problems such as excessive emphasis on test scores, academic credentials, paper publication, and academic titles. The plan advocates for the construction of a multi-dimensional and multi-level education quality evaluation system [6]. Against the backdrop of the rapid development of emerging industries such as engineering management, smart agriculture, and intelligent manufacturing, management–engineering interdisciplinary programs are tasked with cultivating high-quality, interdisciplinary talents for these sectors. Consequently, the demands for comprehensive and rigorous evaluation of educational quality in such programs have become increasingly urgent [7].

Although the curriculum structure and instructional content of management–engineering interdisciplinary programs have been continuously optimized, their teaching quality evaluation systems still rely heavily on traditional quantitative indicators. Such approaches fall short in capturing the diversity of teaching processes and aligning with the objectives of cultivating interdisciplinary talents. There is an urgent need to establish a diversified evaluation system that is aligned with the disciplinary characteristics and talent development goals of these programs. A teaching quality evaluation system constitutes a core component of higher education quality assurance mechanisms. It serves as a critical tool for driving teaching reform, supporting faculty development, optimizing curriculum design, and promoting student growth. A scientifically sound and well-structured evaluation system can facilitate multi-stakeholder participation, continuous improvement, and multidimensional feedback, thereby advancing the shift in talent cultivation from 'teaching well' to 'learning well'.

Taking typical management–engineering interdisciplinary programs such as Industrial Engineering and Information Management as examples, the teaching process often covers multiple dimensions, including decision modeling, system optimization, project management, and data analysis. These areas require a comprehensive assessment of students' knowledge acquisition, practical skills, innovative thinking, and teamwork capabilities. However, in practice, teaching evaluation is still predominantly centered on exam-based assessments, which neglect the multidimensional nature of instructional objectives and the holistic development of students' competencies. As a result, evaluation outcomes fail to effectively reflect teaching quality or support the development of diverse student abilities, thereby hindering further improvements in talent cultivation quality.

Therefore, it is essential to base the construction of a scientific, systematic, and diversified teaching quality evaluation system on the compound talent cultivation objectives of management–engineering interdisciplinary programs. This system aims to establish a closed-loop of 'teaching–evaluation–improvement' to facilitate the continuous enhancement of teaching quality. The framework encompasses diverse evaluation stakeholders and multidimensional evaluation indicators, forming a multi-level evaluation mechanism jointly involving teachers, students, employers, and academic administrators. This study focuses on management–engineering interdisciplinary programs to explore the construction pathways and practical mechanisms of a multi-dimensional teaching quality evaluation system, with the goal of providing theoretical support and practical reference for optimizing professional education quality assurance systems.

2 EXISTING PROBLEMS IN THE TEACHING QUALITY EVALUATION SYSTEM FOR MANAGEMENT – ENGINEERING INTERDISCIPLINARY PROGRAMS

Under the multidisciplinary integration background of the 'New Engineering' and 'New Liberal Arts' initiatives, management–engineering interdisciplinary programs have been continuously developing and expanding, thereby placing higher demands on teaching quality assurance mechanisms. However, current practices of teaching quality evaluation in universities still face multiple constraints, which hinder their effectiveness in supporting the cultivation goals of compound talents. These challenges can be summarized in the following three aspects:

2.1 Limitations of Evaluation Stakeholders and Methods

Currently, the majority of universities still rely primarily on administrative authorities to lead teaching quality evaluation, supplemented by student surveys and teacher self-assessments. This results in a relatively singular set of evaluation stakeholders, lacking collaborative participation from diverse perspectives. Particularly in management–engineering interdisciplinary programs, where course content spans multiple disciplinary fields of management and engineering, a unidimensional evaluation approach fails to fully capture the professional complexity and practice-oriented nature of instruction. Moreover, evaluation methods mostly depend on paper-based surveys and fixed templates, lacking process-oriented, dynamic, and multi-scenario integrated tools, which impedes accurate identification of teaching effectiveness and students' competency development trajectories.

Although the Ministry of Education has proposed a '1+3+3' multi-dimensional evaluation framework in the latest undergraduate education teaching audit and evaluation, comprising a core self-assessment report, process reports such as undergraduate teaching status, current student and faculty experience, and outcome reports including graduate employment and employer feedback—covering perspectives from institutions, teachers, students, and enterprises—most universities remain under predominantly administrative control in actual implementation [8]. Chinese education scholar Xiong Bingqi pointed out in his educational commentary that current student evaluations of teaching exhibit clear formalism in both institutional design and operation. Teachers often adjust course content and methods to cater to students and obtain higher evaluation scores, causing evaluations to be 'more symbolic than substantive,' and even degenerating into 'tools for student punishment or reward of teachers,' severely deviating from the original intention of improving teaching quality [9]. Teaching quality evaluation has yet to achieve deep integration among students, faculty, and industry stakeholders. Furthermore, the methods lack dynamic process evaluation mechanisms, making it difficult to comprehensively capture the effectiveness of interdisciplinary talent cultivation.

2.2 Evaluation Indicators Overlook the Characteristics of Disciplinary Integration

Traditional teaching quality evaluation indicator systems are mostly based on single-discipline frameworks and lack sensitivity to the unique features of interdisciplinary programs. For management–engineering interdisciplinary programs, teaching emphasizes knowledge integration, systems thinking, and comprehensive decision-making abilities. However, current indicators predominantly focus on knowledge mastery and classroom performance, neglecting critical dimensions such as interdisciplinary competencies and engineering management literacy. Consequently, the evaluation outcomes become disconnected from talent cultivation objectives, failing to effectively guide curriculum reform and pedagogical innovation.

Existing indicators often emphasize broad macro-level dimensions highlighted in general university assessments, such as social demand adaptability, resource adequacy, and student satisfaction. Yet, management–engineering interdisciplinary programs place greater importance on capabilities like systems thinking, project-driven learning, and interdisciplinary collaboration, which are either weakened or overlooked in the current indicator frameworks. Allen F. Repko, a leading scholar in interdisciplinary education theory in the United States, proposed a systematic theory of interdisciplinary research, emphasizing that interdisciplinary education should focus on integrating perspectives from different disciplines. This integration fosters the holistic development of students' systems thinking, problem-solving abilities, and collaborative skills through knowledge fusion [10]. Therefore, the existing indicator systems urgently require expansion and optimization from the perspective of disciplinary integration to better serve the talent cultivation goals of interdisciplinary programs.

2.3 Inadequate Feedback and Improvement Mechanisms in Evaluation

The ultimate purpose of teaching evaluation is to support instructional improvement and enhance quality. However, in the current system, evaluation results are often used primarily as criteria for faculty assessment and professional title promotion, lacking effective feedback mechanisms and support tools. Consequently, teachers find it difficult to obtain targeted recommendations for improvement. At the same time, academic management departments have yet to establish systematic follow-up and improvement procedures, and there is a lack of data-driven continuous optimization mechanisms. This culture of 'result-oriented but process-weak' evaluation restricts the dynamic enhancement of teaching quality and the establishment of a virtuous cycle.

The final goal of evaluation is to promote 'closed-loop improvement.' The Ministry of Education's latest undergraduate education teaching audit and evaluation framework explicitly calls for the construction of a full-process teaching quality closed loop centered on 'admission–cultivation–employment,' supported by mechanisms such as 'accountability tracking' and 'review inspections' to strengthen rectification implementation and supervision of outcomes [11, 12]. However, despite the comprehensive design of these systems, there remain significant gaps in practical implementation. Educational researcher Zhang Haojun pointed out that formative evaluation mechanisms in current university course assessments are still incomplete, lacking systematic feedback and improvement stages, making it difficult to achieve the 'evaluation–feedback–improvement–re-evaluation' closed-loop teaching reform process [13]. The failure of teaching evaluation to effectively support teaching capacity building and curriculum optimization, combined with the absence of robust feedback and continuous support systems, has become a critical bottleneck for improving teaching quality.

3 CONSTRUCTION AND IMPLEMENTATION PATHWAYS OF A MULTI-DIMENSIONAL TEACHING QUALITY EVALUATION SYSTEM FOR MANAGEMENT – ENGINEERING INTERDISCIPLINARY PROGRAMS

With the continuous development and deepening of management–engineering interdisciplinary programs, the traditional single-dimensional evaluation model can no longer meet the demands of disciplinary integration and compound talent cultivation. Therefore, constructing a scientific and systematic multi-dimensional evaluation system has become a key link in ensuring teaching quality and promoting talent development. Based on the characteristics of these programs and the aforementioned existing evaluation challenges, the construction and implementation of a multi-dimensional teaching quality evaluation system should follow the following four core pathways:

3.1 Diversified Design of Evaluation Stakeholders

In recent years, the field of educational evaluation has increasingly emphasized the participation of multiple stakeholders, encouraging involvement from teaching administrators, faculty teams, individual students, and employers to form a more comprehensive and objective evaluation perspective. Multi-stakeholder participation in evaluation helps to understand teaching quality from various angles, promotes coordinated development among parties, and avoids the limitations caused by a single viewpoint.

Currently, some institutions still limit their evaluation stakeholders to school administration and student evaluations, lacking effective participation from industry-related stakeholders such as employers. This results in a narrow scope of evaluation information that fails to meet the needs of interdisciplinary programs [14]. Educational researcher Zhang Quanhong, in his analysis of university faculty evaluation mechanisms, pointed out that overly singular evaluation stakeholders—mainly relying on teaching and research groups and school administration—neglect the involvement of students, parents, and teachers themselves. This leads to one-sided results that cannot comprehensively and authentically reflect teaching quality [15]. Particularly for management–engineering interdisciplinary programs, the lack of multi-stakeholder participation restricts comprehensive monitoring and dynamic optimization of teaching quality. Due to their disciplinary integration and strong applied nature, these programs require broad stakeholder involvement, especially feedback from industry enterprises, which plays a crucial role in adjusting talent cultivation plans and optimizing curriculum content. Multi-stakeholder participation not only enriches the evaluation perspective but also promotes deep integration of industry and education, thereby enhancing the quality of talent cultivation.

This study proposes constructing an evaluation stakeholder system centered on ‘multi-stakeholder collaborative participation,’ encompassing a multi-level and multi-dimensional network of teachers, students, administrators, and employers. Teacher evaluation not only focuses on classroom teaching effectiveness but also integrates peer review and teaching achievement demonstrations, reinforcing multi-faceted scrutiny of professional connotations and instructional methods. Student evaluation covers learning attitudes, engagement, and self-reflection, fostering student agency and self-improvement. Administrator evaluation emphasizes the implementation of teaching management policies and resource assurance, ensuring institutional support and enforcement for evaluation. Employers, as key providers of industry practice feedback, participate in evaluating talent cultivation plans and curriculum design to ensure alignment between teaching content and industry demands. Through the collaborative interaction of multi-level and multi-dimensional stakeholders, a scientific, comprehensive, and operational evaluation stakeholder system is established, laying a solid foundation for teaching quality assurance in management–engineering interdisciplinary programs.

3.2 Diversified Design of Evaluation Stakeholders

With the evolution of educational philosophies, evaluation indicators have gradually expanded to encompass multiple dimensions such as competency development, process management, and learning attitudes, aiming to reflect students’ comprehensive qualities and developmental potential. Traditional teaching quality evaluation indicator systems have primarily focused on knowledge mastery, emphasizing the transmission of theoretical knowledge and assessment through examination scores, but have neglected systematic assessment of students’ comprehensive abilities and practical application skills.

Existing indicator systems often fail to capture the disciplinary integration and compound competency requirements of management–engineering interdisciplinary programs. They lack indicators tailored to the intersection of management and engineering, rendering them unable to accurately evaluate students’ interdisciplinary collaboration skills, systems thinking, and practical operational abilities. This deficiency undermines the relevance and effectiveness of evaluations [16]. Particularly when addressing complex project management and technological integration tasks, the compound qualities required of students are difficult to assess effectively through traditional single-dimensional indicator systems. Furthermore, differences in understanding of evaluation dimensions among faculty from various disciplinary backgrounds further weaken the scientific validity and comparability of teaching evaluations in such programs. Therefore, the teaching quality evaluation indicator system for management–engineering interdisciplinary programs should emphasize characteristics of disciplinary integration, strengthening multi-dimensional measurement of students’ interdisciplinary abilities, comprehensive qualities, and practical application skills, in order to enhance the scientific rigor, relevance, and guiding value of evaluation outcomes.

This study designs an evaluation indicator system covering four dimensions: knowledge mastery, skill application, management capability, and attitudinal performance. Core indicators are refined to include interdisciplinary theoretical integration ability, engineering practical operation competence, project management skills, and innovation and entrepreneurship awareness. Within the knowledge mastery dimension, emphasis is placed on assessing students’ understanding and integration of core theories in management and engineering. The skill application dimension focuses on evaluating students’ proficiency and innovation in engineering practice and technical application. The management capability dimension concentrates on the cultivation and evaluation of comprehensive qualities such as project management methods, teamwork, and resource allocation. The attitudinal performance dimension highlights the development of learning attitudes, professional responsibility, and innovation and entrepreneurship awareness. By refining these core indicators, the study constructs a multi-dimensional evaluation framework that is both scientifically rigorous and well-aligned with the compound talent cultivation requirements of management–engineering interdisciplinary programs.

3.3 Operational Mechanism and Process Design of the Evaluation System

A well-established evaluation system operational mechanism requires a scientific evaluation process encompassing stages such as preparation, implementation, result analysis, and feedback. Each phase should have clearly defined standards and responsibilities to ensure that the evaluation work proceeds in a systematic and standardized manner. Traditional mechanisms often rely on unidirectional evaluation with a singular process, making it difficult to form an effective closed loop, thereby limiting the practical application of evaluation outcomes. Within the operational process, phase-specific documentation of teaching behaviors and student learning processes, as well as formative diagnostics, are frequently neglected, leading to a disconnect between feedback and subsequent application.

Currently, the operational mechanisms of evaluations in most universities lack standardization, transparency is insufficient, data collection and processing are delayed, and evaluation information is siloed, which significantly hinders the role of evaluation in promoting instructional improvement [17]. Various types of evaluation data are often managed separately, failing to achieve effective linkage and integrated utilization across different evaluation dimensions. Moreover, teachers and students have limited trust in evaluation data, restricting its application value in teaching adjustments and resource allocation. The evaluation system for management–engineering interdisciplinary programs should break away from traditional single-process evaluation and build a dynamic, multi-stage evaluation mechanism that strengthens the monitoring and adjustment capabilities throughout the entire course implementation.

Reasonable phase-specific evaluation nodes should be established, leveraging digital tools to enhance evaluation efficiency and accuracy, thereby improving the system's real-time responsiveness and operational effectiveness. The focus of mechanism design should be on constructing a closed-loop process throughout the entire cycle, rather than solely emphasizing result feedback, with systematized management aimed at enhancing the organizational effectiveness of evaluation operations.

This study constructs a standardized, clearly defined full-process closed-loop evaluation mechanism and proposes establishing a comprehensive evaluation system covering course design, classroom teaching, student learning, practical training, and graduation quality. The course design phase assesses the rationality of teaching objectives and content, ensuring a scientifically structured curriculum and a complete knowledge system. The classroom teaching phase focuses on dynamic monitoring of teaching methods, classroom interaction, and instructional effectiveness. The student learning process is continuously tracked through multi-dimensional indicators such as stage-based assessments, learning attitudes, and engagement levels. The practical training phase emphasizes comprehensive evaluation of abilities developed through experiments, internships, and project practices. The graduation quality phase centers on the summative assessment of students' comprehensive qualities, professional competencies, and innovative practice outcomes. Through systematic integration and data sharing across these phases, real-time feedback and multi-level analysis of evaluation information are achieved, ensuring scientific regulation and continuous optimization of the teaching process, effectively promoting the enhancement of talent cultivation quality in management–engineering interdisciplinary programs.

3.4 Feedback and Continuous Improvement Mechanism for Evaluation Results

The feedback and improvement of evaluation results are critical components for ensuring the continuous enhancement of teaching quality. Modern teaching evaluation theory emphasizes a 'evaluation–feedback–improvement' closed-loop mechanism, whereby evaluation outcomes guide instructional strategy adjustments to improve teaching effectiveness. Unlike the operational mechanism that focuses on 'how to evaluate,' the key aspect of the feedback mechanism lies in 'how to utilize' the results—specifically, how to effectively transform outcomes into drivers for teaching reform and faculty development.

In practice, teaching evaluations often remain at the stage of result publication, lacking effective feedback channels and improvement measures. Consequently, evaluation results fail to sufficiently translate into enhanced teaching capabilities and motivation for curriculum reform, resulting in the loss of evaluative value [18]. Evaluation results should be detailed down to course modules and individual instructors, and interpreted multidimensionally according to different disciplinary backgrounds, with targeted recommendations for improvement. The application of results should encompass multiple levels, including adjustments to teaching content, updates to instructional methods, and guidance for student learning. For management–engineering interdisciplinary programs, establishing a robust feedback mechanism is particularly important. By integrating faculty development plans and student growth portfolios, the mechanism ensures efficient alignment between evaluation content and talent cultivation objectives, promoting the establishment and implementation of multidimensional improvement pathways.

This study constructs a continuous improvement mechanism integrating feedback, supervision, and incentives to foster a virtuous cycle of 'evaluation guiding teaching, and teaching promoting evaluation,' ensuring the steady and sustained enhancement of teaching quality in management–engineering interdisciplinary programs. Through the establishment of scientific feedback channels, timely communication and effective application of evaluation results are realized, enabling teachers and administrators to adjust teaching strategies and improve instructional practices accordingly. A supervision mechanism is set up to clarify responsibility allocation and timeline checkpoints, ensuring that improvement measures are implemented as planned and progress is continuously maintained. Simultaneously, an incentive mechanism is developed to stimulate faculty engagement in teaching quality enhancement through recognition of outstanding educators and rewards for innovative teaching projects. The coordinated interplay among feedback, supervision, and incentives provides institutional support and practical pathways for the effective transformation of teaching quality evaluation results and precise allocation of educational resources.

4 CONCLUSION

This study focuses on the developmental needs of management–engineering interdisciplinary programs under the dual 'New Engineering' and 'New Liberal Arts' context, grounded in the objective of cultivating compound talents. It systematically reviews and analyzes prominent issues in current teaching quality evaluation systems, including the singularity of evaluation stakeholders and methods, limitations of evaluation indicators, and the absence of effective feedback mechanisms. In response to these challenges, the study proposes a multi-dimensional teaching quality evaluation framework tailored to the characteristics of management–engineering interdisciplinary programs, along with its implementation pathways.

The research constructs a diversified stakeholder structure involving students, teachers, industry experts, and administrators; proposes a multi-dimensional indicator system centered on knowledge mastery, skill application, management capability, and attitudinal performance; designs a standardized, clearly defined full-process closed-loop evaluation mechanism; and establishes a feedback and continuous improvement mechanism. The study achieves systematic optimization of teaching evaluation from structural, content, and procedural perspectives, providing theoretical support and practical pathways to enhance talent cultivation quality and teaching management effectiveness in management–engineering interdisciplinary programs.

The constructed multi-dimensional evaluation system balances scientific rigor, relevance, and sustainability, not only addressing the practical demands of quality assurance in higher education teaching but also offering theoretical foundations and practical approaches for optimizing the talent cultivation model in management–engineering interdisciplinary programs. Future research can undertake empirical studies and application promotion at the university level, integrating specific program contexts to further enrich the system's connotations, refine indicator settings, and continuously drive teaching quality enhancement and disciplinary development.

COMPETING INTERESTS

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

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THE CONSTRUCTION OF GENERAL EDUCATION COURSES OF INNOVATION AND ENTREPRENEURSHIP BASED ON TWO TEACHERS, THREE STAGES, FOUR STEPS AND FIVE EVALUATIONS

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Abstract: This article outlines a progressive approach to cultivating innovative and entrepreneurial talents, focusing on stimulating interest, discovering potential, forming teams, becoming key members, and ultimately becoming core members. It also integrates courses such as college student employment guidance, career planning, and policies to offer general courses in innovation and entrepreneurship, thereby enriching students 'foundational skills in these areas. The article addresses three core issues in the development of these general courses: the disconnection between course content and professional scenarios, insufficient depth in teaching, and a monolithic evaluation system. To tackle these challenges, the article proposes a model for constructing general courses in innovation and entrepreneurship education, known as' dual-teacher, three-stages, four-steps, five-evaluations. 'This model involves school-enterprise collaboration in developing teaching resources, dual-teacher co-teaching to create a professional atmosphere, three-stages and four-steps classroom instruction, and five-evaluations to enhance educational outcomes. By optimizing the resources for general courses in innovation and entrepreneurship, this approach enhances students' practical skills, supports the reform of the 'three teachings', and achieves a talent cultivation model for innovation and entrepreneurship that is aligned with professional scenarios.
Keywords: Double innovation general education course construction mode; Phased course setting; Course evaluation system; School-enterprise "double teacher" education

1 INTRODUCTION

Drawing on the experiences from competitions such as the China International College Students Innovation Competition, the Shanghai Vocational College Students Innovation and Creativity Competition, the National College Students Market Research and Analysis Competition, and the National Digital and Intelligent Enterprise Operation Simulation Competition, we have introduced a general course on innovation and entrepreneurship. This course integrates core competency courses with professional courses, creating a comprehensive innovation and entrepreneurship education chain that covers 'inspiration, creativity, team building, and entrepreneurial practice'. By integrating professional courses with innovation and entrepreneurship education, we introduce relevant content and resources into the curriculum to create a system that combines professional competence courses with innovation and entrepreneurship content, thus forming an integrated general course system. This approach aims to not only equip students with core competencies in various majors but also enable them to apply their knowledge in real-world scenarios. Therefore, the major places significant emphasis on cultivating innovation and entrepreneurship skills, focusing on three key areas: how to develop application-oriented general courses, how to build a teaching model that fosters comprehensive skills, and how to create a classroom atmosphere that aligns with professional scenarios. Through collaboration with enterprises and joint training, students will become proficient in mastering core competencies, familiar with application scenarios, and well-versed in the professional workplace environment, thereby forming a comprehensive set of skills that integrate theory, practice, and professional competence[1-2].
How can we develop a general course on innovation and entrepreneurship tailored to specific application scenarios? The scope of innovation and entrepreneurship education is broad, spanning various industries with significant overlap. However, there is currently no unified model for its development. Existing courses lack focus on the key scenarios of Shanghai as an 'International Digital City', making it difficult for students to establish a clear connection between technology, scenarios, and job positions. There is an urgent need to align with the key scenarios that drive Shanghai's economic development, leveraging the unique features of Shanghai's innovation and entrepreneurship education, to create courses that are directly applicable to real-world scenarios. This article aims to enhance the teaching capabilities and qualities of existing professional course instructors in innovation and entrepreneurship, encouraging them to actively integrate cutting-edge technological advancements, the latest research findings, and practical enterprise experiences into their professional courses. This will continuously improve the integration of professional and innovation and entrepreneurship education[3-4].
How can we develop a curriculum model that fosters comprehensive skills? The core courses and content of the IoT integrated high school program are characterized by their strong theoretical and comprehensive nature. Therefore, all core courses at the Shanghai Advanced Technical School's IoT integrated high school program have achieved 100%

integration of theory and practice, with nearly 50% of the course content dedicated to practical training. However, due to a shortage of specialized training and operational instructors, it is challenging to further increase the proportion of practical content in the curriculum structure, leading to a bottleneck in course optimization. This situation makes it difficult to overcome the challenge of' knowledge instruction as the main focus, fragmented skill training. 'There is an urgent need to collaborate with partner enterprises to jointly enhance students' knowledge, skills, and overall qualities.

How can we create a classroom atmosphere that aligns with professional settings? Students will eventually enter the workforce and become professionals. To prepare students for their future careers, it is essential to replicate real-world workplace processes, such as project management, task execution, and outcome evaluation, by integrating these elements into the classroom through collaborative efforts between schools and enterprises. For instance, when students start working, they often interact most with supervisors, mentors, and colleagues. Transforming these workplace roles into educational roles is a critical aspect of professional development[5-6].

2 THE CONSTRUCTION METHOD OF GENERAL EDUCATION COURSES FOR INNOVATION AND ENTREPRENEURSHIP BASED ON TWO TEACHERS, THREE STAGES, FOUR STEPS AND FIVE EVALUATIONS

2.1 Model Refinement

Based on the characteristics of courses in innovation and entrepreneurship education, schools and enterprises have collaborated to develop a structured model for general education courses in this field. This model features dual-subject entities, three-stage capability progression, four-step standard implementation, and five-dimensional value-added evaluation. Together, they have developed a series of replicable paradigms for engineering courses based on real-world scenarios, industrial equipment, and actual projects, which are suitable for both innovation and entrepreneurship courses and cross-scenario skill development

2.2 Specific Practices

2.2.1 Joint construction between schools and enterprises to create teaching resources

Focusing on the 'life' scenarios in Shanghai's' International Digital Capital 'development, the team behind the innovation and entrepreneurship (I&E) course has collaborated with companies operating in Shanghai's communities, supermarkets, and municipal sectors. They have established various scenario-based training labs, incorporating real-world cases from these enterprises. This initiative aims to create practical learning environments and teaching resources tailored to specific application scenarios within the I&E general education courses. The team regularly invites industry experts and I&E service providers to campus as corporate mentors, attracting a wide range of talented individuals from different sectors to participate in 'Entrepreneur on Campus' activities. These activities introduce students to corporate networks, entrepreneurial experiences, and provide insights into entrepreneurship policies, corporate projects, industry news, innovation experiences, and practical opportunities.

2.2.2 Dual teachers in the same hall to create a professional atmosphere

Based on the characteristics of teaching in schools and enterprises, both parties focus on their respective strengths to conduct teaching activities. Schools, through internal training and external recruitment, dispatch 'dual-qualified' professional teachers with vocational skill certificates and introduce entrepreneurship and innovation guidance teachers from enterprises, forming a team of 'professional teachers + enterprise-introduced entrepreneurship and innovation guidance teachers' to build knowledge systems and teach basic skills. Enterprises, on the other hand, send technical supervisors, senior engineers, or experienced mentors who students are most likely to encounter when they first enter the workplace, to design scenario-based tasks and impart job norms. In the classroom, these real-world professionals create a professional atmosphere by assuming real roles, helping students transition from 'students' to 'professionals'.

At the same time, we will closely track professional graduates and explore outstanding alumni in the field of enterprise work, innovation and entrepreneurship. They will return to school with "projects" and stories to serve "senior students", share their own career choices and development, entrepreneurial history and stories, attract outstanding students to participate in mature entrepreneurial projects, and form a benchmark effect among professional students.

2.3 Design the Course Teaching in Three Steps and Four Steps

Based on BOPPPS model, the construction mode of professional training courses for Internet of Things is constructed, and the courses are divided into three stages and four teaching steps.

2.3.1 Stage 1: Knowledge learning driven by problems

This stage includes knowledge learning, which corresponds to the four elements of import, target, pre-test and participation in BOPPPS model.

Step one: Knowledge learning is primarily the responsibility of professional teachers. They introduce situational questions related to the task, guiding students to clarify teaching objectives, conduct pre-reading tests, and complete knowledge instruction relevant to the task. Situational questions serve as the introduction, presenting real-world problems to create a specific scenario that sparks students' curiosity. Learning objectives are set to reflect the requirements and standards for this task, distinguishing them from those in the skill practice phase. Pre-reading tests, which involve watching micro-lesson videos and completing pre-class assessments, help students review the previous course material and their existing knowledge. Knowledge instruction, through methods such as storytelling, discussions, and Q&A sessions, covers new knowledge, preparing students for skill learning and deepening their skills.

2.3.2 Stage 2: Skill practice driven by tasks

This stage includes skill learning and skill deepening, corresponding to the participating elements of the BOPPPS model. The second step of skill learning is primarily managed by teachers from the Innovation and Entrepreneurship program. Through teacher demonstrations and student operations, students are guided to 'follow the example' in completing core tasks. This step not only encourages students to experiment with new innovations but also emphasizes their understanding and application of 'new knowledge' acquired during the learning phase, helping them build a framework of knowledge and skills related to the current innovation task.

The third step, which deepens skills, is primarily managed by the company. The technical supervisor uses methods such as project kick-off meetings and briefings to clearly outline the work objectives for students. Senior engineers, serving as mentors, provide guidance and support to students in completing innovative tasks in groups. This step requires students to integrate the new knowledge and skills gained during the knowledge and skill learning phases, while also reviewing their previous knowledge. By integrating both new and old knowledge and skills into a cohesive capability structure, this process aims to expand and enhance students' innovation capabilities.

2.3.3 Stage 3: quality improvement in flipped classroom

This stage includes task reporting, involving two elements of post-test and summary in BOPPPS model.

The fourth step involves the task presentation, primarily led by the company's technical director, conducted in a flipped classroom format, such as a roadshow or Q&A session. Students are divided into groups and take turns to present their work progress on the tasks assigned, following the presentation format provided by the technical director. Four teachers form the Q&A panel, asking questions to the presenting students in turn, and the technical director provides feedback and summaries for each group. The group Q&A session serves as a post-test to assess students' mastery of knowledge and skills; the technical director's feedback and summary serve as a summary, providing an opportunity for both teachers and students to reflect together, enhancing their engagement in subsequent teaching and learning activities.

2.4 Five Evaluations to Improve the Effectiveness of Education

The Overall Plan for Deepening the Reform of Education Evaluation in the New Era, issued by the CPC Central Committee and The State Council, points out that we should improve the result evaluation, strengthen the process evaluation, explore the value-added evaluation, and improve the comprehensive evaluation. In professional innovation and entrepreneurship teaching, the main implementation is the process evaluation, value-added evaluation and result evaluation.

Procedural evaluation occurs during the stages of knowledge acquisition and skill practice. The first evaluation, which takes place in the first step of knowledge acquisition, primarily assesses students 'mastery of the material. This step utilizes the evaluation functions of digital teaching platforms to integrate self-assessment, peer assessment, machine assessment, and teacher assessment. The second evaluation, which occurs in the second step of skill practice, focuses on evaluating students' initial and basic skill application. Since this step does not involve group work, self-assessment and teacher assessment are primarily used. The third evaluation, which takes place in the third step of skill practice, assesses students' ability to apply their learned skills in practical scenarios. This step, involving group work and team collaboration, includes self-assessment, peer assessment, and teacher assessment.

The skill deepening phase of the dual-ability practice differs from the previous steps in that it includes a value-added evaluation, marking the fourth evaluation. This evaluation primarily assesses students 'application of' old knowledge 'and skills related to the current task, based on the content covered in the preceding lessons and courses. It evaluates students' skill growth and changes, using self-assessment, peer assessment, and teacher assessment. Considering the impact of the Ebbinghaus forgetting curve on learning outcomes and the fact that skill acquisition typically relies on deliberate practice, we intentionally incorporated students' previous learning content into the practical tasks in this step. This allows students to repeat the skills they have practiced before, enhancing their proficiency and encouraging them to apply their knowledge and skills comprehensively in practice.

The result evaluation, that is, the fifth evaluation occurs in the quality improvement stage and the task reporting step. It mainly examines students' mastery of the three-dimensional learning objectives of knowledge, skills and literacy of this innovation and entrepreneurship course through the report on the completion of work tasks, including the application of self-evaluation, mutual evaluation and teacher evaluation.

At the same time, as innovation and entrepreneurship capabilities are a comprehensive integration of various abilities, they are based on knowledge and skills but surpass them in terms of behavioral standards. This means that innovation and entrepreneurship capabilities are more explicitly expressed through behavior, making it more appropriate to evaluate these qualities alongside their practical application. Therefore, this teaching method for innovation and entrepreneurship courses primarily focuses on evaluating professional qualities and innovation and entrepreneurship capabilities during the skill deepening phase of practice and the task reporting phase of quality enhancement, see Table 1.

Table 1 Evaluation Summary

stage	step	appraise type	appraise content	appraise main body

Knowledge learning	Knowledge learning		knowledge	Self-evaluation, peer evaluation, machine evaluation and teacher evaluation
	skill learning	Procedural	technical ability	Self-evaluation, teacher evaluation
Skill practice	Skills deepened		Skills, literacy	Self-evaluation, peer evaluation and teacher evaluation
		Value-added	Knowledge, skills	Self-evaluation, peer evaluation and teacher evaluation
Quality improvement	Task report	Results-oriented	Knowledge, skills and literacy	Self-evaluation, peer evaluation and teacher evaluation

3 THE ACHIEVEMENTS AND EFFECTS OF THE RESEARCH ON THE CONSTRUCTION OF GENERAL EDUCATION COURSES FOR INNOVATION AND ENTREPRENEURSHIP BASED ON DUAL TEACHERS, THREE STAGES, FOUR STEPS AND FIVE EVALUATIONS

The first step is to upgrade the course resources. Through collaboration between schools and enterprises, a three-tier competition selection and cultivation mechanism has been established, covering class training, major selection, and competition participation. The school and enterprise jointly established the 'Double Innovation Scholarship' to provide angel funds for students 'innovative proposals. Each year, effective innovation and entrepreneurship projects are collected, and a project-demand database is created. Project matchmaking meetings are held, inviting investment institutions and industry associations to participate in the evaluation process, which promotes student entrepreneurial projects and provides strong support for course teaching. By converting real enterprise innovation cases into professional teaching resources, a progressive course chain has been formed, including' Double Innovation Foundation Course '', Double Innovation Core Course ', and' Double Innovation Comprehensive Project Course '. This meets the needs for progressive practical teaching arrangements across semesters. In the first semester, professional teachers are responsible for teaching the basics of double innovation and cultivating basic innovation and entrepreneurship skills. In the second semester, enterprise mentors and professional teachers lead students in a 4-week project-based teaching, completing the' dual-teacher three-stages four-steps five-evaluations' model. In the third semester, students independently enter enterprises for internships, with professional teachers responsible for connecting with enterprises and related double innovation work. In the fourth semester, the summary phase is entered, further enhancing comprehensive and application capabilities in double innovation. In the fifth semester, practical training courses resume to enhance overall application development skills. In the sixth semester, students complete the comprehensive design, development, implementation, and presentation of their projects, completing their graduation design.

Second, to enhance students 'practical skills in innovation and entrepreneurship education. This involves strengthening the basic qualities and comprehensive application abilities of students in entrepreneurship education. Through completing projects, students learn knowledge, apply skills, and gain hands-on experience. The curriculum includes extensive case studies and practical analyses, featuring numerous successful and failed cases of innovation and entrepreneurship. These cases guide students to analyze, discuss, and distill valuable lessons. Practical skill training is provided, including design thinking, business model canvas, lean startup, prototyping, pitch techniques, intellectual property protection, and financial basics. Additionally, the curriculum integrates interdisciplinary knowledge, encouraging the integration of technology, business, design, and humanities into projects to foster students' ability to solve problems comprehensively.

The third aspect is the practical application of radiating curriculum reform. By accumulating and refining the 'dual-teacher, three-stages, four-steps, five-evaluations' model for entrepreneurship and innovation education in general courses, this article extends the experience of integrating industry and education and fostering suitable talents through school-enterprise cooperation to the research on entrepreneurship and innovation education courses in various majors at vocational colleges. It encourages students to venture beyond the campus, engaging with communities, industrial parks, and rural areas to identify real social needs and market challenges, and to propose solutions. The focus is not only on the final outcomes, such as business plans, awards, and company registrations, but also on the students' performance during the project process, including their problem-solving skills, teamwork, iterative improvement, stress management, and learning capabilities.

4 THE EXPERIENCE SUMMARY OF THE CONSTRUCTION OF GENERAL EDUCATION COURSES FOR INNOVATION AND ENTREPRENEURSHIP BASED ON TWO TEACHERS, THREE STAGES, FOUR STEPS AND FIVE EVALUATIONS

4.1 “Theory, Practice and Nature” are Integrated, and the Teaching Content is Complex

The general education curriculum for innovation and entrepreneurship is structured around professional scenarios, guided by practical work tasks. It aims to achieve three-dimensional teaching goals: theoretical knowledge, practical skills, and professional qualities, through three stages of learning: knowledge acquisition, skill practice, and quality enhancement. Supported by school-enterprise collaboration, this model leverages the strengths of professional teachers in teaching and enterprise employees in technical expertise. Through alternating teaching methods, it ensures that knowledge is imparted in context, skills are trained according to standards, and qualities are developed through practical carriers, thus achieving a comprehensive cultivation of innovation and entrepreneurship capabilities that integrate theory, practice, and quality.

4.2 “Learning, Practice and Evaluation” is Progressive, and Teaching Subjects are Diversified

In response to the needs of courses and teaching, four full-time and part-time teachers from both schools and enterprises have been selected to participate in the dual innovation education project. This collaboration aims to leverage their unique strengths and advantages, promoting multidimensional learning, practice, and evaluation, as well as diversifying the teaching subjects. Full-time professional teachers, who typically enter the school directly after graduating from university, are familiar with teaching but lack experience in innovation and entrepreneurship in enterprises and institutions. Therefore, they are assigned to knowledge-based teaching activities. The number of full-time enterprise teachers is limited, but their teaching abilities and technical skills are relatively balanced, making them suitable for innovative teaching activities. Based on the actual situation, full-time professional teachers and full-time enterprise teachers can also share responsibilities, covering both knowledge and dual innovation skills. Part-time enterprise teachers, while familiar with the dual innovation skills in their field, lack teaching experience at schools and have relatively limited teaching methods and skills. Thus, they can primarily focus on task assignment, acceptance, and skill guidance. By designing a four-step teaching process, the learning (knowledge construction), practice (skill solidification), and evaluation (ability diagnosis) are integrated into each part of the course. A digital platform is utilized to achieve seamless data integration for 'teaching-learning-evaluation', enabling real-time optimization of teaching strategies.

4.3 “School-Enterprise-Student” Cooperation, Teaching Activities are Contextualized

In the dual innovation education, each school-enterprise collaboration starts with a real-world scenario, immersing students in training, work, and acceptance processes that closely resemble those of industry enterprises. This setup simulates the learning and innovation environment of employees and professionals. During practical teaching, schools and enterprises provide contextual backgrounds and tasks, allowing students to engage in learning as if they were real employees. This approach makes the teaching environment more realistic, ensuring that the three-dimensional goals of knowledge, skills, and literacy are integrated throughout the teaching and learning process. In the general courses of dual innovation education, the entire process, from course introduction to outcome acceptance, is designed to simulate a professional workplace. Students participate in projects as 'quasi-employees', while the teacher team acts as 'technical supervisors and mentors'. This setup creates an immersive learning environment, helping students adapt more quickly from being 'students' to becoming 'professionals'.

5 PROMOTION AND APPLICATION OF THE CONSTRUCTION METHOD OF GENERAL EDUCATION COURSES FOR INNOVATION AND ENTREPRENEURSHIP BASED ON TWO TEACHERS, THREE STAGES, FOUR STEPS AND FIVE EVALUATIONS

Scope of application: This construction mode of general education course for innovation and entrepreneurship is suitable for the courses of all majors in higher vocational colleges.

Application scenario: This model for the construction of general education courses on innovation and entrepreneurship is designed for general education courses equipped with digital teaching platforms and resources, including foundational courses in innovation and entrepreneurship, practical courses, and courses aimed at enhancing comprehensive skills in innovation and entrepreneurship. The evaluation scheme can also be independently applied to various general education courses on innovation and entrepreneurship.

Note: This dual innovation education course model requires a professional team of full-time and part-time teachers, including 1-2 full-time teachers responsible for theoretical and practical training, and 2 part-time teachers, such as technical supervisors and senior engineers. The general education course model for this dual innovation education can be tailored to the characteristics of the professional courses and the actual faculty situation, using either step one and two or step one, two, and three[7-8].

6 DISCUSSION AND CONCLUSION

The proposed "dual-teacher, three-stages, four-steps, five-evaluations" model for constructing general education courses in innovation and entrepreneurship (I&E) addresses critical gaps in traditional I&E education by integrating school-enterprise collaboration, scenario-based learning, and multidimensional evaluation. This model bridges the disconnect between course content and professional scenarios, enhances teaching depth, and diversifies evaluation systems, fostering students’ practical skills and entrepreneurial mindset.Key achievements include: (1) Resource optimization, where school-enterprise partnerships transform real-world cases into progressive course chains (e.g., foundational, core, and project-based courses); (2) Skill enhancement, as students gain hands-on experience through interdisciplinary projects, case analyses, and competitions; and (3) Curriculum reform, with the model’s scalability across vocational majors, emphasizing process-oriented and value-added evaluations. The integration of "theory-practice-quality" and immersive professional scenarios ensures students transition smoothly from learners to innovators.However, challenges persist, such as the need for sustained enterprise involvement and faculty upskilling. Future work should explore digital tools to further streamline "teaching-learning-evaluation" workflows and expand cross-institutional collaborations.

Ultimately, this model not only enriches I&E education but also aligns with broader goals of vocational education reform, cultivating talent tailored to industry needs[9-11].

COMPETING INTERESTS

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

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THE CONSTRUCTION OF PRACTICE TEACHING IN PRINCIPLES OF URBAN PLANNING COURSE

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Abstract: Under the background of integration of specialization and creation, the practical teaching of Principles of Urban Planning is reformed and explored based on the CDIO concept in the Human Geography and Urban and Rural Planning Program of Xinjiang Normal University as an example. We reconstructed the four-in-one curriculum system of "theory+ practice+ innovation+ ideological and political education" and designed the practical teaching framework and cases based on CDIO concept. The teaching practice has achieved the results of improving students' ability and the effectiveness of course construction, but it also faces some challenges. In the future, we will continue to optimize the teaching mode in order to cultivate high-quality urban planning professionals.
Keywords: Principles of urban planning; Curriculum construction; Practical teaching; CDIO concepts

1 INTRODUCTION

Principles of Urban Planning, as a core course in the specialty of human geography and urban and rural planning, is the cornerstone for constructing students' knowledge system of urban and rural planning[1]. Under the strong impetus of the trend of specialized and creative fusion education, the traditional teaching mode has been difficult to meet the needs of cultivating innovative and practical talents, and the reform of the practical teaching of the course has become imperative[2-4].

Based on the human geography and urban-rural planning major of Xinjiang Normal University, this study introduces the concept of CDIO (Conceive-Design-Implement-Operate) engineering education[5], and devotes itself to reconstructing the curriculum system of Principles of Urban Planning, exploring effective practical teaching methods, and deeply integrating innovation and entrepreneurship education with the practical teaching of the curriculum, so that the students The students can apply theoretical knowledge in real project situations, enhance their ability to solve real urban problems, and promote the comprehensive development of their comprehensive literacy[6-7].

2 RECONSTRUCTION OF CURRICULUM SYSTEM

Integrate innovation and entrepreneurship education into the Principles of Urban Planning course, and construct a four-in-one curriculum system of "theory + practice + innovation + ideological and political education ".

2.1 Basic Theory Module

Diversified teaching methods, such as classroom lectures, literature reading, case studies and project-driven teaching, are adopted to help students master the basic principles and framework of urban planning. Taking the project of urban historical and cultural district protection planning as an example, the theoretical teaching covers various aspects and lays the foundation for practical operation.

2.2 Practical Skills Module

Through experimental courses, practical projects and software operation training, students' practical skills are effectively enhanced. In the practice of urban historical and cultural neighborhood conservation planning projects, students use various technologies to obtain spatial data, analyze and present the planning scheme, so that they can master the key skills of data processing and expression of results.

2.3 Frontier Topics Module

Organize classroom discussions, group research and case study activities to guide students to pay close attention to industry dynamics. For example, discussing the impact of big data analysis on the planning decisions of historical and cultural neighborhoods, analyzing the application of innovative technologies in successful cases at home and abroad, broadening students' professional horizons, understanding the cutting-edge trends of the industry, and providing theoretical foundations and technical reserves for innovation.

2.4 Ideological and Political Education & Integration of Specialty and Innovation Module

Organically integrate the elements of ideology and politics and innovation and entrepreneurship education into the curriculum. In the historical and cultural neighborhood protection planning project, students are guided to think about its significance to cultural heritage and social stability, encouraged to propose innovative business models combining cultural and creative industries, emphasized to follow the principles of scientific and sustainable development, and cultivated correct values and professional views.

3 CONCEPTUALIZATION OF THE PRACTICAL TEACHING FRAMEWORK BASED ON THE CDIO CONCEPT

In order to better combine theoretical knowledge with practical operation, actual urban planning projects are introduced, and project-driven teaching guides students to carry out full-scale practical activities in an orderly manner according to the CDIO concept.

3.1 Conceive Stage

Focusing on the hot topics of urban development, the design theme stimulates students' interest and social responsibility. For example, for the transformation of old neighborhoods in the city, students are guided to go deep into the community to find out the problems, so as to provide a context for the subsequent design.

3.2 Design Stage

Students are organized into groups to collaborate, formulate planning schemes combining course knowledge and ideological and political requirements, encourage innovative thinking, and comprehensively consider various factors. For instance, in the design of old residential quarter renovation, factors such as residents' needs, cultural inheritance, and environmental friendliness are taken into account.

3.3 Implement Stage

Organize field research for students to collect data, verify and improve the preliminary plan. Adopt innovative practice methods, such as public participatory planning, to improve the scientific and democratic nature of the program.

3.4 Operate Stage

Use advanced technology to simulate the implementation process and impact of the program, and develop students' ability of prediction and evaluation. Students present the results in various forms and receive comments, and think about the social value of the program.

3.5 Reflect and Improve

Establish a feedback mechanism to assess and summarize the results of the program from multiple dimensions. Organize students to share their experiences and adjust and optimize the teaching content and methods according to the feedback.

4 DESIGN OF PRACTICAL TEACHING ACTIVITIES BASED ON THE CDIO CONCEPT

Starting from the conception phase, innovative urban planning solutions are proposed for specific urban spatial issues, thus forming preliminary design schemes.

4.1 A Case Study on "Current Situation Investigation of Urban Functional Zoning and Land Use Selection"

4.1.1 Conceive stage

(1) Theme Determination: The theme of "Analyzing the current situation of urban functional zoning and land use selection, and optimizing urban spatial layout" is clarified, with focuses on the rationality of urban spatial structure, land use efficiency, coordination between industrial layout and functional zoning, and ecological environment protection.
(2) Problem Analysis: Students are organized into groups to conduct in-depth investigations in various urban areas, aiming to identify problems in functional zoning and land use selection, such as the concentration of functions in urban central areas, inappropriate separation between industrial and residential areas, inadequate supporting facilities in residential areas, and the existence of idle or inefficiently used land.
(3) Goal Setting: To cultivate students' abilities in comprehensive application of interdisciplinary knowledge, investigation and research, innovative thinking, teamwork, and communication.

4.1.2 Design stage

(1) Theoretical Learning: In-depth study is conducted on urban planning-related theories and technologies, including functional zoning theory, principles of land use planning, and GIS applications. Students are required to understand the characteristics, formation mechanisms, and development laws of different functional zones, and master methods such as land suitability evaluation and land use efficiency assessment, so as to provide theoretical support for field investigations and data analysis.

(2) Field Research: A combination of multiple research methods is adopted. On-site surveys are carried out in different urban functional zones to observe the current situation of land use, building types and distribution, transportation facilities, and environmental quality. Scientific and reasonable questionnaires are designed to investigate different groups regarding their satisfaction with functional zoning, land use needs, and expectations for urban development. Interviews are conducted with relevant departments, enterprise representatives, and community residents to obtain first-hand information, including urban planning policies, land transfer information, enterprise development plans, and residents' living demands. Remote sensing images and GIS technology are used to acquire basic data such as urban topography, land cover types, and transportation networks. Detailed maps of the current situation of urban functional zoning and land use selection are drawn to provide an accurate data basis for subsequent analysis.

(3) Conceptual Design: Based on the research results and theoretical knowledge, group brainstorming is carried out to conceive an analysis framework and preliminary optimization ideas for the current situation of urban functional zoning and land use selection. Combined with the urban development orientation and goals, innovative investigation and analysis perspectives and potential solutions are proposed. Preliminary conceptual maps are drawn to show the current situation of urban functional zoning, characteristics of land use selection, spatial distribution of existing problems, as well as preliminary optimization directions and ideas.

4.1.3 Implement stage

(1) Detailed Design: Professional software is used for in-depth analysis and data processing. The economic, social, and environmental benefits of different functional zones and land use types are evaluated, the causes of problems in functional zoning and land use selection are analyzed, and optimization suggestions are put forward, including functional zone adjustment, land replacement, and development intensity control.

(2) Simulation and Demonstration: Simulation software or physical models are used to simulate the urban operation status. By simulating processes such as traffic flow, population distribution changes, industrial development trends, and ecological environment evolution, the problems and impacts of urban spatial layout are demonstrated. Based on the simulation results, the conclusions of the current situation investigation and analysis are verified and improved to provide a basis for optimization schemes.

(3) Expert Consultation: Experts from multiple fields are invited to form a team to review the current situation investigation results and optimization suggestions. Students revise and improve the results according to the experts' opinions to ensure the professionalism and practicability of the outcomes.

4.1.4 Operate stage

(1) Achievement Display and Communication: The investigation results are displayed to all sectors of society through various forms to promote communication and cooperation between the government, academia, and the public, and to collect opinions and suggestions from all parties.

(2) Simulation Implementation: VR or AR technology is used to simulate the implementation process and possible effects of the optimization scheme for urban functional zoning and land use selection, evaluate the feasibility and effectiveness of the scheme, and collect feedback to provide a basis for the dynamic adjustment of the scheme.

4.1.5 Reflect and improve

(1) Feedback Integration: Feedback information from all parties is collected, the advantages and disadvantages of the research results are sorted out and summarized, and the key factors and difficult problems affecting the optimization of functional zoning and land use selection are clarified.

(2) Reflection and Summary: Students are guided to write practical summary reports, reflect on their personal growth and team collaboration processes, provide references for subsequent learning and practice, and put forward suggestions for teaching improvement.

4.2 A Case Study on "Campus Master Plan Design"

4.2.1 Conceive stage

(1) Theme Determination: The theme of "Creating a campus master plan with complete functions, beautiful environment, and rich cultural characteristics" is focused on, with emphasis on teaching and research needs, convenience of students' life, inheritance and innovation of campus culture, and ecological environment protection.

(2) Problem Analysis: Students are organized to conduct a comprehensive survey of the campus, and problems are sorted out, such as the long distance between teaching and living areas, chaotic traffic flow, insufficient public activity space, lack of distinctive landscapes, and irrational building functional layout that cannot meet the needs of modern education and teaching.

(3) Goal Setting: To cultivate students' ability to solve practical campus problems using urban planning principles, stimulate their innovative thinking, improve their teamwork and communication skills, and provide planning suggestions for campus construction.

4.2.2 Design stage

(1) Theoretical Learning: In-depth study is conducted on knowledge related to campus planning and design, and students are required to fully master the principles of campus functional zoning, building layout requirements, traffic organization methods, landscape creation techniques, and ecological sustainable development strategies to lay a theoretical foundation for scheme design.
(2) Field Research: Campus information is obtained through multiple methods such as field measurement, questionnaire survey, and interviews with teachers and students. Basic data are measured, teachers' and students' satisfaction with the current campus layout, expectations for future campus construction, and actual needs in daily study and life are collected, and the school's development plan, characteristics of teaching and research activities, and needs of student associations are understood. A detailed campus current situation map is drawn, covering building distribution, traffic flow, green space system, and public facility distribution, to provide data support for design.
(3) Conceptual Design: Based on the research results and theoretical knowledge, group discussions are held to conceive the design concept and framework of the campus master plan. Combined with the school's historical and cultural traditions, disciplinary characteristics, and future development direction, innovative ideas are put forward. Preliminary conceptual design sketches are drawn to show the overall ideas of campus functional zoning, building group layout, transportation network planning, and landscape space creation.

4.2.3 Implement stage

(1) Detailed Design: Professional design software is used for scheme design. According to the school's scale and development needs, the layout of buildings and functional areas is reasonably determined, spatial relationships are optimized, and transportation systems are designed. Combined with campus cultural characteristics and landscape resources, landscape node design and greening system planning are carried out, with consideration of ecological and environmental protection factors.
(2) Simulation and Demonstration: VR technology or models are used to simulate the actual operation of the campus under different master plans, experience the spatial environment, evaluate the rationality of different traffic organization schemes, test the scientificity of functional zoning layout, and optimize landscape design schemes. Problems and deficiencies in the scheme are identified based on simulation results to provide a basis for optimization.
(3) Expert Consultation: Experts from multiple fields are invited to review the scheme. Experts put forward opinions and suggestions from multiple dimensions, and students revise and improve the scheme accordingly to ensure its feasibility.

4.2.4 Operate stage

(1) Achievement Display and Communication: Design results are displayed to all parties of the school through various forms, opinions and suggestions are widely listened to, and the scheme is optimized.
(2) Simulation Implementation: Digital simulation technology or sand table models are used to simulate the implementation process of the campus master plan and the actual operation status after completion, evaluate the impact of the scheme on existing campus infrastructure during implementation, predict possible problems and challenges, and formulate response measures to provide suggestions for the sustainable development of the campus.

4.2.5 Reflect and improve

(1) Feedback Integration: Feedback information from all parties is collected, the advantages and disadvantages of the scheme are analyzed and summarized, and the key factors affecting the implementation effect are clarified.
(2) Reflection and Summary: Students are guided to write practical summary reports, reflect on their personal growth and team collaboration processes, provide references for subsequent learning and practice, and put forward suggestions for teaching improvement.

5 EFFECT OF PRACTICE TEACHING BASED ON THE CDIO CONCEPT

5.1 Improvement of Students' Abilities

5.1.1 Enhancement of professional skills

Through participation in practical projects and case studies, students have accumulated rich practical experience, and their professional skills in the application of urban planning principles, operation of planning and design software, field research, and data analysis have been significantly improved. For example, in the urban historical and cultural block protection planning project, students proficiently mastered historical building surveying and mapping technology, used total stations and other equipment to accurately measure building dimensions and spatial relationships; through GIS spatial analysis, they deeply explored the spatial characteristics and historical and cultural value of the block; and used CAD drawing software to carefully draw detailed planning drawings, accurately evaluate the protection value of the block, and formulate reasonable planning strategies.

5.1.2 Stimulation of innovative thinking

Innovative practical activities and diversified teaching models have effectively stimulated students' innovative thinking. In the campus master plan project, students put forward many innovative ideas, such as an intelligent building management system under the concept of a smart campus to realize efficient energy utilization and intelligent control of campus buildings; an ecological wetland purification system under the concept of an ecological campus to treat campus sewage and create ecological landscapes; and a campus cultural exhibition corridor under the concept of a cultural campus to display the school's historical culture and teachers' and students' artworks. These innovative ideas are skillfully integrated into the planning scheme to improve the campus quality.

5.1.3 Improvement of teamwork and communication skills

Project-driven teaching and group cooperative learning have cultivated students' good teamwork and communication skills. In the urban new district traffic planning project, students divided labor and cooperated: traffic engineers were responsible for traffic flow analysis and road design; geographic information experts used GIS technology for spatial analysis and data processing; environmental experts evaluated the impact of traffic planning on the environment. Students with different professional backgrounds cooperated and complemented each other to complete the planning task, effectively improving teamwork efficiency. Meanwhile, students' communication skills were exercised in group discussions, exchanges with experts, and presentation of results to the society.

5.2 Achievements in Curriculum Construction

5.2.1 Optimization of curriculum system

The reconstruction of the curriculum system based on the CDIO concept has made the content of the *Principles of Urban Planning* course more diverse and the structure more reasonable. The integration of innovation and entrepreneurship education and curriculum ideological and political education has not only kept the course in line with the times but also enhanced its educational function, realizing the organic unity of knowledge impartment, ability training, and value shaping. For example, integrating innovative cases and entrepreneurial practice requirements into the course content cultivates students' innovative awareness and entrepreneurial spirit; through the infiltration of ideological and political elements, students are guided to establish correct professional ethics and social responsibility.

5.2.2 Innovation of teaching methods

The application of diversified teaching models has enriched teaching methods and significantly improved teaching quality. In the flipped classroom model, students independently learn relevant knowledge and cases before class, enter the classroom with questions and thoughts, and through in-class discussions and teacher's answers, they have a deeper understanding of knowledge and can better apply theoretical knowledge to practice. Project-driven teaching allows students to exercise their abilities in real projects, stimulating their learning interest and initiative.

5.2.3 Expansion of teaching resources

In the process of practical teaching, rich teaching cases, practical project results, and enterprise cooperation resources have been accumulated. These resources provide strong support for curriculum teaching and lay a solid foundation for subsequent teaching reform and curriculum construction. For example, the detailed case materials formed by students in the urban historical and cultural block protection planning project, including research data, planning schemes, and implementation effect evaluation, can be used as vivid teaching cases for subsequent students; carrying out projects in cooperation with enterprises not only provides practical opportunities for students but also enables the school to obtain cutting-edge industry information, promoting the close integration of the curriculum with market demand.

6 CONCLUSION

The practical teaching reform of Principles of Urban Planning based on the concept of CDIO under the background of specialized integration is an important exploration to adapt to the development of the times and improve the quality of talent cultivation. A series of reform measures, such as reconstructing the curriculum system and designing the framework and cases for practical teaching, have achieved remarkable results in the improvement of students' ability and the effectiveness of curriculum construction. However, the reform process still faces some challenges, such as the further optimization of teaching articulation, the deeper integration of cutting-edge technologies and the improvement of the evaluation system. In the future, it is necessary to continue to deepen the reform, constantly optimize the teaching mode, strengthen the cooperation between schools and enterprises, improve the evaluation system, promote teachers to actively carry out teaching research and practical exploration, and make unremitting efforts to cultivate high-quality urban planning professionals.

COMPETING INTERESTS

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INTERDISCIPLINARY INTEGRATION OF ANALOGICAL THINKING IN REAL ANALYSIS TEACHING FROM THE PERSPECTIVE OF CORE COMPETENCIES

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Abstract: This study systematically explores the cross-disciplinary application model of analogical thinking in real analysis teaching based on the core competencies education concept. By constructing a three-dimensional teaching framework of "concept-method-thinking" and integrating interdisciplinary content from courses such as complex analysis, probability theory, and mathematical analysis, a multi-course integrated teaching strategy using analogical thinking as a nexus is proposed. Practice shows that this method effectively reduces the abstraction of real analysis, enhances students' mathematical modeling abilities and higher-order thinking skills, and provides theoretical references for teaching reform in analysis courses.
Keywords: Core competencies; Analogical thinking; Real analysis; Interdisciplinary integrated teaching model

1 INTRODUCTION

Real variable functions are a core course in mathematics and applied mathematics, covering three major modules: set theory, measure theory, and integral theory, with a high degree of abstraction and logical rigor. In recent years, with the deepening penetration of core literacy concepts in mathematics education, the teaching reform of real variable function courses has gradually focused on cultivating students' higher-order thinking abilities. The current research on the teaching of real variable function courses mainly focuses on innovative teaching modes, problem driven design, literacy development paths, and cognitive conflict resolution, presenting a characteristic of emphasizing both theory and practice. Cao[1] proposes a "project-based teaching" model, transforming abstract concepts into research topics to enhance logical reasoning and mathematical abstraction. Wang and Yang[2] advocates "problem-set reflective teaching" to build knowledge networks and critical thinking. Wang and Gao[3] highlights "problem chains" as core tools for deepening conceptual understanding. Wang[4] analyzes real analysis' unique role in cultivating abstract thinking, rigorous reasoning, and application skills. Reed[5] analyzes the mechanism of sense-making in real analysis. Dumitraşcu[6] analyzes integration teaching of real analysis. Rezky[7] analyzes mathematics teaching materials.
However, there is still a significant lack of interdisciplinary connection in the current teaching research of real variable function courses, specifically manifested as a lack of collaborative teaching research related to complex variable functions, probability theory, mathematical analysis, and other related courses. Based on this, this article takes the "Core Literacy" framework proposed in the 2024 Ministry of Education Briefing as a guide to explore innovative interdisciplinary collaborative teaching. We innovatively proposes the cross-disciplinary teaching model, which integrating real analysis with other mathematical disciplines via analogical thinking. This paper is based on the three-dimensional teaching framework of "concept method thinking", and explores the interdisciplinary application of analogical thinking in the teaching of real variable functions by analyzing the correlation between relevant concepts in courses such as complex variable functions, probability theory, and mathematical analysis. Finally, demonstrate the practical path of analogical thinking in cultivating students' knowledge transfer ability through typical examples.

2 PRACTICAL APPLICATION OF ANALOGICAL THINKING IN INTERDISCIPLINARY TEACHING

2.1 Practice in Set Theory Teaching

Equivalence is a fundamental concept in set theory of real variable functions, used to describe the one-to-one correspondence between two sets. This concept provides a theoretical basis for studying the cardinality of sets.
Definition 1[8] Sets A, B are two nonempty sets, if there exists a bijection $\varphi : A \to B$, then call A and B are equivalent，denoted by $A \sim B$.
The abstraction of the concept of equivalence can be intuitively explained through examples of complex functions. In the course of complex functions, the concept of extending a complex plane to an expanded complex plane by introducing infinity points can be geometrically represented as a complex sphere under spherical pole projection. From the perspective of set theory, there exists a one-to-one correspondence between the expanded complex plane and the complex sphere, which is a concrete manifestation of the concept of "equivalence" in real variable functions.
Example 1 Prove that the sphere minus one point is equivalent to the entire plane.

Proof Let the equation of sphere S be $x^2+y^2+\left(z-\frac{1}{2}\right)^2=\left(\frac{1}{2}\right)^2$. Let L be the straight line which connect vertex $(0,0,1)$ to point (x,y,z) on S, the equation of L is $\frac{X}{x}=\frac{Y}{y}=\frac{Z-1}{z-1}=t$ So that $\begin{cases} X=tx \\ Y=ty \\ Z=t(z-1)+1 \end{cases}$

By substituting the equation into the plane xoy, the solution is $t=\frac{1}{1-z}$. Thus, the coordinates of the intersection point are $\left(\frac{x}{1-z},\frac{y}{1-z},0\right)$.

Let $\varphi: S\setminus(0,0,1)\rightarrow \text{plane } xoy$, and $\varphi(x,y,z)=\left(\frac{x}{1-z},\frac{y}{1-z},0\right)$. Next we prove that there exists $\varphi^{-1}: \text{plane } xoy \rightarrow S\setminus(0,0,1)$. Let l be the straight line which connect vertex $(0,0,1)$ to point $(x,y,0)$ on plane xoy, then the equation of l is $\frac{X}{x}=\frac{Y}{y}=\frac{Z-1}{-1}=t.$

By the equation of S we have $t=\frac{1}{x^2+y^2+1}$. Therefore, $\varphi^{-1}(x,y,0)=\left(\frac{x}{x^2+y^2+1},\frac{y}{x^2+y^2+1},\frac{x^2+y^2}{x^2+y^2+1}\right)$.

It turns out that φ is a bijection, thus $S\setminus(0,0,1)$ and plane xoy are equivalent.
From Example 1, it can be seen that expanding the complex plane and the complex spherical plane are equal. The teaching implementation of this section is as follows:
(1) Conceptual analogy: expanding the equivalent concepts of the complex plane and complex sphere conceptual analogy set.
(2) Visual guidance: Establish geometric intuition through spherical projection animation demonstration.
(3) Sublimation of thinking: Guide students to discover the core idea of "equipotential of infinite sets" in real variable functions.
Outcome: Classroom feedback shows that 85% of students indicate that this analogy significantly reduces the difficulty of accepting the concept of set equivalence.

2.2 Practice in Measure Theory Teaching

Measurement convergence is a fundamental concept in the theory of real variable function measurement, which reflects the limit behavior of function sequences in the sense of measurement.
Definition 2[8] Let $\{f_n\}$ be a sequence of a.e. finite measurable functions on $E\subset\mathbb{R}^n$. It is called that $\{f_n\}$ converges to f in measure on E if for any $\varepsilon>0$ and $\delta>0$, there exists positive integer $N(\varepsilon,\delta)$, such that for any $n>N(\varepsilon,\delta)$, $mE\left[\left|f_n-f\right|\geq\sigma\right]<\varepsilon.$
Metric convergence can be intuitively explained through the special case of probabilistic convergence in probability theory. In probability theory, when conducting a large number of independent Bernoulli experiments, the frequency of events will converge to their theoretical probability values according to probability. For example, when repeatedly tossing a coin, the probability of facing up is $\frac{1}{2}$. Let be a probability measure, From the perspective of convergence according to measurement, $\frac{1}{2}$ means that for any $\varepsilon>0$ and $\delta>0$, there exists positive integer $N(\varepsilon,\delta)$, such that for any $n>N(\varepsilon,\delta)$, $\left[\left|p_n-\frac{1}{2}\right|\geq\sigma\right]<\varepsilon.$

This case not only provides a specific probabilistic explanation for convergence based on measurement, but also reveals the inherent unity between measurement theory and probability theory in the concept of convergence, reflecting the important significance of abstract measurement theory in practical applications.

The teaching implementation of this section is as follows:

(1) Commonality analysis: Taking coin toss as an example, demonstrate the concept connection between probability convergence and measure convergence.

(2) Application extension: Through the cognitive cycle of "concrete → abstract → re concrete", help students establish an operable thinking bridge between probability intuition and measurement abstraction, and cultivate their mathematical modeling ability from special to general.

Outcome: Classroom practice data shows that classes using this method have a 37% increase in accuracy in dictation defined by the concept of convergence based on measurement.

2.3 Practice in Integration Theory Teaching

The Lebesgue control convergence theorem is a core criterion in the theory of real variable functions regarding integration and limit exchange problems, which is in sharp contrast to the uniform convergence condition of function sequences in mathematical analysis.

Theorem 1[8] Let $E \subset \mathbb{R}^n$ be a measurable set, $\{f_n\}$ be a sequence of measurable functions on E, F be an nonnegative Lebesgue integrable function on E. If for all $n \in \mathbb{N}$, $|f_n(x)| \le F(x)$, a. e. $x \in E$, then $\lim_{n\to\infty} \int_E f_n(x)\,\mathrm{d}x = \int_E f(x)\,\mathrm{d}x.$

Example 2 Let $f_n : [0,1] \to \mathbb{R}$ and $f_n(x) = n \cdot \chi_{(0,1/n]}(x)$, $n = 1, 2, \cdots$. Prove that $\{f_n\}$ isn't convergence to 0 uniformly, but $\{f_n\}$ still satisfies $\lim_{n\to\infty} \int_E f_n(x)\,\mathrm{d}x = \int_E f(x)\,\mathrm{d}x = 0.$

Proof For any $x \in (0,1]$, if $n > \frac{1}{x}$, then $f_n(x) = 0$. Hence, $\lim_{n\to\infty} f_n(x) = 0 = f(x)$, a. e. on $[0,1]$.

Since $\sup_{x\in[0,1]} |f_n(x) - 0| = n \to \infty$, so that $\{f_n\}$ isn't convergence to 0 uniformly.

On the other hand, take $g(x) = \frac{1}{\sqrt{x}}$, then $g(x)$ is an nonnegative Lebesgue integrable function on $[0,1]$, and for all $n \in \mathbb{N}$, $|f_n(x)| \le g(x)$, a. e. on $[0,1]$. Theorem 1 deduces that $\lim_{n\to\infty} \int_E f_n(x)\,\mathrm{d}x = \int_E f(x)\,\mathrm{d}x = 0.$

The teaching implementation of this section is as follows: Through specific function sequence cases, compare the limit integral exchange condition that relies on uniform convergence in mathematical analysis with the weakening condition of Lebesgue control convergence theorem in real variable functions (almost everywhere convergence and integrable control), highlighting the universality of Lebesgue integral in dealing with complex limit problems. Teaching effectiveness: By analogy with the mathematical analysis course, students can clearly grasp the core knowledge points and theoretical advantages of Lebesgue integral in limit exchange problems.

3 CONCLUSION

This article proposes the teaching strategy of "analogy anchor": setting up interdisciplinary reference frames in each knowledge module. Analogical thinking, as an important tool for cognitive transfer, has teaching value reflected in: (i) constructing new knowledge through known cognitive schemas; (ii) Promote concept transfer between disciplines; (iii) Cultivate the ability to abstract mathematics (one of the core competencies in mathematics). This cross disciplinary analogy not only concretizes abstract concepts, but also reveals the inherent connections between different branches of mathematics. This study confirms that analogical teaching based on core competencies can effectively break through the teaching bottleneck of real variable functions and provide an operational paradigm for interdisciplinary integration of analytical courses. In the future, we can further explore the systematic application path of analogical thinking in advanced mathematics courses.

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FROM PASSIVE LISTENING TO ACTIVE LEARNING: REFORMING MANAGEMENT INNOVATION EDUCATION TO BOOST STUDENT ENGAGEMENT

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Abstract: Low student engagement has long been a key issue in management education, especially in courses requiring creativity and critical thinking, such as the course of Management Innovation. This study investigated how effectively active learning strategies improved student engagement under these circumstances. The research took place at Guilin University of Aerospace Technology in China from March to June 2025. It used a quasi-experimental design which involved undergraduate students from three business-related majors: Marketing, Human Resource Management, and Logistics Management. One class from each major received teaching reforms focused on student-centered and participatory methods. The remaining classes used the traditional lecture format. Data came from classroom observations, teacher reflections, student assignments, and informal feedback. The findings showed that students in the classes with immediate teaching reforms demonstrated higher levels of behavioral, emotional, and cognitive engagement. They participated more actively, collaborated more effectively, and displayed deeper critical thinking in their coursework. The discussion explained these results through constructivist learning theory and emphasized the alignment between course objectives, assessments, and learning strategies. This study concluded that active learning provides a sustainable and practical solution for improving engagement in management courses focused on innovation. It contributed to the literature on teaching reform in higher education, offering actionable insights for educators and institutions aiming to create student-centered learning environments.
Keywords: Active learning; Student engagement; Management Innovation; Pedagogical reform; Higher education; China

1 INTRODUCTION

In recent years, developing innovation ability has become a central goal of management education, especially in courses like management innovation [1]. These courses strengthen students' grasp of organizational change, strategic renewal, and creative problem-solving skills [2-3]. However, although the importance of innovation keeps growing in both academic and business settings, the course “management innovation” still relies heavily on traditional lecture-style teaching in China. This passive learning approach often fails to spark students' curiosity, motivation, and deep involvement with the subject [4-6].

Low student engagement remains a persistent problem in teaching “management innovation” around the authors teaching experience. While the course content is naturally forward-looking and dynamic, its delivery often involves unidirectional instruction, limited interaction, and insufficiently applying concepts to practical contexts [7]. As a result, students may find the course abstract, too theoretical, or disconnected from actual management challenges. Previous research indicates student engagement strongly predicts learning outcomes, knowledge retention, and cultivating higher-order thinking skills [8-9]. Therefore, exploring teaching strategies that turn students from passive listeners into active participants is essential.

Active learning, recognized as a student-centered teaching method, is widely known to promote deeper thinking, collaborative learning, and better critical thinking [10]. Approaches such as project-based learning, group discussions, flipped classrooms, and case studies are becoming more common in management education, boosting student engagement [11-13]. However, within the specific context of management innovation course, how well these methods work is still not fully explored, especially in non-Western university settings where lecture-based teaching remains dominant [14].

This study aims to address this gap by designing and evaluating a teaching reform project for a management innovation course from a Chinese university. It focuses particularly on improving student engagement through active learning. Based on theoretical insights and practical strategies, the research introduces a mixed teaching model. This model combines flipped classrooms, collaborative group projects, and discussions of real cases. This approach's effectiveness is evaluated through student feedback, classroom observations, and engagement measures [15-16].

Documenting this pedagogical redesign's design, execution, and outcomes, the study contributes to expanding research on management education innovation. It provides real-world evidence for the benefits of active learning in complex, concept-driven courses. It also offers educators seeking to foster deeper student engagement a practical framework they can use. Finally, this study supports a change from passive listening to active learning. This shift aligns educational practice with the dynamic and engaging nature of managing innovation.

2 LITERATURE REVIEW

2.1 Active Learning

Active learning was widely considered a teaching method that placed students at the heart of the learning process. It encouraged them to engage in meaningful tasks, which promoted analysis, synthesis, and evaluation [17]. Unlike traditional lecture-based teaching where students passively absorbed information, active learning expects students to construct knowledge via discussion, problem-solving, and reflection [18]. This approach agreed with Constructivist Learning Theory, which stressed the importance of the learner's active role in creating understanding [18-19].

Research demonstrates active learning enhances students' cognitive engagement, knowledge retention, and critical thinking across disciplines, particularly within management education [6, 20-21]. Common approaches included collaborative projects, classroom debates, simulations, case analysis, and flipped classroom models [22-25]. These techniques not only enhanced understanding of the content but also developed interpersonal and decision-making skills essential for future managers [26-27].

Although active learning was proven beneficial, it remained underused in many higher education settings, especially in courses covering abstract or conceptual subjects like management innovation. Integrating active learning into these contexts needed careful design and adaptation to specific course goals and student characteristics.

2.2 Student Engagement

Student engagement was widely regarded as a critical determinant of effective learning outcomes and academic success in higher education. It referred to the degree of attention, curiosity, and investment students showed in the learning process. This concept included behavioral, emotional, and cognitive dimensions [28-30]. High levels of engagement were associated with improved academic performance, deeper learning, and stronger motivation for lifelong learning [29, 31-32].

In management education, student engagement played a crucial role in helping learners connect abstract theories to real-world practices [11, 22]. However, engagement was often hindered by passive instructional strategies, the perceived irrelevance of content, or a lack of interactive opportunities in the classroom [6, 18]. Scholars emphasized that teaching approaches significantly shaped students' engagement levels. For example, active learning methods were shown to foster greater participation, attention, and intellectual involvement [31-33].

Moreover, the nature of the course itself influenced engagement. Courses like Management Innovation, which involved complex and often abstract concepts, could appear disconnected from students' personal experiences or career aspirations without careful design. Therefore, fostering engagement in such courses demanded intentional teaching strategies that made learning more participatory, relevant, and reflective [11, 34-35].

2.3 The Teaching Reform Trend in Management Courses

Over the past twenty years, management education underwent significant teaching reforms. This initiative sought to connect teaching methods with the evolving business landscape and developing 21st-century skills [36]. The traditional lecture-driven model was increasingly replaced or supplemented by student-centered methods [7]. These comprised experiential learning, case-based teaching, action learning, and flipped classrooms. Researchers prioritized cultivating critical thinking, creativity, collaboration, and solving practical challenges. These abilities were essential core competencies in modern management practice [37].

Business schools and universities around the world adopted various innovative teaching designs. They integrated technology-enhanced learning platforms, interdisciplinary projects, and simulations to encourage deeper student involvement [38-39]. Courses became more interactive. Faculty required students to assume more ownership of learning by engaging in inquiry, reflection, and peer collaboration [40-41].

In emerging economies like China, teaching reforms in management programs made progress. However, challenges remained due to deep-rooted exam-focused traditions and limited resources [42]. Still, a growing number of institutions experimented with blended teaching models. They aimed to stimulate student engagement and foster innovation.

2.4 The Teaching Pain Points of Management Innovation Course

Management innovation course focuses on novel management practices, organizational change, and strategic renewal. Compared to other management subjects, this course presents unique teaching challenges. Its content was often abstract, conceptual, and drew knowledge from many fields, including innovation theory, organizational behavior, and strategic management. As a result, students frequently feel the course lacks concrete application, which lowers their learning motivation and participation.

A key problem seens to be the gap between the theoretical content and students' real-world experiences. This is especially true for undergraduate students who had limited contact with actual organizational environments [43]. Furthermore, the course often do not have enough teaching materials to effectively translate management innovation theory into accessible and interactive forms. Due to time limits or a lack of training in hands-on teaching methods, teachers sometimes depend too much on lectures.

In the Chinese higher education setting, these problems become more serious because of a traditional culture of passive learning and the limited use of real-world cases or collaborative learning platforms [44]. Therefore, student participation remains low, and learning outcomes often show superficial.

2.5 The Research Gap

Past research widely recognized the benefits of active learning and its positive effect on student engagement across different subjects [6, 18]. However, a noticeable gap would exist regarding the application of active learning strategies in management innovation course. Unlike the other courses such as marketing or logistics, this course often involves abstract theorization, cross-disciplinary perspectives, and forward-looking strategic thinking, which makes traditional lecture-based methods particularly inadequate. Current research indicated that abstract and cross-disciplinary characteristics often result in lower student engagement [45]. Moreover， most existing studies on teaching innovations in management education focused on broader topics like leadership, entrepreneurship, or operations management. Less attention was paid to conceptually abstract and cross-disciplinary topics [46].

Furthermore, while some research within the Chinese context highlighted common challenges like passive learning and rigid curricula, few studies explored specific teaching reform strategies designed to improve engagement in innovation management courses [47]. Case-based, project-driven, or flipped-classroom models tailored to innovation topics remain insufficiently evaluated in real teaching contexts. Prior research neglected empirical and applied studies measuring how redesigned methods affect student engagement, interest, and outcomes.

Given the growing emphasis on cultivating innovation capabilities in undergraduate business education, addressing this pedagogical blind spot is both timely and necessary. This study aimed to address this gap by proposing and testing an active learning-driven reform model specifically designed for management innovation education. Its goal was to produce practical insights to guide future course design and teaching practices, especially within the Chinese higher education context.

3 METHOD

3.1 Research Design

This study used a qualitative action research design to explore and carry out teaching innovations designed to improve student participation in the Management Innovation course. Action research is especially suitable for educational reform projects because it allows teachers to make changes in real classroom settings, observe the effects, and think carefully about the results [48]. This study adopted a cyclical process of planning, action, observation, and reflection, lecturer functioning in dual capacities as educator and researcher.

3.2 Research Setting

The teaching reform took place at Guilin University of Aerospace Technology which is a regional undergraduate university in China. The study focused on the Management Innovation course which is a required module for third-year undergraduate students majoring in Marketing, Human Resource Management, and Logistics Management. There is three classes in each of these majors, labeled as Class 1, Class 2 and Class 3, with which having around 45 students.

For this study, Class 1 and Class 3 from each major (Marketing Class 1 & 3, Human Resource Management Class 1 & 3, Logistics Management Class 1 & 3) were picked as the research subjects. All Class 1 from each major served as the experimental group for the teaching reform, where the teaching intervention was used. All Class 3 from each major served as the observing control group and continued with the traditional lecture-based teaching. Therefore, this design created three experimental classes (134 students in total) and three observing control classes (137 students in total), providing a good basis for comparing the effects of the teaching reform.

The same course lecturer taught all participating classes (All Class 1 sections were taught by professor A, all Class 3 sections by professor B). This ensured consistency in teaching content, grading standards, and classroom management. The teaching intervention lasted the whole Spring 2025 semester, from March 1 to June 31, matching the university's academic calendar.

3.3 Core Teaching Intervention

The teaching intervention involved adding active learning strategies throughout the semester for the experimental group. Based on earlier needs assessments and literature reviews, the course was redesigned for the experimental group to reduce passive lectures and increase student participation through several methods, including:

1. Case-based discussions using local and international innovation examples [49].
2. Group action learning projects where students proposed solutions for real-world management innovation situations [50].
3. Role-playing and simulation exercises exploring strategic decision-making in innovation settings [51].
4. Student-led mini-presentations on new trends in innovation practices.
5. Reflection journals requiring weekly entries about learning experiences and team dynamics [52].

All lessons for the experimental group used the Chinese online learning platform Rain Classroom. This platform allowed students to access materials, respond during class, and join discussions outside class time. In contrast, the control group continued with traditional lecture-based teaching, occasionally including teacher-led questions and answers, but without structured active learning activities.

3.4 Data Collection

Because the study was exploratory and practical, no standard end-of-course surveys were used. Instead, data was collected through:

1. Classroom observations by the teaching lecturers, with notes taken during and after lessons for both experimental and control groups [53].
2. Student feedback gathered through informal class discussions and weekly open-ended reflections from the experimental group [41].
3. Review of student work, including group project reports and presentation slides, to find evidence of participation and understanding of innovation [54].
4. Reflective journals kept by the teaching lecturers, recording weekly teaching adjustments, student reactions, and teaching insights [55].

This method of using multiple qualitative sources allowed for triangulation of the data, helping to ensure the findings were trustworthy and credible [56-57].

3.5 Data Analysis

The collected qualitative data was analyzed using thematic analysis, following the steps described by Braun and Clarke [58]. First, the data was coded inductively to find patterns related to student participation, engagement behaviors, and learning attitudes. Then, these patterns (themes) were grouped into broader categories like cognitive engagement, collaboration, and emotional engagement. NVivo software helped organize and manage the coding process. Comparisons were made between the experimental and control groups to highlight differences in participation patterns resulting from the teaching intervention. The lecturers' reflections further supported the interpretation and helped explain the situational factors affecting student behavior.

3.6 Ethical Considerations

This study followed ethical guidelines for classroom research. At the start of the semester, students were informed that the course involved a teaching experiment for research purposes and gave their verbal agreement. Students were not told specific details about the teaching reform by preventing them from acting more engaged than usual on purpose of pleasing the teacher. No personally identifiable information was used in the analysis or reporting. The research process did not focus on individual students and did not affect student grades outside the normal course assessment, regardless of participation or not.

4 FINDINGS

4.1 Overview of Student Engagement Outcomes

Following the teaching reforms implemented from March to June 2025, student engagement showed a significant improvement in the experimental group compared to the control group. These reforms focused on active learning strategies, which led to more lively class participation, increased interest in project-based assignments, and gave students greater independence during collaborative activities.

In contrast, the control group, which continued with traditional lecture-based teaching, demonstrated relatively lower levels of engagement, limited peer interaction, and a less proactive approach to learning. Classroom observations by teachers, patterns of assignment completion, and informal student feedback all indicated that the revised teaching methods created a more engaging learning environment. These findings suggested that the teaching innovation effectively addressed the engagement challenges identified earlier and set the stage for deeper exploration of changes in student learning behavior.

4.2 Increased In-Class Interaction

One of the most significant improvements observed in the experimental group was the increased student participation in classroom activities. Unlike the control group, where students mostly remained passive and hesitant when answering questions, students in the experimental group actively joined class discussions, case analyses, and brainstorming sessions. The integration of interactive teaching methods, such as think-pair-share, scenario simulations, and group-based problem-solving, encouraged students to express their own views and challenge each other's ideas.

Teachers reported a noticeable increase in voluntary participation, with more students asking questions and contributing to group discussions. Classroom observation records showed that the number of student-to-student and student-to-teacher interactions per class in the experimental group was more than double that in the control group. Furthermore, students demonstrated higher levels of focus and frequently actively connected course content to real-world business cases, especially in lessons involving innovation case studies.

These changes indicated a shift from passive listening to active involvement. This shift not only enhanced the classroom atmosphere but also cultivated critical thinking and communication skills. The success of this shift highlighted the value of active learning strategies in promoting deeper engagement and more meaningful classroom experiences within management education.

4.3 Improved Assignment and Project Participation

Besides increased classroom interaction, the experimental group also made significant progress in completing assignments and course projects. Unlike the control group students, who usually finished assignments passively or with minimal effort, the students in the experimental class showed higher levels of interest, creativity, and dedication. This difference was especially clear in the mid-term and final project tasks. These tasks required students to design innovative management solutions for actual or hypothetical business problems.

Students in the experimental group had more freedom when handling these tasks. They often went beyond the basic requirements by conducting interviews, integrating knowledge from different subjects, and using multimedia tools to present their findings. Compared to the outputs from the control group, project submissions were generally more detailed and better structured, showing deeper analytical thinking.

Furthermore, the group dynamics within the experimental group improved noticeably. Students demonstrated stronger collaboration and more effective division of responsibilities. Records from peer assessments and informal teacher evaluations confirmed higher levels of participation and cooperation. In contrast, students in the control group tended to rely on individual effort. They showed limited coordination with peers, resulting in project work that lacked cohesion and insight. These results indicated that the teaching reform not only encouraged classroom participation but also successfully extended students' active learning behaviors beyond the classroom environment.

4.4 Enhanced Peer Collaboration and Initiative

Another significant outcome of the teaching reform was a clear increase in peer collaboration and student initiative. In the experimental group, students showed a greater willingness to work with classmates, took leadership roles in group tasks, and actively contributed to shared learning goals. This change was mainly due to the use of collaborative learning strategies, such as group case competitions, peer reviews, and cross-functional team assignments. Throughout the semester, students in the experimental class often formed self-organized discussion groups after class, shared learning resources, and coordinated their preparation for presentations. Teachers noted that students spontaneously rotated roles within teams, such as discussion leader, researcher, and presenter, which promoted mutual accountability and shared leadership.

What was more noteworthy was something unexpected that happened in Marketing Class 1 during the experiment. When the teacher started a small project, the students in Marketing Class 1 independently proposed a challenge highly relevant to their professional interests: analyzing management innovation in short video advertisements on TikTok platform. In the control group, this level of initiative was largely absent, as learning remained more teacher-centered with less interaction. The growth in peer collaboration and initiative not only enriched the learning experience but also developed key soft skills highly valued in management innovation education, such as teamwork, self-direction, and entrepreneurial thinking.

4.5 Summary of Key Outcomes

In summary, the use of active learning strategies in the management innovation course clearly improved student involvement in several ways. Students in the experimental group showed higher levels of classroom interaction, participated in assignments and projects more thoughtfully and actively, and displayed greater initiative in peer collaboration. These results presented a clear difference compared with the control group, where traditional lecture-based teaching led to lower involvement and limited collaborative activities. Overall, the teaching reform effectively addressed the involvement challenges previously identified in the course. Evidence collected from teacher observations, student feedback, and performance records highlighted the value of shifting from passive to active learning methods. These findings not only supported the reform approach but also offered practical insights for wider use in management education.

5 DISCUSSION

The findings of this study provided convincing evidence that active learning strategies significantly improved student engagement in the Management Innovation course. By moving beyond traditional lecture-based teaching and integrating interactive, student-centered methods, the course successfully transformed the learning environment from passive reception to active involvement.

5.1 Linking Active Learning to Constructivist Theory

The positive results observed in the experimental group were closely connected to the constructivist learning theory. This theory emphasizes that learners actively build knowledge through experiences, interaction, and reflection [59]. The increase in classroom interaction and peer collaboration aligned with Vygotsky's social constructivism[59], which highlights the importance of social context and cooperative dialogue in cognitive development. Through methods like case discussions and group problem-solving, students did not just absorb information. They worked together to build understanding and applied theory to practice, which was a key part of meaningful learning.

5.2 Redefining Engagement in Management Education

In the context of management education, engagement meant more than just paying attention; it included emotional, behavioral, and cognitive involvement in the learning process [60]. The teaching reform strengthened all three aspects. Behaviorally, students participated more in class and group activities. Emotionally, they showed greater interest and motivation, especially when working on projects related to their career goals. Cognitively, they demonstrated deeper processing by connecting theoretical knowledge to real-world innovation challenges. These changes represented a comprehensive improvement in student engagement, essential for developing future professionals who can think critically, collaborate effectively, and innovate continuously.

5.3 Implications for Course Design

The success of the reform suggested that courses like Management Innovation should prioritize experiential and inquiry-based learning methods. Traditional lectures often failed to meet the expectations of today's digitally literate and career-focused students [61]. Instead, educators should consider redesigning courses to include collaborative projects, real-world case analysis, peer assessment, and formative feedback cycles [62]. These strategies not only maintained engagement but also developed practical abilities in communication, leadership, and innovation. Furthermore, this study highlighted the importance of aligning assessment tasks with the course's experiential learning approach. Students in the experimental group were more engaged when assignments allowed for creativity, autonomy, and real-world relevance. This indicated a need for more authentic assessments that went beyond tests and essays, such as innovation proposals, group presentations, and design thinking challenges.

5.4 Limitations and Sustainability

Although the reform achieved positive results, it was not without limitations. First, this study did not include formal survey tools or long-term impact evaluations. Future research could benefit from mixed methods, combining qualitative insights with quantitative measures like engagement scales or academic performance comparisons. Second, the successful implementation of active learning depended heavily on instructor capability and student readiness. Some students might resist participation initially, especially if they were used to passive learning styles. Therefore, gradual adaptation and scaffolding strategies were necessary. To ensure sustainability, institutional support was crucial. This included teacher training, flexible classroom environments, and a culture that valued teaching innovation. Without this structural support, active learning risked becoming a temporary effort rather than a lasting reform.

6 CONCLUSION AND IMPLICATIONS

This study aimed to address the persistent challenge of low student engagement in management innovation course by introducing reforms based on active learning principles. Through a comparative intervention conducted in a Chinese undergraduate setting, the findings confirmed that shifting from passive listening to active participation significantly improved student engagement, collaborative learning, and classroom dynamics.

The integration of case-based discussions, project-driven assignments, and peer collaboration enable students to take charge of their own learning process. Compared to traditional lecture-centered classrooms, the reformed teaching methods cultivate higher levels of behavioral, emotional, and cognitive engagement. This alignes with the goals of management education for the 21st century.

The implications for educators would be both practical and strategic. At the classroom level, instructors are urged to reconfigure their instructional methods to incorporate more interactive and learner-focused activities. They also need to align learning objectives, tasks, and assessments. At the institutional level, universities should have supported such reforms through professional development, resource allocation, and evaluation systems that recognized teaching innovation.

Furthermore, this study adds support to the existing literature in related fields. These literatures argued for redefining the issue of student engagement in business and management education, particularly within the Asian higher education context [14]. It also highlights the need for future research to explore long-term effects, include multi-dimensional engagement indicators, and investigate how different learner profiles responded to active learning environments.

In conclusion, improving student engagement in management education requires more than just content delivery. The success of this reform shows that, through thoughtful design and committed implementation, active learning could create a more dynamic, inclusive, and effective learning experience for students.

COMPETING INTERESTS

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

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A SELF-EVALUATION SYSTEM FOR INDIVIDUAL LEARNING OUTCOMES OF COLLEGE STUDENTS BASED ON THE FIVE-EDUCATIONS WITH QUANTITATIVE SUPPORT

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Abstract: A questionnaire survey was conducted among 348 college students, 68 teachers and 63 business people from outside Guangdong Technology College. Reliability analysis and inductive analysis of the data were carried out through the 4th Generation Statistical Analysis Software (SPSSAU), and "five educations" were identified as the primary indicators. The individual evaluation system for college students, which consists of 14 basic elements (secondary indicators) and 26 literacy elements (tertiary indicators), was verified among some undergraduate students of Guangdong Polytechnic. The evaluation system basically covers all aspects of college students' study and life during their school years. It can combine process evaluation (semester evaluation) with summative evaluation (academic year evaluation), qualitative evaluation (qualitative elements) with quantitative evaluation (quantitative supporting elements), and incentives with guidance (explanations of bonus and deduction points). It is simple and easy to implement and conducive to promotion.
Keywords: Individual college students; Evaluation system; Quantification; Learning outcomes

1 INTRODUCTION

In the design and implementation of the evaluation system for college students, it is essential to comprehensively reflect the all-round development and individual characteristics of students in the context of the "five-pronged education" (morality, intelligence, physical fitness, aesthetics, and labor education). This should also incorporate students' subjective awareness and objective self-understanding, as well as illustrate the process of their development and the achievements they have attained. By doing so, the incentive and guiding functions of educational evaluation can be fully realized.In accordance with the requirements of college students' cultivation goals, the evaluation system should be structured around the "five-pronged education". The core competencies of college students' development should be further refined into multiple evaluation criteria. Emphasis should be placed on integrating formative evaluation with summative evaluation, qualitative assessment with quantitative measurement, and incentives with guidance.Maximizing the effectiveness of the college student evaluation system is contingent upon a scientific evaluation framework and an efficient evaluation mechanism. However, the subjective awareness and self-cognition of individual college students remain pivotal in this process.

2 RESEARCH BACKGROUND AND SIGNIFICANCE

The Overall Plan for Deepening the Reform of Education Evaluation in the New Era proposes that education evaluation should "adhere to the effectiveness of moral education as the fundamental criterion", and sets out the basic task of "innovating the process evaluation methods of morality, intelligence, physical fitness, aesthetics and labor, and improving the comprehensive quality evaluation system". From the perspective of individual evaluation of college students, learning outcomes should include both the comprehensive and integrated effects required by the training objectives and the effects of individual development and innovation. In the past, the evaluation of college students had problems such as incomplete connection between the evaluation content and the requirements of the training objectives, simply replacing individual evaluation with group evaluation, obvious utilitarian orientation of the evaluation purpose, insufficient exertion of the incentive and guiding functions, virtual moral evaluation, single intellectual evaluation, and weakened evaluation of physical, aesthetic and labor education. Therefore, in-depth research and implementation of comprehensive evaluation under the framework of individual "five educations" for college students is an urgent requirement to implement the modern educational evaluation concept and promote the reform of higher education evaluation, especially the student evaluation model.

Student evaluation is at the core of school education evaluation. Improving the elements of individual comprehensive evaluation of college students and constructing an evaluation system that fully and truly reflects learning outcomes is of great significance for giving full play to the incentive and guiding functions of education evaluation, promoting the all-round development and individual expression of students, and fulfilling the fundamental task of fostering virtue and nurturing talent[1-2]. At the same time, the reform of the student evaluation model plays an important role in promoting educational and teaching reform, improving the quality and level of school operation, and meeting the practical requirements of society for the selection of talents. The individual evaluation of college students should change the simple quantitative and vague qualitative evaluation model, build a learning effect evaluation system that promotes the attainment of the five education standards and individual development, and conduct practical verification[3-4].

3 RESEARCH DESIGN AND IMPLEMENTATION

3.1 Basic Ideas of the Research

College student evaluation can be divided into group evaluation and individual evaluation. From the perspective of the goal of cultivating virtue and nurturing talents, college student evaluation should ultimately be implemented in individual evaluation. Group evaluation is aimed at the overall development of college students and is applicable to the evaluation of the level of college students in higher education institutions. It is characterized by integrity, hierarchy and utilitarianism. Individual evaluation is targeted at individual college students, with the basic requirement of meeting the Five-educations. It is applicable to the evaluation of individual development of college students and has the characteristics of individuality, development and non-utilitarianism. The attainment of the Five-educations is a common requirement for the group of college students, a prerequisite and foundation for individual development, and individual development is a reasonable extension of the attainment of the Five-educations, an important condition for innovation and creation[5-6]. Individual evaluation of college students should establish a complete and effective evaluation system based on the attainment of the five aspects of education, should reflect the internal logic and interaction of the five aspects of education, should be based on self-evaluation by students, should reflect the mutual corroboration of qualitative evaluation and quantitative evaluation, and should have the operability of common evaluation plus individualized adjustment evaluation. The evaluation results should be conducive to guiding autonomous learning and self-development, and provide references for schools' operation and society's selection of talents.

The individual evaluation of college students should, on the basis of meeting the Five-educations standards, respect and guide students to enhance their sense of autonomy and encourage creative development. This is both a requirement of the goal of cultivating virtue and nurturing talent and a regular requirement of the individual development and evaluation of college students[7]. The "five educations" involve the qualities of ideals and beliefs, physiology and psychology, thinking level, learning ability and practical creation in the individual development of college students. They are independent of each other and influence and support each other as a whole[8]. The principles that should be followed in the design of the evaluation system are: to implement modern educational evaluation theories and embody the concept of development evaluation; Reflect the core literacy requirements for college students' development, and demonstrate the internal logic and interaction of the "five educations"; Highlight the positive guiding function of individual evaluation of college students, and show the individual development process and potential of college students; Reflect the interlocking and corroboration of qualitative and quantitative elements; The evaluation elements are composed of what to do and what not to do to facilitate actual operation and practice.

3.2 Formulation of the Evaluation Index System

The basic framework of the Five-educations evaluation index system was designed by referring to the literature and taking advice from experts within the school. Questionnaires were conducted among 348 college students, 68 teachers of Guangdong Technology College and 63 business people outside the school. Reliability analysis of the collected data was carried out through the 4th Generation Statistical Analysis Software (SPSSAU). Through semi-structured interviews, online interviews and key case studies, the data from the questionnaires and interviews were summarized and analyzed to determine the individual evaluation system for college students (Table 1), with moral, intellectual, physical, aesthetic and labor education as the primary indicators and 14 basic elements such as ideological and political, knowledge and skills, physical health as the secondary indicators. Twenty-six quality elements, including life ideals and moral identity, are the third-level indicators. Weights are assigned to each level of indicators, and qualitative and quantitative supporting elements are set for each level of indicators.

Table 1 Evaluation Form for Individual Learning Outcomes of College Students (Experimental Version)

Five educations (Score)	Basic elements (fractions)	Literacy elements (points)	Qualitative elements	Quantitative supporting elements (abbreviated)	Points added or deducted
Moral education (30 points)	Ideological and political (8 points)	Life ideals (3 points)	Life ideals and value judgments	Career planning, postgraduate entrance examination, ideological and political course qualification	Receiving scholarships, being awarded as an advanced individual, etc. can add points
		Social responsibility (3 points)	Fulfill the mission and take on responsibilities	Group activities, social research, voluntary blood donation	Bonus points for winning an activity, minus points for not participating in a group activity
		Abide by the rules	Democracy, rule of	Do not be late or	Points will be added for

Five educations (Score)	Basic elements (fractions)	Literacy elements (points)	Qualitative elements	Quantitative supporting elements (abbreviated)	Points added or deducted
		(2 points)	law and sense of rules	skip classes, do not copy homework, do not cheat in exams, and pass the rule of law course	winning relevant activities or competitions, while points will be deducted for illegal acts, cheating, truancy, etc
	Civilized progress (8 points)	Moral cognition (4 points)	Moral concepts and value recognition	Identify with the core socialist values and social morality	Relevant behavior will earn extra points
		Civilized behavior (4 points)	Public morality and behavioral habits	Reason, hygiene, good behavior	Providing evidence of doing good deeds earns extra points, while frequent waste and wearing slippers to class deduct points
	Social participation (8 points	Social identity (4 points)	National identity and cultural identity	Expressed identification with national identity and the excellent culture of the nation	Additional points will be given for supporting evidence
		Social service (4 points)	Practical experience and contribution to society	Volunteer service, social welfare, community service	Bonus points can be added for winning or being awarded in activities
	Self-development (6 points)	Personal strengths (3 points)	Innovative experiences and achievements	Competitions, performances, project research, clubs	Innovative achievements such as winning awards, applying for patents, publishing papers, etc. are added points
		Self-management (3 points)	Self-awareness and self-restraint	Have a study plan	Extra points for positions such as student leader, student information officer, club leader, etc
Intellectual Education (26 points)	Cultural foundation (8 points)	Humanistic background (4 points)	Cultural knowledge and humanistic sentiment	Self-reading habits, borrowing of humanities books, participation in related activities	Bonus points for winning awards in related activities and having related test works
		Scientific spirit (4 points)	Advocate true knowledge and rational thinking	Have scientific thinking, have raised questions and analyzed scientifically and reasonably	Participation in scientific research or technical research can earn extra points
	Knowledge and skills (12 points)	Comprehensive knowledge (4 points)	Knowledge breadth and thought depth	Complete the required credits and meet the standards for public course grades	30% of the total class ranking, bonus points for obtaining non-professional qualification certificates, and deduction points for failing courses
		Professional knowledge (4 points)	Professional knowledge and learning application	Complete credits and professional course grades	Bonus points for ranking in the top 30% of the class in major courses, minus points for failing major courses
		Professional skills (4 points)	General skills and professional skills	Experimental training and skills competitions	Bonus points for obtaining professional skill certificates and winning competitions
	Self-study (6 points)	Enjoy learning and be good at learning (3 points)	Learning interest and learning literacy	Classroom interactions, lectures, learning clubs, library learning records	Bonus points for participating in science and technology, innovation and entrepreneurship activities, lectures, and learning clubs
		Self-improvement (3 points)	Self-management and self-reflection and self-confidence	Offline self-study, online learning	
Sports	Good health (8	Physical fitness (4 points)	Athletic interest and athletic will	Physical education class grades,	First aid skills earn extra points

Five educations (Score)	Basic elements (fractions)	Literacy elements (points)	Qualitative elements	Quantitative supporting elements (abbreviated)	Points added or deducted
(24 points)	points)			physical fitness test scores	
		Participation in sports (4 points)	Motor skills and scientific exercise	Extracurricular sports, sports competitions	Participating in sports competitions and winning awards, sports meeting bonus points
	Sound personality (8 points)	Self-confidence and self-love (4 points)	Attitude towards life and mental state	Upward, inquisitive, communicative, generous and comforting others	
		Psychological adjustment (4 points)	Self-regulation and mental health	Adaptability, stress relief ability	Having relevant qualifications is a plus
	Love life (8 points)	Healthy living (4 points)	Health awareness and rational consumption	Cherish life, pay attention to health, use medicine properly, consume civilly	
		Good habits (4 points)	Self-regulation and habit formation	Have good study, exercise and sleep habits, and do not stay up late or sleep in	
Aesthetic Education (10 points)	Aesthetic taste (6 points)	Aesthetic taste (6 points)	Aesthetic cognition and aesthetic taste	Aesthetic interest and the ability to discover beauty	Having related works will add points
	Aesthetic experience (4 points)	Aesthetic experience (4 points)	Aesthetic practice and aesthetic outcomes	Aesthetic exhibition, aesthetic creation	Awards for calligraphy, painting, design, etc., patent design, etc. will be added points
Labor Education (10 points)	Labor cognition (6 points)	Labor cognition (6 points)	Labor value and labor identity	Labor courses, daily labor	Points will be deducted for failing labor courses
	Labor experience (4 points)	Labor Experience (4 points	Labor practice and labor outcomes	Participating in labor, labor outcomes	Those who have been awarded the title of "Advanced Individual in Hygiene", "Civilized Dormitory Head", "Civilized Dormitory Member", or have won awards in the Labor Skills Competition will be given bonus points

3.3 Implementation of the Evaluation Index System

The purpose of the empirical study is to test whether the evaluation system can reflect modern educational evaluation concepts and methods and effectively solve the predicaments in student evaluation; Whether it can be understood and accepted by students, and provide them with methods of self-awareness and evaluation, so as to better play the main role in educational evaluation; Can it reflect the objectivity of student evaluation and the effectiveness of its motivational and guiding functions; Whether it is convenient and practical, simple and easy to implement, and conducive to promotion.

Randomly select Class 3 of the 22nd grade of the Finance Management major and Class 3 of the 24th grade of the Environmental Design major at Guangdong Technology College to distribute the "Individual Learning Effect Evaluation Form for College Students (Experimental Version)" offline. A total of 83 questionnaires were distributed and 82 were retrieved, with a recovery rate of 98.8%. Among them, 48 from Class 3, Grade 22 of the Finance Management major, accounting for 58.5%, and 34 from Class 3, Grade 24 of the Environmental Design major, accounting for 41.5%. In addition to the content of the evaluation system, five additional questions were given to further listen to students' opinions and suggestions on the evaluation system.

4 RESULTS ANALYSIS

4.1 Questionnaire Reliability Analysis

Cronbach reliability analysis indicated that the *Cronbach α* coefficient was 0.906, greater than 0.8, suggesting high reliability quality of student self-assessment data, which could be used for further analysis and research.

4.2 Total Score of Student Self-Assessment and Analysis

Table 2 results show that students' total self-assessment scores are hierarchical, with less at both ends and more in the middle, and the situation of inflated scores in previous evaluations is not obvious. Eight students rated themselves 100 points, accounting for 9.76%; 70 people scored between 70 and 99, or 85.36 percent; Four people scored between 60 and 69, accounting for 4.88%; None of the students rated their total score as failing, which is in line with the actual situation of the students that the teachers have in mind. It indicates that students basically understand the content of the evaluation system, have a relatively normal mindset during self-evaluation, have less arbitrariness, and have a certain degree of objectivity in self-evaluation. At the same time, it is also indicated that the evaluation index points adopted in the evaluation system have both qualitative evaluation guidance and quantitative evaluation support methods, which are reasonable and feasible in practice.

Table 2 Summary of Students' Self-assessment

Statistical items	Full marks	Minimum score	Converted points	Number of full marks and proportion		(Converted) 90-99 points and proportion		(Converted) 80-89 points number and proportion		(Converted) 70-79 points and proportion		(Converted) 60-69 points and proportion		(Converted) The number of people who failed and the proportion	
Total score	100	61	61	9	10.98%	32	39.02%	22	26.83%	15	18.29%	4	4.88%	0	0
Moral education	30	20	66.7	19	23.17%	29	35.37%	22	26.83%	11	13.41%	1	1.22%	0	0
Intellectual education	26	9.5	47.5	16	19.51%	14	17.07%	21	25.61%	12	14.63%	11	13.41%	8	9.76%
Sports	24	13	54	24	29.27%	20	24.39%	14	17.07%	17	20.73%	6	7.32%	1	1.22%
Aesthetic Education	10	4	40	49	59.76%	2	2.44%	26	31.71%	0	0	4	4.88%	1	1.22%
Labor education	10	4	40	64	78.05%	0	0	9	10.98%	1	1.22%	7	8.54%	1	1.22%

4.3 Additional Questions Student Evaluation and Analysis

The additional questions included five questions: the content of the index system, the weight of the index system, the bonus points of the index system, whether the deduction points of the index system were reasonable, and whether the students' self-evaluation was meaningful. It was clear that students could freely choose whether to fill in or not, and all students chose optional filling. Table 3 shows that 93.90 percent of students consider the content and weights of the evaluation index system to be very reasonable and relatively reasonable overall, and 6.10 percent think that some indicators or weights need to be adjusted. The design of adding and subtracting points on the basis of the basic score for the index system is considered reasonable by most students. It can be seen that the overall design of the index system is in line with the wishes of the majority of students and is supported by the vast majority of students.

Table 3 Evaluation Statistics Table of Additional Questions

Evaluation content	Very reasonable		Fairly reasonable		Basically reasonable		Some unreasonable		Basically unreasonable	
Index System content	28	34.15%	49	59.75%	0	0	5	6.10%	0	0
Metric system Weights	21	25.61%	56	68.29%	0	0	5	6.10%	0	0
Design for bonus points	31	37.80%	44	53.66%	2	2.44%	5	6.10%	0	0
Design for deduction	29	35.36%	42	51.22%	7	8.54%	4	4.88%	0	0

It is worth noting that when answering the question "Is the self-evaluation of students meaningful?", 86.59% of the students thought it was very meaningful, and 9.76% thought it was relatively meaningful. This clearly demonstrates the students' autonomous awareness and high attention to evaluating their own learning outcomes. However, 3.66% of students thought it was dispensable, showing a low level of concern or indifference. The reasons might include insufficient understanding of the role of self-evaluation, insufficient engagement in self-study leading to poor academic performance in the course, less participation in the "five educations" practice, and few learning outcomes available for display, and it is not ruled out that "the evaluation of students' learning outcomes is ultimately decided by the teacher.

The view that self-evaluation is unnecessary for students. The fact that no student considers self-evaluation meaningless indicates that the majority of students highly recognize and actively participate in the college student evaluation system that increases self-evaluation.

4.4 Analysis of the Five Aspects of Students' Self-Evaluation Results

The following analysis can be made by comparing the differences in the number, proportion, and score of evaluation points (i.e. literacy elements) of students' self-assessment of the "five educations" category with a converted score of more than 80 points:

1. 70 students scored 80 or above in moral education self-assessment, accounting for 85.37%. There were significant differences in the scores of the nine literacy elements, and the proportion of self-assessment full marks was as follows: Social identity (96.34%) > Compliance with law (90.24%) > moral perception (86.59%) > civilized behavior (84.15%) > social responsibility (65.85%) > self-management (62.20%) > social service (54.88%) > life ideals (45.12%) > personal strengths (39.02%). Among them, social identity and law-abiding accounted for more than 90%, and moral cognition and civilized behavior accounted for more than 80%, indicating that students attach great importance to social identity, have a correct level of cognition and strong self-confidence in terms of moral cognition and civilized behavior, and have the self-restraint ability of basic behavioral norms. Students' self-assessment in terms of life ideals, social responsibility, social service, and self-management is relatively scattered, indicating that most students have certain ideal pursuits, recognize social responsibility and social service, but a few have problems of vague cognition and insufficient action in actual implementation. Less than 40 percent of students rated their strengths above 80, indicating a low proportion of students who recognize and fully utilize their strengths. Some students are rather cautious in evaluating their strengths, fail to see their strengths or have a dependent "lying flat" mentality, lack of confidence and practical training in self-development, which may deviate from personal perception, and have weak initiative in participation. It is related to the relatively weak abilities. Schools should encourage students to develop hobbies and participate in group activities through evaluation feedback, and guide them to engage in practical innovation to discover and play to their strengths.
2. Fifty-two students scored 80 or above in their self-assessment of intellectual education, accounting for 63.41%. The self-assessment full score ratios for the seven evaluation points were relatively close but generally lower than those for morality, physical education, aesthetics, and labor, in the following order: self-improvement 65.85% > comprehensive knowledge 57.32% > professional skills 56.10% > love of learning 53.66% > professional knowledge 46.34% > humanistic background 42.68% > scientific spirit 34.15%. Among them, self-improvement, comprehensive knowledge, professional skills, and love of learning accounted for more than 50%, indicating that college students generally recognize the importance of autonomous learning, hold a positive attitude towards self-improvement, and most students have a relatively high level of confidence in professional skills, and most students' learning attitudes, learning methods, and learning effects meet the basic requirements. The proportion of students who scored full marks in professional knowledge, humanistic background and scientific spirit is less than 50%, indicating that most students have a positive attitude towards the cultivation of humanistic background and scientific spirit literacy and are basically adapted to professional learning, but some students find themselves lacking in the breadth and depth of knowledge and the rigor of learning attitude. The overall self-assessment score of intellectual education is relatively low, which may be related to the insufficient learning engagement of some students and quantitative evaluations such as course assessment results. Schools should pay close attention to the relevant curriculum, and teachers should guide students to improve their autonomous learning ability through measures such as improving teaching and educational methods, enhancing the attractiveness of classroom teaching, and improving assessment methods.
3. 58 students scored 80 or above in physical education, accounting for 70.73%. There was little difference in self-assessment scores among the six evaluation points. The proportions of full marks for self-assessment were as follows: healthy living 78.05% > self-confidence and self-love 73.17% > psychological adjustment 59.76% > living habits 57.32% > physical literacy 54.88% > participation in sports 47.56%. Among them, the evaluation indicators such as self-confidence and self-love, healthy living, accounted for more than 70%, indicating that the majority of students highly recognized self-confidence and self-love, had a generally good cognition of physical and mental health and basic life attitude, had a high degree of love for healthy living, paid attention to physical and mental health and could put it into practice; The proportion of evaluation indicators such as psychological adjustment, living habits, and physical literacy exceeded 50%, indicating that the majority of people recognized and actively participated in physical literacy and psychological adjustment ability; The proportion of students participating in sports was less than 50%, with 29.3 percent of students scoring less than 80 in their self-assessment of sports, indicating that some students have deficiencies in sports participation, which may be related to personal cognition, academic pressure, sports organization methods and sports atmosphere. Guidance should be strengthened in areas such as raising awareness, sports organization, and the cultivation of good living habits.
4. 78 people scored 80 or above in their self-assessment of aesthetic education, accounting for 95.12%. There were significant differences in the self-assessment scores of the two evaluation points. Among them, 90.24% of the students self-assessed full marks for aesthetic taste, while only 63.41% self-assessed full marks for aesthetic experience. This phenomenon indicates that the majority of students have basic aesthetic awareness and confidence in their own aesthetic cognition and aesthetic taste, but only a few students have participated in different forms of aesthetic experience, and the proportion of those who have participated insufficiently or have no relevant results is small, which may be related to

personal initiative, academic pressure, and fewer opportunities for related activities. Schools should increase the intensity of aesthetic education, focus on integrating college students' aesthetic sense with professional learning, campus cultural activities, daily life and social participation, organize aesthetic experience activities through various channels, cultivate aesthetic taste, and guide college students to improve aesthetic literacy.

5. 73 students scored 80 or above in labor education, accounting for 89.02%. There was little difference in the self-assessment scores for the two evaluation points, which were 84.15% for labor cognition and 82.93% for labor experience. Based on the current situation of students' participation in daily labor, internships and practical training, innovation practice and social practice, it shows that the correct labor values of the majority of college students have basically formed, and they are willing to realize their own value through labor. The vast majority can voluntarily participate in daily labor experience, and some students perform outstandingly in applied research, science and technology competitions and social service labor practice. There are some positive labor outcomes. At the same time, some students' understanding of the value of labor is not accurate and profound enough, and they participate less in innovative labor and social labor experience, which may be related to a lack of initiative, negative influence from family and society, and insufficient support from related conditions. Conditions should be actively created to encourage more students to give full play to their strengths, combine learning with labor practice innovation, improve cognition through labor, and achieve positive labor results.

5 DISCUSSION

5.1 There are Differences in Self-Assessment among Students of Different Majors

Studying the differences in self-assessment among students of different majors has practical significance for student evaluation. In the practice of student evaluation, the basic evaluation indicators and weights can be adjusted in combination with the characteristics of different majors to make the evaluation more in line with the actual situation of students of relevant majors, thereby generating more direct incentives and guidance. Statistics show that the self-assessment scores of aesthetic education and labor education of students in the two majors are relatively close. The differences are mainly reflected in the fact that students majoring in financial management pay more attention to moral education, while those majoring in environmental design pay relatively less attention, which may be related to the background of the major or the curriculum of the major; Environmental design students scored significantly lower in self-assessment of intellectual education than financial management students, had a lower score in humanistic background, and had a higher score in scientific spirit, which may be related to the curriculum and the students' focus on learning. Environmental design students rated lower than financial management students in terms of consistent participation in sports, but higher than financial management students in terms of psychological adjustment, which may be related to the learning burden and pressure; In terms of aesthetic taste and experience, environmental design students show a stronger sense of identity and engagement, which may be related to more opportunities for aesthetic practice in professional courses and professional practice. The differences in self-assessment between students of the two majors should be related to the differences in the perspective of professional thinking, the actual learning pressure faced, the future employment expectations, etc. There are differences in the political and academic cognition, thinking methods and sports participation among students of different majors. This leads to differences in the psychological state of self-evaluation. It should be noted that these differences are objectively existent, but the contradictions and differences can be resolved by correctly understanding the relationship of the Five-educations and rationally planning college life. The key lies in the establishment of individual ideal goals and active participation behaviors, as evidenced by a group of outstanding college students who have achieved remarkable results in the Five-educations and individual development in reality.

5.2 Students' Self-Assessment of Low Scores Deserves Attention and Analysis of the Reasons

It is normal for some students to have lower scores in group evaluations, but for individual evaluations of students, low scores deserve special attention. It is often considered normal for a student class to have 10% failing in a certain course assessment, but for the individual students in the 10%, it means 100% failing. According to Table 1, nearly 15% of students scored below 80 in moral education, 37.80% scored below 80 in intellectual education, and 9.76% failed in self-assessment. Nearly 30 percent of physical education students scored less than 80 points, and there were also cases of self-assessment failure in aesthetic and labor education. This phenomenon is characterized by distinct personality traits and is somewhat representative. Among the 26 evaluation points of the Five-educations, low scores of 0-0.5 for students' self-assessment occurred in six evaluation points, namely: personal strengths, scientific spirit, comprehensive knowledge, professional knowledge, professional skills and aesthetic experience. The reasons for this phenomenon may be multifaceted. From the perspective of students, some college students have problems and difficulties in certain aspects, such as lack of self-awareness and confidence, low learning attitude, insufficient learning motivation, improper learning methods, etc. From the perspective of the student evaluation model, due to the use of qualitative evaluation plus quantitative support, some students who do not meet the quantitative data standards give themselves low scores. In terms of the purpose of the evaluation, the feedback of the evaluation results can serve as a warning, guiding students to reflect on themselves, face positively, and improve.

6 CONCLUSIONS AND PROSPECTS

6.1 Conclusions

The study of the evaluation system for individual learning outcomes of college students is an objective requirement for the comprehensive promotion of evaluation innovation in higher education, to achieve the goal of fostering virtue and nurturing talent, and to comprehensively enhance the core literacy of college students on campus, it is necessary to fully consider the laws of individual development and evaluation of college students as well as the technical feasibility. The empirical study, using the evaluation index system and students' self-evaluation data, conducted a comprehensive analysis of students' overall self-evaluation scores and classified self-evaluation of "five educations". The experiment was generally successful, verifying the rationality of the index system from multiple aspects and achieving the expected goals.

The main conclusions of the empirical research are as follows: First, the index system reflects the modern educational evaluation concept. The evaluation content and methods have been recognized by the vast majority of students participating in the experiment, creating conditions for college students to play the role of the evaluation subject. Second, by combining the all-round development of the five aspects of education with the encouragement of individual development of students, by integrating process evaluation with summative evaluation, and by integrating qualitative evaluation with quantitative evaluation, it has better solved the problems existing in previous student evaluation. Third, from the perspective of students' self-evaluation scores, quantitative data support qualitative conclusions, and the integration of bonus and deduction points basically solves the problem of inflated evaluation scores, enhances the objectivity of evaluation, and is more conducive to improving students' self-awareness and the effectiveness of the incentive and guiding functions of educational evaluation; Fourth, the evaluation system is relatively comprehensive in content, clear in logic and reasonable in design, basically achieving the goal of being easy to understand and convenient to use. Fifth, the evaluation is not primarily aimed at ranking students. It strengthens the role of students' self-evaluation, reduces the subjectivity and blindness of teachers and administrators in student evaluation, achieves objective evaluation, enhances the credibility of evaluation results and makes them publicly available to a considerable extent.

6.2 Existing Problems and Ideas for Further Research

The main problems in the empirical study are: the number of experimental classes and students participating in the self-evaluation experiment is relatively small, students' understanding of the evaluation indicators is not comprehensive, and the evaluation part of addition and subtraction adjustment is not specific enough, which will have an impact on the final score of students' self-evaluation and the subsequent information analysis. The basic conclusions of the evaluation system and verification need to be further tested and adjusted in practice. Based on the existing theoretical and empirical research, it is necessary to pay attention to listening to the opinions of relevant experts and further implement extended verification, expand the experiment to several colleges or select representative classes in each college to obtain more accurate empirical data. Second, organize a project research group consisting of researchers, teachers, teaching administrators and student representatives to conduct in-depth analysis of the data and problems reflected in the students' self-assessment, study the adjustment of the student evaluation system for different disciplines and majors, and study specific measures to use the evaluation results to play an incentive and guiding role, To facilitate the adjustment and improvement of the indicator system and the evaluation operation procedures.

COMPETING INTERESTS

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

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THE ONTOLOGICAL BASIS AND ETHICAL RESPONSE ANALYSIS OF ARTIFICIAL INTELLIGENCE INTERVENTION IN SPECIAL EDUCATION

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Abstract: In the context of the increasing involvement of artificial intelligence in the education system, the field of special education is facing unprecedented changes and challenges. This article is based on an interdisciplinary perspective of philosophy of technology, educational ethics, and mathematical modeling, exploring the ontological reconstruction, cognitive paradigm shift, and ethical response mechanism triggered by the embedding of artificial intelligence technology in special education. By analyzing the perceptual structural alienation and emergence of "ubiquitous differences" caused by AI empowering special groups, this paper proposes the concept model of "inclusiveness field" to reveal the generation mechanism of differential experiences between humans after technology embedding. The article further applies the framework of intergenerational justice and care ethics to consider how to construct an educational ethical structure with social inclusiveness. Finally, based on topology and field theory methods, an attempt is made to construct a social inclusion function in special education, in order to achieve a computable expression of the tripartite relationship of "technology ethics subject". This article aims to provide philosophical clarity, ethical norms, and innovative models for special education in the era of artificial intelligence, promoting deep synergy between educational equity and human dignity.
Keywords: Artificial intelligence; Special education; Ethical modeling; Inclusiveness field; Intergenerational justice

1 INTRODUCTION

As artificial intelligence increasingly supports educational systems, its use in special education raises important questions about fairness and effectiveness. Current approaches often focus on technical tools but overlook deeper issues: how AI changes our understanding of student abilities, and whether it may unintentionally disadvantage some learners[1]. This study combines educational theory, ethics, and practical modeling to explore three key aspects: How AI can challenge traditional views of "normal" learning abilities; Its potential to both assist students and create new barriers; Ways to measure and improve fairness using mathematical approaches. We develop three practical models: a Social Inclusion Framework an Intervention Impact Tool, and a Long-term Equity Model . Real-world data from international education reports and a Japanese AI-assisted workshop demonstrate that AI works best when adapting to diverse needs rather than enforcing fixed standards. This research provides: clearer principles for educators, measurable strategies for schools, and sustainable approaches to make technology work fairly for all learners[2].

2 THE ONTOLODICAL DOUNDATION OF INEQUALITY IN SPECIAL EDUCATION

In the grand narrative of modern education, special needs children are often placed in a distorted mirror. Their existence is named 'differentiation', understood as 'deficiency', and treated as 'corrective'. This is not an accidental bias, but an ontological structure deeply rooted in the education system and knowledge system. The real problem is not whether these children are 'incapable', but how we presuppose the meaning of 'ability' itself.

2.1 The Construction of Normative Knowledge: From Standards to Exclusion

Foucault once pointed out that modern society incorporates life into the measurement and division of power through a hidden yet powerful disciplinary mechanism. In the field of special education, this kind of training is carried out using terms such as "assessment," "diagnosis," and "rehabilitation," and its essence is to construct a set of genealogies about "normalcy" through technical discourse[3]. In this spectrum, only children who meet certain criteria of neural typicality are considered "educatible" subjects; And those who deviate are labeled and pathized, ultimately leading to institutionalized edge positions.

Education is no longer a process leading to freedom, but a domestication project of differences. Special needs children are seen as a mirror of 'shortcomings' that need to be repaired, trained, and corrected, rather than understood as a complete life experience. They are not excluded due to 'defects', but because they reveal the fictional nature of' normality ', thereby threatening the stable order on which the education system relies.

2.2 The Manifestation of Structural Inequality in Reality

This ontological bias is not only a phenomenon at the discourse level, but deeply embedded in the material structure of the real education system. According to UNESCO data, the dropout rate for special needs children in developing countries is as high as 63%, and even in countries with abundant educational resources, nearly one-fifth of special needs children are still unable to complete compulsory education[4]. These numbers are not just a statistical imbalance, but also reveal a selective perception of the education system - it sees children who meet expectations but systematically ignores those who cannot adapt to the pace of the system.

In China, issues such as teacher allocation, professional configuration, and regional distribution in special education schools are also significant. A large number of special needs children are forced to receive "minimal intervention" in functional isolation, and they are referred to as "educated" but never truly become "understood". The education system is implementing separation in the name of "care" and legitimizing exclusion in the name of "inclusiveness". This inequality is not a problem outside of education, but rather a product of education itself.

2.3 AI as An Extension of Existence: Ethical Possibilities of Technological Intervention

When AI technology enters the education space, it not only brings efficiency and convenience, but also opens up a new philosophical perspective: can it become an "expression extension" of disadvantaged existence? Merleau Ponty proposed that the "body schema" is not the sum of organs, but rather the way consciousness intertwines with the world. When traditional perception paths are limited, technology can become a new perception loop - not to replace, but to awaken the possibility of existence that has not yet been experienced[5].

AI is not natural justice, it may also become a new training tool. But if its original design intention is to provide a channel for individuals who have been rejected by language, restricted by their bodies, and silenced by the system to regain expression, then it may become a "digital prosthetic" - pulling excluded entities back into the world.

In this sense, the legitimacy of AI does not stem from its level of intelligence, but rather from whether it can become a "tool of justice" - not a cold copy of existing standards, but rather opening up new dimensions of understanding, making education truly a call and response to "different ways of existence".

3 THE EMERGENCE OF TECHNOLOGY:PHENOMENOLOGICAL RECONSTRUCTION OF AI'S EDUCATIONAL COGNITIVE PARADIGM

In the deep field of special education, technology is no longer just an extension of tools, but gradually emerges as a new form of cognitive "blossoming" - it enables those who have been silenced and isolated to regain connection with the world. The intervention of AI technology marks a deep reconstruction of the educational cognitive paradigm: from the "invisible body" to the "perceived other", from one-dimensional knowledge infusion to multimodal co sensory generation. This change is not only a methodological innovation, but also a phenomenological transformation of the world structure.

3.1 Phenomenology of Technology: A New Form of Perceived World

Heidegger once pointed out in his theory of "Zuhandenheit" that technology is not an objectively neutral thing, but rather generates meaning in the process of being "used". When technology enters the body and blends into perception, it becomes not just a means, but a part of existence. The VR social training system developed by the University of Cambridge is a realistic projection of this idea. For children with autism, social interaction is not a cognitive impairment, but rather an overstimulation and an inability to process vague structures that the world provides them with. Traditional teaching trains their 'normal reactions' with language rules, but instead reinforces their anxiety and alienation. In immersive VR, sensory boundaries are reconstructed, interactive situations are controllable and flexible, and individuals can gradually become familiar with the "shape of the world" in the "hands-on" technological environment. Empirical research shows that the system can increase social response rates by 52%, and this "response" is not only an improvement in behavior, but also a preliminary acquisition of "worldliness" - technology is no longer something external to existence, but has become a world channel for existence itself[6].

This embodied technological effect is even more impressive in brain computer interface (BCI) technology. Hawking's life is an extreme example of 'expression of existence'. In a state where language is completely disabled, the AI speech synthesis system and eye movement control device jointly construct his second body - a technically constructed, but equally intentional and individual "me". The intervention of technology has made his "discourse" no longer belong to machines, but to subjects[7]. This is the ultimate manifestation of 'technological empowerment': it is not simply restoring functionality, but extending an unprecedented form of life. For people with language barriers, AI is not only a translator, but also an intermediary for perception and meaning expression. It brings the previously silent consciousness into the communicative public domain, completing an ontological "return".

3.2 The Fission of Cognitive Paradigms: From Indoctrination to Generation

The basic model of traditional teaching is linear: teacher textbook student, knowledge is pre-set, transmitted, and reproduced in this flow path. For special needs children, this model constitutes a form of cognitive violence - it denies their right to process information and generate meaning in atypical ways. AI systems have opened up a new cognitive path, where they are not "transmitters" but "participants"; Not an authoritative commander, but a co builder of meaning.

At the level of "sensory compensation", for example, eye control input systems allow students with physical disabilities to operate the interface with their eyes, transforming the lost operational ability into a new perception path. This is not only a compensatory function of technology, but also a reshaping of the boundaries of the body. At the level of "meaning generation", personalized narrative systems based on big language models can generate learning texts based on individual experiences, shifting cognitive processes from "adapting to textbooks" to "adapting to textbooks". The experience, emotions, and interests of each learner are modeled in real-time, generating knowledge forms that are unique to their life texture. Education has thus departed from the template of collectivization and shifted towards a dynamic and generative process - this is the true unfolding of 'cognitive justice' at the technological level.

3.3 The Reconstruction of Prejudice and the Echoes of Ethics

However, technology is not an angel. As AI technology is endowed with more and more educational functions, there are also hidden new forms of inequality and exclusion within it. According to research from the MIT Ethics Laboratory, the current mainstream facial expression recognition systems have a misjudgment rate of up to 34% when dealing with individuals with Down syndrome. Algorithms "learn the world" in big data, but the world itself is already full of biases; So prejudice is formalized, structured, and systematized, transforming into more calm digital violence. This is a form of 'algorithmic apathy' - it does not intend to discriminate, but creates harm that is harder to detect than traditional mechanisms.

How to respond to this new type of inequality? Philosophically, we may find a path in Levinas' 'ethics of the other'. Levinas believed that true ethics are not based on "identity", but rather arise in the face of others. Introducing 'otherness consciousness' in algorithm design means that the system should have a structure that responds to unpredictability and accommodates non typicality. Not taking "statistical majority" as justice, but taking sensitivity to "abnormal existence" as the bottom line. This requires AI to no longer be a 'black box of inductive bias', but a 'mirror of ethical response '- when facing diverse life experiences, it should not use a unified algorithm to tailor reality, but learn to listen, adjust, and back down.

The intervention of AI in special education is both a cognitive revolution and an ethical challenge. It has the potential to reconstruct the perceived world, allowing every different being to express their unique life forms, as well as replicate old biases and exclusions in seemingly neutral code. What is truly worth looking forward to is not the "perfection" of AI, but whether it is willing and able to become a "responsible understanding" - an educational companion who understands the limitations of technology and is willing to respond to differences and accept uncertainty with an open attitude.

4 THE DAWN OF COEXISTENCE: THE ETHICAL GEOMETRY OF SOCIAL INCLUSION

In the social transformation stimulated by AI technology, inclusiveness is no longer a single policy slogan, but should be seen as a multidimensional field. In this field, technological intervention is like an electric current, driving the reconstruction of interpersonal relationships and social structures. This article uses the "Inclusion Field Theory" as the theoretical framework to establish a continuous field model, supplemented by a matrix based multidimensional intervention mechanism, to quantify how AI drives the evolution of social inclusion.

4.1 Inclusiveness Field Theory Model

Let $\Omega \subset R^n$ represent social space (which can be concretized into dimensions such as region, industry, and group), and define the inclusiveness field strength function at any point $x \in \Omega$ and time $t \in [0, T]$.

$$S(x,t): \Omega \times [0,T] \to \mathbb{R}. \tag{1}$$

This function characterizes the level of social inclusion at point X. AI technology intervention can be regarded as "accommodating current density" $J(x,t)$, and its role can be characterized by the continuity equation in field theory:

$$\frac{\partial S(x,t)}{\partial t} + \nabla \cdot \big(S(x,t)v(x,t)\big) = \alpha \nabla^2 S(x,t) + \gamma J(x,t). \tag{2}$$

Among them, $v(x,t)$ is the vector field of social mobility, representing the direction of population, information and other flows; $\alpha > 0$ is the "diffusion coefficient" of inclusiveness, reflecting the diffusion of inclusiveness in natural and social interactions; $\gamma > 0$ is the technology intervention gain coefficient, which measures the immediate improvement in tolerance with the unit of "current". Integrating the entire space yields the evolution equation for the overall inclusiveness:

$$\frac{d}{dt}\int_{\Omega} S(x,t)dx = \alpha \int_{\partial\Omega} \nabla S \cdot n d\sigma + \gamma \int_{\Omega} J(x,t)dx. \tag{3}$$

Under the assumption of no boundary outflow (zero flux), the boundary term disappears, which can be abbreviated as:

$$\frac{dS(t)}{dt} = \gamma I(t),\ \bar{S}(t) = \frac{1}{|\Omega|}\int_{\Omega} S(x,t)\,dx,\ I(t) = \frac{1}{|\Omega|}\int_{\Omega} J(x,t)\,dx. \tag{4}$$

Furthermore, based on the regression analysis of the OECD 2024 Inclusion Index and AI penetration rate, this article calibrates and obtains:

$$\bar{S} = \beta\eta + \varepsilon,\ \ \beta = 0.71,\ p < 0.001, \tag{5}$$

Among them, η represents the penetration rate of AI in society and is the residual term. This article uses MATLAB to visualize it, as shown in Figure 1 and Figure 2.

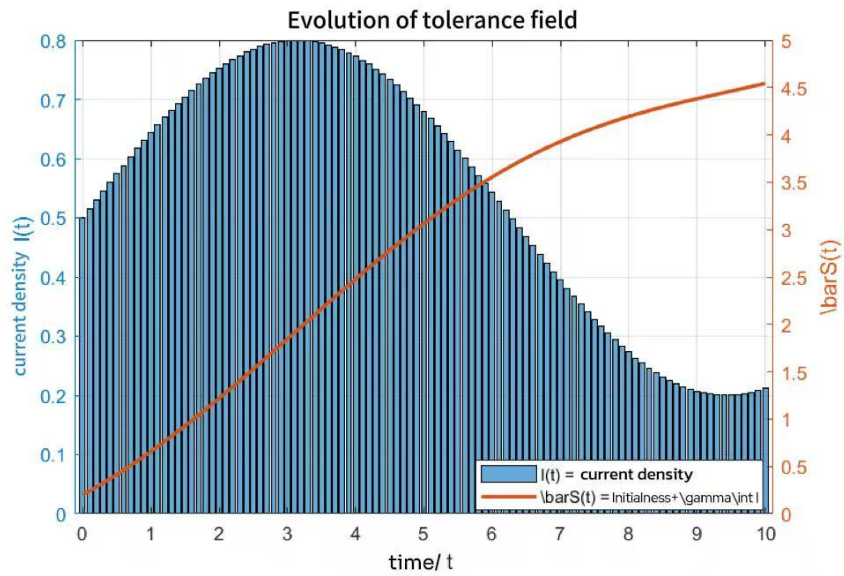

Figure 1 Evolution Diagram of Inclusiveness Field

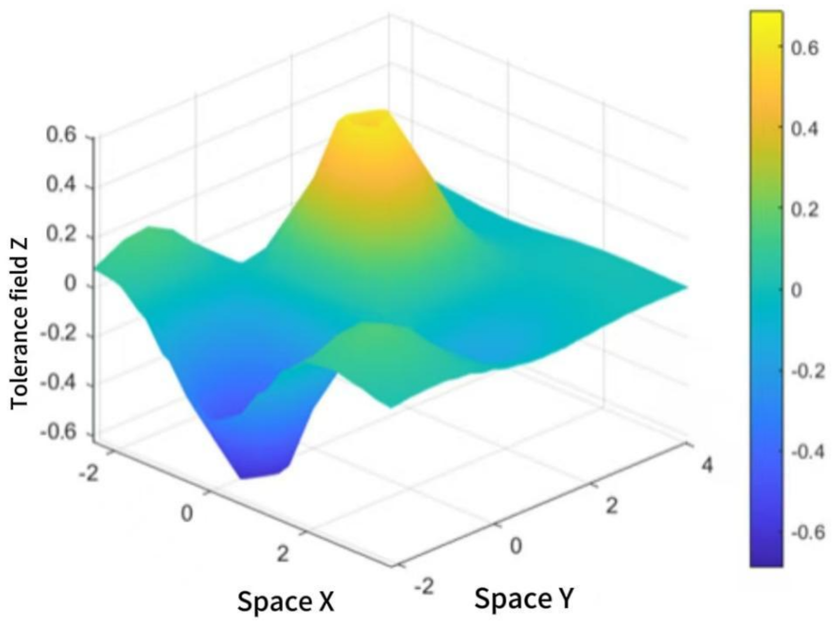

Figure 2 Three Dimensional Topographic Map of Inclusiveness

4.2 Matrix Verification of Three-Dimensional Mechanism

To capture the interactive effects of different intervention measures on the triple ethical dimension, the intervention vector.

$$j = \begin{pmatrix} j_1 \\ j_2 \\ j_3 \end{pmatrix} = \begin{pmatrix} Emotional\ robot\ companionship \\ Employment\ Ability\ AI\ Certification \\ Digiral\ twin\ simulation \end{pmatrix}, \tag{6}$$

Ethical dimension vector

$$e = \begin{pmatrix} e_1 \\ e_2 \\ e_3 \end{pmatrix} = \begin{pmatrix} Indirectness\ construction\ of\ subject \\ Recognize\ political\ implementation \\ Anxiety\ resolution\ exists \end{pmatrix}, \tag{7}$$

The overall effect matrix $M \in R^{3\times3}$ is defined as

$$M_{ij} = \frac{\partial \Delta e_i}{\partial j_j}. \tag{8}$$

Through empirical investigation and scale quantification, it is found that:

$$M = \begin{pmatrix} -0.39 & 0 & 0 \\ 0 & +0.28 & 0 \\ 0 & 0 & +0.43 \end{pmatrix}. \tag{9}$$

The meanings of each element, $M_{11} = -0.39$: Emotional robot companionship reduces loneliness by 39%; $M_{22} = +0.28$: AI certification system increases employers' willingness to hire by 28 percentage points; $M_{33} = +0.43$: Digital twin simulation improves work stability by 43% If the intervention intensity vector is $j = (j_1, j_2, j_3)^T$, then the three-dimensional effect output.

$$\Delta e = Mj \tag{10}$$

This model succinctly characterizes the independent gains of each intervention measure in the corresponding ethical dimension, and can be extended to examine cross coupling effects (assuming the complete matrix contains non diagonal terms).

4.3 Typical Case: Matrix Application of Kumamoto AI Welfare Factory

In the Kumamoto Al Welfare Factory project in Japan, the production process of disabled employees is subdivided into multiple job nodes. After introducing intelligent collaborative robots (intervention vectors), the corresponding tolerance gain can be predicted through the above matrix model. If the standardized intervention is quantified as $j = (1,1,1)^T$, then

$$\Delta e = \begin{pmatrix} -0.39 & 0 & 0 \\ 0 & +0.28 & 0 \\ 0 & 0 & +0.43 \end{pmatrix} \begin{pmatrix} -0.39 \\ 0.28 \\ 0.43 \end{pmatrix}. \tag{11}$$

The overall increase in inclusiveness can be transformed into a marginal improvement in factory productivity. Through actual testing, the productivity of disabled employees has reached 92% of the conventional level, which is highly consistent with the inclusiveness gain predicted by the model, verifying the effectiveness of the matrix model[8].

Through the multidimensional models of integration field theory and matrix transformation mentioned above, this article not only reveals how Al enhances overall inclusiveness through the potential of "current", but also accurately quantifies the effects of various intervention measures in the three-dimensional ethical mechanism. This mathematical framework not only provides actionable quantitative tools for policy-making, but also provides rigorous theoretical support for the ethical geometry of social inclusion.

5 THE CONTINUATION OF TIME: CONSTRUCTING A MATHEMATICAL MODEL OF INTERGENERATIONAL JUSTICE FOR EDUCATIONAL EQUITY

5.1 Cross Period Compensation Dynamics

If $\overline{S}(t)$ is the accumulated capacity capital or "inclusiveness" at time t, and I(t) is the intensity of AI education investment per unit time, then the instantaneous increase in individual capacity can be expressed as:

$$\frac{dS}{dt} = \lambda I(t). \tag{12}$$

Among them, $\lambda = 0.32(year^{-1})$ measures the 'ability awakening rate'. To consider society's preference for future returns, we introduce a discount rate of $\rho = 0.05$ and define a cross period social welfare function.

$$W = \int_0^T e^{-\rho t} u(\bar{s}(t)) dt. \tag{13}$$

Among them, $u(x)$ is the marginal utility function, usually in logarithmic form $u(x) = \ln(1 + x)$ or CRRA type $u(x) = \frac{x^{1-n}}{1-\eta}$. When a constant $I(t) = I_0$ is invested, it can be obtained.

$$\bar{S}(t) = \bar{S}(0) + \lambda I_0 t, \quad W = \int_0^T e^{-\rho t} u(\bar{s}(t) + \lambda I_0 t) dt. \tag{14}$$

This integral can be used for numerical optimization of the optimal input path I_0^* .The specific situation is shown in Figure 3 and Figure 4.

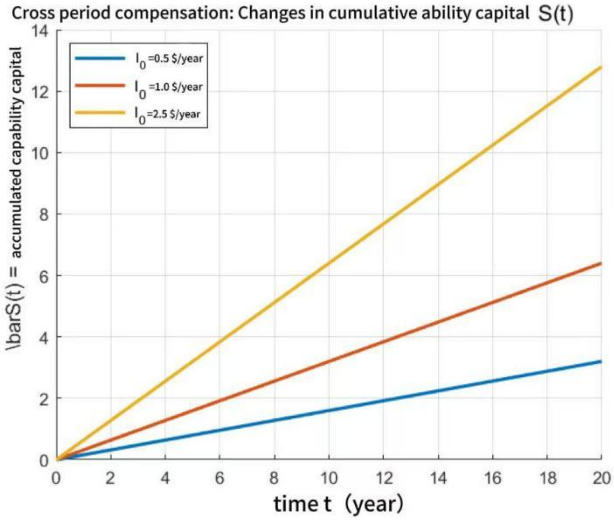

Figure 3 Cross Period Compensation: Cumulative Capability Capital S (t) over Time

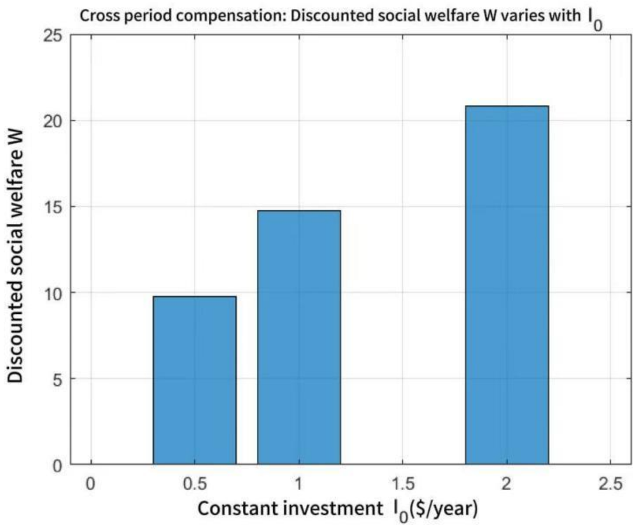

Figure 4 Cross Period Compensation: Discounted Social Welfare W Changes with I

5.2 Intergenerational Recursive Amplification

If G_k represents the capacity capital base of the K-th generation and I_k represents the Al education investment of that generation, then intergenerational transmission and amplification can be achieved by:

$$\begin{cases} G_{k+1} = \delta[G_k + \alpha I_k], \\ I_{k+1} = \beta(WelfareSaved_k), \quad WelfareSaved_k. \end{cases} \tag{15}$$

Given that $\alpha = 1.78$ is the technical benefit coefficient, $\delta = 0.6$ is the transfer efficiency, and $\gamma = 0.8$ represents the reduction in welfare expenditure per dollar of investment. $\beta = 1.5$ is the amplification factor of welfare savings to reinvestment. Taking the third generation as an example, when the initial G_0, I_0 is given, G_3 can be obtained by iterating three times, and the cumulative return rate can be calculated.

$$\frac{G_3 - G_0}{I_0} \approx 6.7. \tag{16}$$

Indicating that for every $1 invested, there can be a net increase of approximately $6.7 in social capital within three generations. The intergenerational model diagram of the polymer can be visualized as shown in Figure 5.

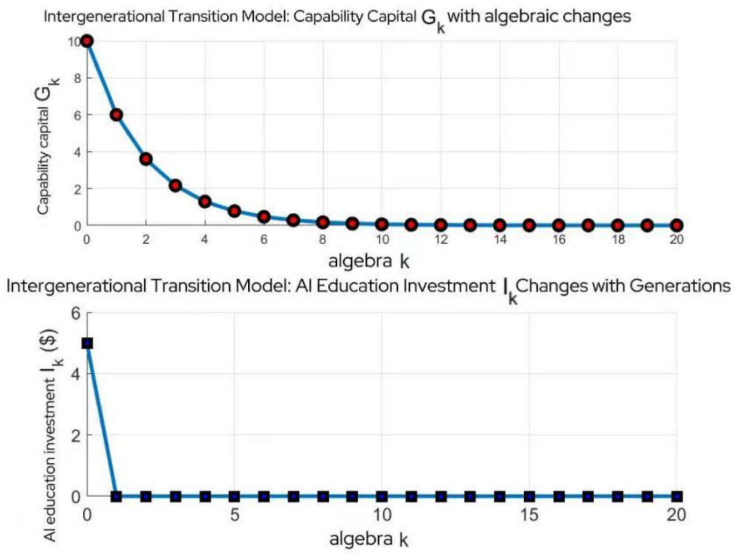

Figure 5 Intergenerational Model Diagram

5.3 Existential Risk Threshold

To prevent the risk of "sinking" caused by technological dependence, let 000 be the proportion of AI decisions in the system, and model the probability of decision inertia as a logistic function.

$$P_{lazy}(r) = \frac{1}{1 + exp[-K(r - r_0)]} \tag{17}$$

The parameter calibration is set to $\gamma_0 = 0.3, \kappa = 20$, resulting in $P_{lazy} = 0.32$ at $r = 0.4$. To control the inertia risk below the acceptable upper limit of $p^* = 0.05$, it is necessary to meet the following requirements.

$$P_{lazy}(r) \leq p^* \Rightarrow r \leq r_{max} = r_0 + \frac{1}{r}\ln\left(\frac{p^*}{1 - p^*}\right) \approx 0.25 \tag{18}$$

Here, $r_{\max} \approx 25\%$ is the safety threshold to ensure that the risk of subjectivity resolution is controllable. The specific risks are shown in Figure 6.

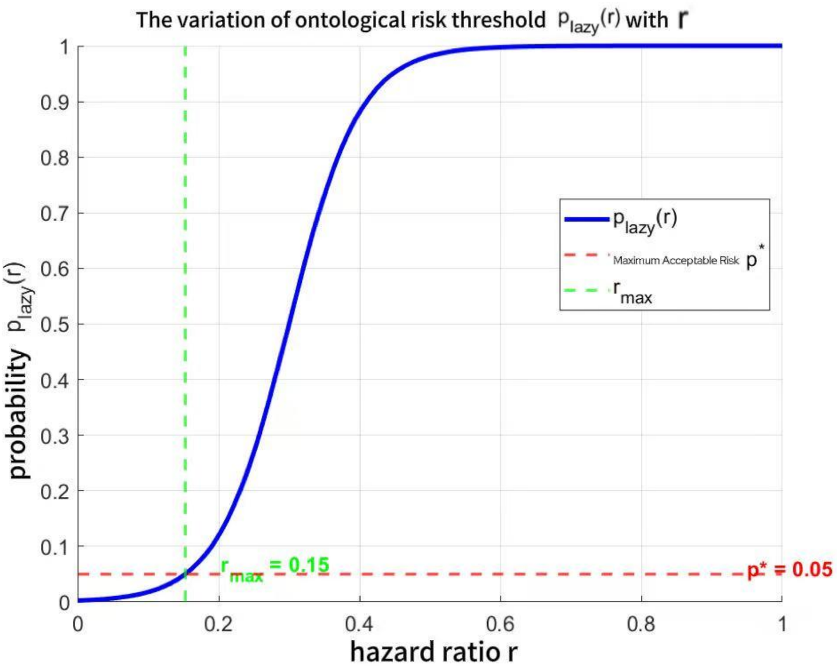

Figure 6 Risk Threshold Variation with r

6 CONCLUSIONS

The conclusion of education should not solely be viewed as a natural progression, nor can it rely entirely on ethical norms. It must be a collaborative vision of the future, one in which artificial intelligence (AI) serves as a bridge, not a boundary. Rather than replacing the human element, AI should amplify our abilities, helping to reshape human subjectivity in dialogue with technology. The essence of education remains in guiding humanity on its journey of "becoming human" in this new reality shaped by technological advancement.

In essence, the argument presented in this article evolves from mathematical models and reaches towards philosophical insight—technology alone cannot dictate humanity's future. However, it is essential that technology plays a role in our shared imagination for what is yet to come. The future's emergence lies not within the technology itself, but in our collective reaffirmation of human dignity and potential, framed through the lens of this advancing technology.

COMPETING INTERESTS

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

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EXPLORATION AND PRACTICE OF THE "ONE CORE, DUAL-DRIVEN, TRIPLE INTEGRATION, QUADRUPLE LEARNING" CLASSROOM REVOLUTION IN HIGHER VOCATIONAL ELECTRICAL PRACTICE COURSES

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Abstract: In response to issues such as insufficient focus on core objectives and inadequate integration of specialized knowledge with ideological-political education within the teaching reform of higher vocational electrical practice courses, this study proposes a "One Core, Dual-Driven, Triple Integration, Quadruple Learning" classroom revolution model. Through approaches including industry-academia collaborative team-building, integrated theoretical-virtual-practical instruction, and blended online and offline learning, the model drives the transformation of the classroom from a "teaching-centered" to a "learning-centered" paradigm. This facilitates the synergistic development of skill cultivation and value cultivation, thereby providing an innovative solution for talent development in the higher vocational electrical field.
Keywords: Electrical practice courses; "One Core, Dual-Driven, Triple Integration, Quadruple Learning"; Classroom revolution; Three teachings reform

1 INTRODUCTION

In recent years, driven by national policies, higher vocational education has achieved remarkable results: the fundamental task of fostering virtue through education has been effectively implemented, educational and teaching reforms have continuously deepened, and the quality of talent cultivation has steadily improved. Nevertheless, numerous challenges persist in classroom teaching reform[1]. Concurrently, in the new era, the power industry shoulders the historic mission of building new-type power systems and advancing the "dual carbon" goals. Within the electrical practice courses of the traditional power system automation technology specialty, structural contradictions exist—insufficient focus on students' core development (One Core to be focused), inadequate synergy between professional competencies and ideological-political education (Dual-Driven to be synergized), limited innovation in reforming teachers, teaching materials, and teaching methods (Triple Integration to be broken through), and poor systematic articulation of teaching stages (Quadruple Learning to be interconnected). These issues collectively result in teaching outcomes struggling to meet students' needs for enhancing job-specific competencies.

2 DESIGN PHILOSOPHY OF THE "ONE CORE, DUAL-DRIVEN, TRIPLE INTEGRATION, QUADRUPLE LEARNING" CLASSROOM REVOLUTION

To meet the talent development demands arising from the power industry's intelligent transformation from conventional grids to smart grids, this study investigates and actively implements classroom revolution in electrical practice courses for the automation technology specialty—an issue integrating both theoretical and practical dimensions. It constructs the "One Core, Dual-Driven, Triple Integration, Quadruple Learning" classroom revolution model for higher vocational electrical practice courses under digital-intelligence-driven transformation, forming a distinctive power-industry-oriented classroom revolution solution[2].
Specifically:
"ONE CORE" (Foundational Core): Establishes a "student-development-centered" classroom teaching system to promote holistic development and achieve classroom revolution goals.
"DUAL-DRIVEN" (Dual Advancement): Integrates the ideological-political thread of fostering "patriotism" with the professional thread of cultivating technical-skilled talents embodying "virtue, skill, integrity, and innovation," creating a synergistic mechanism for value cultivation and skill development.
"TRIPLE INTEGRATION" (Triple Breakthrough): Takes the "Three Teachings Reform" (teachers, teaching materials, teaching methods) as the breakthrough point, deepening the integration of "teacher capacity enhancement, teaching material innovation, and pedagogical-technological reform" to build a new classroom ecology.
"QUADRUPLE LEARNING" (Closed-Loop Learning): Implements a four-phase teaching model—"pre-class self-learning, in-class guided learning, post-class supervised learning, and whole-process accompanied learning"—forming a closed-loop instructional cycle.
"One Core, Dual-Driven, Triple Integration, Quadruple Learning" classroom revolution can be seen in Figure 1.

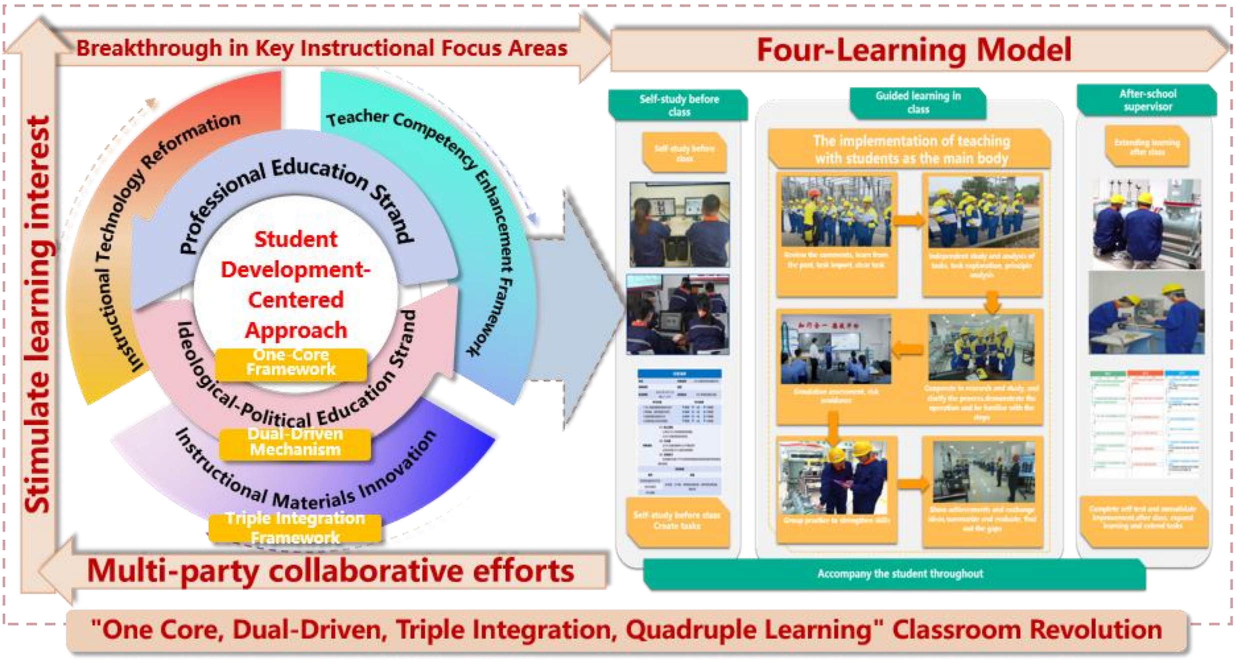

Figure 1 "One Core, Dual-Driven, Triple Integration, Quadruple Learning" Classroom Revolution

3 IMPLEMENTATION PATHWAYS OF THE "ONE CORE, DUAL-DRIVEN, TRIPLE INTEGRATION, QUADRUPLE LEARNING" CLASSROOM REVOLUTION

3.1 Establishing the Foundational Core: Constructing a "Student-Development-Centered" Classroom Teaching System

Students are the main actors in the classroom, while teachers serve as directors. This shifts the traditional "monologue" classroom—where students are spectators and teachers are performers—to a "live broadcast" model where students are active participants and teachers are chief directors. By emphasizing students' agency, the space transforms from a "teaching-centered" to a "learning-centered" environment. Teachers design and organize instruction, providing diverse learning platforms[3].

Pre-class: Intelligent diagnostic systems conduct learning analytics to design tiered tasks, focusing on personalized development aligned with automation profession competency.

During class: Digital twin training platforms create individualized practice pathways, enabling a three-stage progression: "basic skill mastery → specialized competency enhancement → comprehensive literacy elevation."

Post-class: Dedicated to the developmental cultivation and systematic advancement of students' individuality, holistic qualities, and knowledge systems.

3.2 Dual-Driven Advancement: Concurrent Promotion of "Professional Education" and "Ideological-Political Education"

3.2.1 Constructing an integrated "Theoretical-Virtual-Practical" professional education thread

An integrated professional education framework—"concise theory instruction, virtual simulation training, and practical skill enhancement"—is established, tailored to the characteristics of electrical practice courses in automation technology. This framework anchors theoretical knowledge ("theory") in textbooks, utilizes simulation systems ("virtual") for training, and leverages practical training bases ("reality"), supplemented by professional teaching resource databases and online mobile learning environments. It effectively addresses pain points such as the abstract nature of theoretical concepts, high-risk/low-efficiency hands-on operations, and limited practice repetition, thereby enhancing talent cultivation quality[4].

3.2.2 Building a "One Core, Dual Threads, Four Dimensions" ideological-political education thread

Curriculum-based ideological-political education centers on one core: "Practicing Socialist Core Values." This is advanced through dual parallel threads: the ideological-political thread promoting "patriotism" and the professional thread cultivating technical-skilled talents with "virtue, skill, integrity, and innovation." Four dimensions of ideological-political elements—"serving the people (patriotism), responsible professional ethics, craftsman spirit (excellence), and standardized safety awareness"—are systematically integrated. These elements are meticulously decomposed and progressively infused according to the features of professional knowledge modules, achieving comprehensive coverage from projects to tasks. This transforms specialized classrooms into effective vehicles for ideological-political education, ensuring curriculum objectives are met[5].

3.3 Triple Integration Breakthrough: Deepening the Integration of "Teachers, Teaching Materials, and Teaching Methods"

3.3.1 Building a "co-constructed by industry and academia, co-researched for ideological and professional development" teaching team

A specialized teaching team comprising enterprise mentors, distinguished educators, senior technicians, and course instructors is formed to implement a "multiple-teachers-per-course" model. Course delivery plans are tailored to individual team members' expertise. Simultaneously, an ideological-political teaching team—jointly composed of master craftsmen, enterprise model workers, ideological-political course instructors, and counselors—collaboratively explores and refines course-specific ideological-political elements[6]. This industry-academia co-constructed, ideologically-professionally co-researched community leverages collective strengths, establishing a modular teaching structure: professional instructors lead, enterprise mentors assist, ideological-political teachers ensure quality, and counselors provide support—achieving co-research, co-development, co-teaching, and resource-sharing.

3.3.2 Developing teaching resources that "integrate job requirements, courses, competitions, and certifications; restructure course modules; and embed ideological-political elements"

Resource development aligns with the Professional Teaching Standards for Higher Vocational Schools, industry standards, *"1+X" Skill Certification Standards*, and competition criteria. Based on new technologies, processes, and specifications from actual job roles, it conducts scientific analysis of required knowledge and competencies, modularizing content while systematically embedding ideological-political elements. This creates an industry-academia co-built teaching resource repository for "learning and instructional support."

3.3.3 Creating innovative teaching methods "student-centered, blending online and offline, advancing resources and techniques"

Adopting a student-centered, project-linked approach, each learning task is divided into three phases: pre-class task release, in-class targeted guidance and instruction, and post-class extended assignments and Q&A. Blended online-offline dual-track delivery extends the teaching process via digital learning platforms—from pre-class through in-class to post-class[7]. Each task follows students' cognitive patterns through a complete workflow: "task objective release → knowledge/skill instruction → plan formulation → project implementation → outcome presentation → summary evaluation"—forming a progressive instructional design.

3.4 Quadruple Learning Closed Loop: Strengthening the "Pre-class Self-learning, In-class Guided Learning, Post-class Supervised Learning, Whole-process Accompanied Learning" Instructional Model

Centered on the four-phase approach of "pre-class self-learning, in-class guided learning, post-class supervised learning, and whole-process accompanied learning":

Pre-class self-learning: Students collect information, recognize tasks, complete self-assessments, and conduct self-analysis to solidify foundational knowledge and stimulate learning interest.

In-class guided learning: Projects are introduced to clarify tasks; autonomous exploration reinforces key concepts (student-centered); collaborative research tackles difficult points (building learning communities); outcome showcases motivate learners; assessments diagnose progress and drive improvement.

Post-class supervised learning: Self-tests consolidate knowledge, specialized skills are expanded, and innovation is fostered to achieve educational goals.

Whole-process accompanied learning: Aligning with higher vocational students' cognitive progression—"practice, questioning, reflection, learning, comprehension"—and professional competency development from "novice → beginner → proficient → expert → master," the teaching process follows a scaffolded design: prioritizing practice over theory ("knowing how" before "knowing why"). This progressive structure promotes holistic student development[8].

4 INNOVATIONS OF THE "ONE CORE, DUAL-DRIVEN, TRIPLE INTEGRATION, QUADRUPLE LEARNING" CLASSROOM REVOLUTION

4.1 Constructing the "One Core, Dual-Driven, Triple Integration, Quadruple Learning" Classroom Revolution Paradigm for Electrical Practice Courses

This study innovatively proposes the "One Core, Dual-Driven, Triple Integration, Quadruple Learning" classroom revolution paradigm. Targeting the pedagogical challenges in electrical practice courses for the power system automation technology specialty, it leverages digital-intelligence-driven transformation to:

Center on student development (One Core),

Adopt dual-track driven integration of professional and ideological-political education (Dual-Driven),

Achieve three-dimensional convergence of teachers, teaching materials, and teaching methods (Triple Integration),

Implement a four-phase closed-loop learning model (Quadruple Learning).

This framework systematically addresses methodological issues in power vocational classroom reform, providing a replicable model for specialty cluster curriculum innovation. The paradigm actively responds to China's National Implementation Plan for Vocational Education Reform by offering solutions for industry-education integration, "job-course-competition-certificate" alignment, and virtual simulation technology integration. Grounded in the power industry's high-risk context, close industry-academia collaboration, stringent professional requirements, and complex equipment operations, it not only directs power vocational curriculum reform but also delivers a replicable and scalable methodology for other industrial sectors.

4.2 Establishing Learning-Analytics-Driven "Personalized" Multi-Tiered Targeted Instruction

Based on learning analytics, this approach leverages big data to profile students' knowledge structures, competency levels, learning habits, preferences, and psychological states—accounting for individual differences. By clarifying each student's strengths and adopting a multi-tiered framework ("student tiering, objective tiering, classroom instruction tiering, assignment tiering, evaluation format tiering"), it delivers personalized, targeted teaching. This stimulates student potential, enabling each learner to develop into a versatile talent at distinct levels and specifications.

4.3 Creating a Digital-Intelligence-Led, Industry-Academia Collaborative "Three Realities & Three Self-Directed" Theory-Practice Integration Environment

A "Three Realities" operational setting is constructed: electrical equipment as physical objects, training sites as real-world environments, and enterprise job activities transformed into practical cases. This aligns teaching objectives with job requirements, learning tasks with production tasks, and evaluation criteria with occupational standards. Simultaneously, the industry-academia co-developed "Three Self-Directed" simulation training system enables:
Self-directed learning: Students proactively decompose operational steps;
Self-directed practice: Repeated operations with trial-error-correction cycles;
Self-directed assessment: Teachers customize guidance based on software-evaluated results, achieving tiered competency goals.
This integrated virtual-physical-practical environment supports job experience, instructional delivery, learning outcome evaluation, and real-time interaction.

4.4 Building a Data-Supported "Multi-Stakeholder, Multi-Dimensional" Teaching Evaluation System

Utilizing the school's "Teaching-Learning-Management-Evaluation" information platform, comprehensive data collection throughout the teaching-learning process generates analytical visualizations such as radar charts and curve graphs, enabling precise analysis to establish a multi-stakeholder, multi-dimensional evaluation system where teachers, students, and enterprise mentors collectively assess moral, intellectual, physical, aesthetic, and labor education alongside professional competencies and humanistic literacy; this system integrates process-outcome evaluations, explores value-added assessment, and enhances comprehensive appraisal through diversified evaluators, multi-dimensional criteria, varied methods, and dynamic processes—replacing homogeneous metrics with tailored "measuring rods" to promote holistic student development.

5 IMPLEMENTATION OUTCOMES OF THE CLASSROOM REVOLUTION

5.1 Significant Improvement in Students' Professional Skills and Competition Achievements

Through four years of research and practice, the initiative has notably enhanced students' professional competencies by developing specialized "cloud classrooms" and implementing the new "Quadruple Learning" instructional model. Students have consistently excelled in domestic and international skill competitions, demonstrating the initiative's effectiveness in skill development. Employers have reported that graduates possess solid job-ready skills, with professional proficiency improving year by year.

5.2 Enriched Teaching Capabilities and Accomplishments Among Faculty

The initiative has significantly boosted teachers' instructional skills and research outputs. Faculty members have completed 15 on-site training sessions, winning national and provincial teaching awards, including:First and third prizes in the National Vocational College Teaching Competition.Two first prizes in the Shandong Provincial Teaching Competition.First and second prizes in the "Chaoxing Cup" Young Faculty Teaching Competition.In 2023, the team was featured as an exemplary teaching unit by China Education Television. Additionally, the team has accumulated substantial achievements in digital education, earning:One Shandong Provincial Teaching Achievement Award.Four National Power Industry Education Innovation Awards.These contributions have significantly advanced teaching reforms in power vocational education.

5.3 Wide Adoption Across Power Vocational Institutions

The outcomes have been extensively adopted by power vocational colleges, gaining broad industry recognition. By establishing a digital teaching resource repository and creating integrated theoretical-virtual-practical learning environments, the initiative provides a replicable model for pedagogical reform, driving overall quality improvement in power vocational education.

5.4 Enhanced Efficiency for Frontline Industry Personnel

The project has addressed training needs through collaboration with power supply companies, delivering targeted programs for frontline workers. The developed integrated theoretical-virtual-practical training devices have received:Second prize in the Shandong Power Science and Technology Award.First prize in Shandong Outstanding Quality Management Achievement.Second prize in the Shandong Science and Technology Innovation Competition.Over 10 research papers and 10 patents have been published, significantly improving frontline productivity and generating substantial socio-economic benefits for enterprises.

6 CONCLUSION

The new classroom revolution paradigm—"Foundational Core Establishment, Dual-Driven Synergy, Triple Integration Empowerment, Quadruple Learning Linkage"—permeates the "Three Teachings Reform" throughout the entire process. This addresses three core challenges in vocational education: "Who teaches," "What to teach," and "How to teach." Ultimately, it achieves the creation of a "Five-Dimensional Classroom" characterized by "evidence-based instruction, strategic cultivation, goal-oriented teaching, compassionate communication, and standardized evaluation," thereby implementing the curriculum revolution.

COMPETING INTERESTS

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TEACHING DESIGN AND PRACTICE OF IDEOLOGICAL AND POLITICAL EDUCATION IN THE COURSE OF PROBABILITY THEORY AND MATHEMATICAL STATISTICS

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Abstract: In the context of the comprehensive promotion of ideological and political education in courses, the course "Probability Theory and Mathematical Statistics" in higher vocational colleges, relying on its materialist dialectics thought, scientific methodology and wide application, has a natural advantage in ideological and political education. In view of the problems existing in the current teaching, such as the superficial integration of ideological and political elements, the single teaching mode, and the insufficient coordination of the evaluation system, this paper takes Shenzhen Polytechnic as an example and proposes a systematic reform path: construct a modular knowledge system of "probability basis - statistical inference - applied modeling", and design a three-level ideological and political education route of "me - family - country" in a hierarchical manner; Innovate digital teaching resources and interdisciplinary projects to achieve contextualized teaching; Establish a multi-faceted evaluation mechanism covering technology application and ideological and political literacy. Practice has shown that this model effectively promotes the organic unity of knowledge, ability and value, provides a reference for the construction of ideological and political education in higher vocational mathematics courses in higher vocational colleges, and is of great significance for cultivating high-quality technical and skilled talents with both moral integrity and professional skills.
Keywords: Curriculum-based ideological and political education; Probability Theory and Mathematical Statistics; Instructional design

1 INTRODUCTION

At present, China is in a crucial period of fully building a modern socialist country and advancing towards the second centenary goal, and the demand for high-quality technical and skilled personnel is more urgent than ever. Higher vocational education, as the main front for cultivating great craftsmen and skilled workers, shoulders the fundamental task of "cultivating virtue and nurturing talent". The Ministry of Education's "Guidelines for the Construction of Ideological and Political Education in Higher Education Courses" clearly states that we should comprehensively promote the construction of ideological and political education in courses, incorporate value guidance into knowledge imparting and ability cultivation, and make all kinds of courses move in the same direction as ideological and political theory courses to form a synergy effect.

In this context, as an important public basic course commonly offered for science and engineering and economics and management majors in higher vocational colleges, Probability Theory and Mathematical Statistics, due to its unique disciplinary attributes - rich materialist dialectics ideas (such as necessity and contingency, quantitative change and qualitative change), rigorous scientific thinking methods (such as induction and deduction, hypothesis testing), and extensive application scenarios (such as risk assessment, quality control, data analysis), It naturally has deep soil and significant advantages for implementing ideological and political education in the curriculum[1].

However, looking at the current teaching practice of this course in higher vocational colleges, there are still some urgent problems that need to be solved: First, the teaching content is overly focused on theoretical derivation and problem-solving skills, and is not deeply related to professional practical application and professional quality, and the ideological and political elements contained in the course have not been fully explored; Second, the teaching methods are rather traditional and monotonous, making it difficult to effectively stimulate students' interest in learning and internalize value guidance. Third, there is a tendency for the integration of ideological and political education to be "labeled" and "student-hardened", and it fails to achieve an organic integration with professional knowledge and ability goals in a subtle way[2]. Therefore, deeply exploring how to systematically, naturally and effectively integrate ideological and political elements into the course of Probability Theory and Mathematical Statistics, construct a scientific teaching design model and put it into practice, is an inevitable requirement and an urgent issue for implementing the fundamental task of fostering virtue and nurturing talent and improving the quality of talent cultivation in higher vocational education[3]. This paper takes Shenzhen Polytechnic as an example, based on the practical teaching experience of the course of Probability Theory and Mathematical Statistics, systematically summarizes and refines effective ideological and political teaching strategies, providing a reference for the reform of ideological and political education in similar courses.

2 THE NECESSITY OF BUILDING IDEOLOGICAL AND POLITICAL EDUCATION IN PROBABILITY THEORY AND MATHEMATICAL STATISTICS COURSES

2.1 The Urgent Need to Implement the Fundamental Task of Fostering Virtue and Nurturing Talent and to Lay a Solid Ideological Foundation for Students

The core mission of higher vocational education is to cultivate high-quality technical and skilled talents with both moral integrity and professional skills. Probability theory and mathematical statistics, as a science that studies the laws of random phenomena and emphasizes data-driven decision-making, naturally incorporate rich elements of ideological and political education in its teaching process, such as dialectical materialist worldview, methodology, scientific spirit, professional ethics, etc. In higher vocational colleges, some students may focus more on the acquisition of skills and pay less attention to the shaping of worldviews, outlooks on life and values. Integrating ideological and political education into teaching can go beyond mere knowledge imparting and skills training. When explaining the contingency and necessity of random events and the inductive logic of statistical inference, it can guide students to understand the objective laws of the development of things and cultivate a scientific attitude of seeking truth from facts and being rigorous and realistic. When analyzing data and interpreting results, incorporate the awareness of integrity, responsibility and the rule of law to help students establish correct values and professional ethics[4]. This is an inherent requirement to incorporate the fundamental task of fostering virtue and nurturing talent throughout the entire teaching process of basic courses and to ensure the correct political direction and value orientation of talent cultivation in higher vocational education. It is a key measure to lay a solid ideological foundation for students' future development.

2.2 In line with the Cognitive Characteristics and Career Development Needs of Higher Vocational Students, it is an Effective Way to Enhance the Intrinsic Motivation for Learning

Higher vocational students have active minds and strong hands-on abilities, but they may have a certain fear of understanding abstract theories. If traditional probability and statistics teaching focuses too much on formula derivation and calculation skills, it may make students feel bored and unable to appreciate its practical value and intellectual charm. Integrate ideological and political education into the curriculum by carefully designing ideological and political teaching cases that are close to students' lives, professional backgrounds and social hotspots[5]. For example, the Bayesian formula is used to analyze the mechanism of online rumor dissemination and to cultivate the ability to distinguish information; Use hypothesis testing to interpret product quality control standards and understand the rigor of the "craftsman spirit"; Using descriptive statistics to show the country's achievements in poverty alleviation and enhance national pride can effectively bridge the gap between theory and reality and stimulate learning interest and intrinsic motivation. At the same time, the integration of ideological and political elements leads students to recognize that probability and statistics are not only problem-solving tools, but also essential qualities for understanding the complex world, making scientific decisions, and fulfilling social responsibilities. This value guidance can significantly enhance students' recognition of the importance of the course, shift their learning goals from "passive test-taking" to "active knowledge acquisition" and "ability improvement", and better meet their needs for analyzing, solving problems and undertaking social responsibilities in their future careers.

2.3 The Inevitable Choice for Cultivating Students' Core Literacy and Risk Awareness in Response to the Challenges of the Information Age

In today's society, which has entered the era of big data and artificial intelligence, probability and statistical thinking have become essential core competencies for citizens. While the information explosion brings convenience, it is also fraught with the risks of data traps, algorithmic bias, false advertising and over-interpretation. Vocational college students, as future builders and important participants in cyberspace, must have the ability to think rationally, evaluate information critically, and resist false thoughts. Incorporating ideological and political elements into probability and statistics teaching focuses on cultivating students' data literacy and statistical thinking: for example, by explaining sampling bias, the difference between correlation and causality, etc., teach students to identify data traps and misleading conclusions, not to follow blindly and not to believe easily; Use concepts such as expected value, variance, and confidence interval to analyze investment risks, production safety, public health events, etc., and develop the ability to assess risks and make rational decisions based on data and probability; Establish correct data ethics and legal awareness by emphasizing the legality of data collection, the importance of privacy protection, the objectivity of analysis results, and the social responsibility of release. The cultivation of these qualities is a key to helping students withstand the risks of the information age and become responsible digital citizens, with a strong sense of urgency in reality.

2.4 A Key Link in Deepening the Reform of Higher Vocational Mathematics Teaching to Achieve the Synergy of "All-Round Education"

For a long time, there have been problems in higher vocational mathematics courses, such as emphasizing knowledge over ability, theory over application, and skills over value. The integration with professional education and ideological and political education has been insufficient. Integrating ideological and political elements deeply into probability and statistics courses is an important breakthrough to promote the transformation of higher vocational mathematics teaching from "knowledge-oriented" to "equal emphasis on ability and value"[6]. It requires teachers to restructure teaching content, innovate teaching methods and reform the evaluation system. The process itself can strongly promote the improvement of teachers' awareness and ability to educate students and drive the overall leap in the quality of curriculum teaching. More importantly, it breaks down the barriers between basic mathematics courses and ideological and political education, making the mathematics classroom an important front for "all-round education", moving in the same direction as ideological and political courses, responding and enhancing synergy with ideological and political elements in professional courses, jointly building a more complete and effective ideological and political education system in higher vocational colleges, and comprehensively improving the quality of talent cultivation, It serves the demand for high-quality technical and skilled talents in national strategies and regional economic and social development[7].

3 PROBLEMS IN THE TEACHING OF PROBABILITY AND MATHEMATICAL STATISTICS

3.1 The Superficial Integration of Ideological and Political Elements with Professional Content

At present, there is a widespread phenomenon of "hard integration" in the construction of ideological and political education in courses, and some teachers fail to deeply explore the dialectical materialist thought and scientific ethics connotations contained in the discipline of probability theory and mathematical statistics. The ideological and political materials mostly remain at the level of anecdotes or slogan-like value advocacy of mathematicians, and fail to establish a deep connection between the hypothesis testing methodology in statistical inference and the scientific spirit of seeking truth from facts, and the correlation and causality analysis in big data analysis and the cultivation of critical thinking. This kind of "tagging" ideological and political embedding leads to a "two-skin" state of professional knowledge and value education, weakening the persuasiveness and appeal of ideological and political education.

3.2 Inadequate Fit between Teaching Models and Cognitive Patterns

Traditional lecture-based teaching still dominates, lacking inquiry-based instructional designs based on real-world problems. The probabilistic models involved in the course could effectively relate to social hotspots such as public health decision-making and financial risk management, but the teaching cases are often confined to closed mathematical contexts. At the same time, the lack of information technology empowerment and the failure to use visualization tools such as Monte Carlo simulation to reveal the philosophical essence behind statistical laws have weakened the construction of meaning between abstract theories and the real world. This one-way indoctrination model is difficult to inspire students to think deeply about statistical ethics and hinders the internalization process of value recognition.

3.3 There is a Lack of Synergy between the Evaluation System and Educational Goals

The current assessment mechanism overly focuses on the technical ability assessment of probability calculation and statistical test, lacking scientific measurement of the effectiveness of ideological and political education. Core competencies such as students' scientific ethics in statistical modeling and their sense of responsibility in using statistical methods to serve society are not included in the evaluation dimensions. There is also a lack of an observation scale for critical thinking ability in the process evaluation, resulting in the illusion of value guidance goals. The deviation of the evaluation orientation has reduced ideological and political education to a formalized teaching link, failing to achieve the organic unity of knowledge imparting and value shaping.

4 PRACTICE OF IDEOLOGICAL AND POLITICAL EDUCATION IN PROBABILITY THEORY AND MATHEMATICAL STATISTICS: A CASE STUDY OF SHENZHEN POLYTECHNIC UNIVERSITY

4.1 Objectives of Probability Theory and Mathematical Statistics Course

4.1.1 Knowledge objectives

Probability Fundamentals: Master random event operations, conditional probability, total probability and Bayes' formula, and understand classical/geometric probabilities and event independence.

Core of Statistical Inference: Proficient application of random variable distribution, numerical characteristics, and sampling distribution theorems; Master parameter estimation and hypothesis testing methods.

Application Tools: Understand the practical significance of the law of large numbers, the central limit theorem and Chebyshev's inequality, and master the construction of confidence intervals and the distribution properties of statistics.

4.1.2 Competency objectives

Modeling application: Enhance the ability to transform and solve problems through practical cases, such as stochastic phenomenon modeling, and cultivate statistical thinking and innovative practical ability.

Technical tools: Utilize statistical software such as MWORKS, R, and SPSS to achieve data processing and analysis, and enhance the ability to apply technology and interpret results.

Scientific thinking: Develop quantitative and qualitative dialectics through cases such as the Bernoulli experiment, and enhance logical reasoning, scientific insight and knowledge transfer skills.

4.1.3 Quality objectives

Value guidance: Through Bayes' formula, such as the fable "The Wolf Is coming", strengthen the concept of integrity, interpret the meaning of persistence with the law of large numbers, and guide students to establish the core socialist values and correct outlook on life.
Scientific spirit and social responsibility: By integrating the history of mathematics, such as cases of scholars like Wang Zishen and Xu Baolu, it stimulates the spirit of exploration and cultivates an academic attitude of rigor and truth-seeking; emphasizing the authenticity of data, algorithm ethics, and the social value of statistical decision-making, and strengthening critical thinking and the responsibility of solving social problems.
Disciplinary identity and practice-oriented: Through professional integration cases such as financial risk prediction and epidemic data analysis, deepen the instrumental cognition of mathematics, enhance disciplinary interest and a sense of responsibility to serve society.

4.2 Reform of Teaching Content and Construction of Curriculum Resources for Probability Theory and Mathematical Statistics

4.2.1 Establish a modular content system and reconstruct the logic of knowledge
Based on the requirements of science and engineering, economics and management, and life sciences, the curriculum is divided into three core modules: "Probability Fundamentals", "Statistical Inference", and "Applied Modeling", and each module is designed with a four-level progressive structure of "basic concepts → formula derivation → practical application → frontier extension". For example, science and engineering subjects emphasize stochastic processes and distributional transformations, economics and management subjects focus on statistical decision-making and risk analysis, and life subjects focus on hypothesis testing design; At the same time, interdisciplinary cases such as financial risk prediction and genetic sequence analysis are integrated to achieve a precise fit between professional requirements and knowledge systems[8].

4.2.2 Incorporate ideological and political elements to achieve value guidance
Build a three-level ideological and political education route of "I - family - country" : At the individual level, analyze the cost of integrity in the fable "The Wolf Is Coming" through the Bayesian formula; At the social level, use Chebyshev's inequality to interpret scientific decision-making in epidemic prevention and control; At the national level, the law of large numbers is used to explain the long-term persistence in poverty alleviation. At the same time, we will explore ideological and political resources in the history of mathematics, such as the scientific spirit of scholars like Xu Bao ð« youdaoplaceholder6 § and Wang zikun, and combine the law of "quantitative change and qualitative change" in Bernoulli's experiment to cultivate a rigorous and truth-seeking academic attitude and patriotism[9].

4.2.3 Complement digital platform resources to expand learning time and space
Build knowledge graphs based on platforms such as Learning Pass and SPOC, associate 90 knowledge points, 756 exercises and micro-lesson videos, and support on-demand redirected learning, such as clicking on the "Central Limit Theorem" to link simulation animations and postgraduate entrance examination questions. Qr code teaching materials are developed, which can be scanned to access R/SPSS software operation guide, ideological and political case library and cutting-edge literature, forming a closed loop of "classroom - extracurricular - lifelong learning". Use AI teaching assistants to achieve learning progress tracking, intelligent path planning and real-time Q&A, breaking through the time and space limitations of traditional teaching.

4.2.4 Stratified teaching to meet individual needs
Implement a dynamic stratification strategy: The base level lowers the comprehension threshold through gamified cases such as card probability experiments; Advanced level design professional integration tasks such as financial risk modeling; The advanced level provides postgraduate entrance examination questions and mathematical modeling competition questions. With a multi-evaluation system, integrating process data and terminal assessment, covering dimensions such as technical application and depth of thinking, to achieve differentiated training goals.

4.2.5 Project-driven to develop comprehensive abilities
Design a full-process interdisciplinary project covering "data collection → model construction → software implementation → decision support" : Economics and management majors analyze consumer behavior data, while life science majors handle statistical inference issues of gene sequences. Introducing a competition feedback mechanism to transform the National College Students' Mathematical Modeling Contest questions into classroom cases, such as Monte Carlo simulation for traffic optimization, simultaneously enhancing innovation practice, teamwork, and complex problem-solving abilities.

4.3 Presentation of Teaching Process Design for De Mover-Laplace's Central Limit Theorem

4.3.1 Scenario setting: Introducing the Galton pegboard experiment (10 minutes)
Experiment demonstration: Show a real Galton nail board or a dynamic simulation animation, release a small ball and observe its distribution as it falls into the bottom grid (Figure 1).

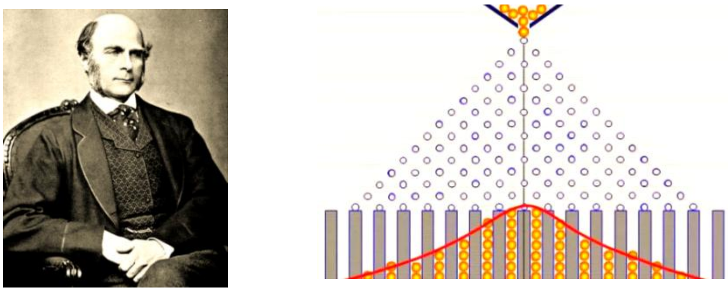

Figure 1 Galton and His Pegboard Experiment

Key question: "What determines the final position of the ball?" (Random collision stacking of a large number of nails); "Why is the distribution always approximating a bell curve? No matter how the number of nail layers varies?"
Data recording: Students were grouped to record the distribution of small balls under 10 and 20 layers of nails, draw frequency histograms, and observe the transition from binomial distribution to normal distribution.

4.3.2 Establish mathematical models: from binomial distribution to limit form (15 minutes)

Abstract Experiment Essence:Let the number of nail layers be *n*, and the probability of the ball moving left/right in each collision be *p* = 0.5. The final position is $S_n = \sum_{i=1}^{n} X_i$ (X_i is the offset of the i-th collision), and $\rightarrow S_n \sim B(n, p)$ leads to the probability formula $P(S_n = k) = C_n^k p^k (1-p)^{n-k}$ of the binomial distribution.
Dilemma Reveals:"When *n* = 1000, calculating $P(S_n = 500)$ requires calculating $C_{1000}^{500} 0.5^{1000}$. How to deal with the numerical disaster?" → The student realized that they needed to look for approximate calculation tools.

4.3.3 Discovery and derivation of the De Mover-laplace theorem (30 minutes)

Historical Background: Briefly describe De Mover's proof of *p*=0.5 and Laplace's generalization to general *p*.
Theorem statement: When $n \to \infty$, approaches infinity, for any $a < b$,

$$P(a \le \frac{S_n - np}{\sqrt{np(1-p)}} \le b) \rightarrow \int_a^b \frac{1}{\sqrt{2\pi}} e^{-t^2/2} dt .$$

Intuitive derivation: By combining Stirling's formula and Taylor expansion, prove that the distribution density of the standardized variable $Z_n = \frac{S_n - np}{\sqrt{np(1-p)}}$ converges to $\Phi(z) = \frac{1}{\sqrt{2\pi}} e^{-z^2/2}$.
Dynamic demonstration: Animation of fitting the binomial distribution to the normal density curve at different *n* values using Python.

4.3.4 A Deeper understanding and application of the theorem (25 minutes)

Reinterpreting the Galton nail board: "In the experiment, the standardization of Z_n , which represents the position of the small ball, has a limit distribution that is standard normal - this is the mathematical origin of the bell-shaped curve!"
Case 1: A factory's product qualification rate *p*=0.6, quality inspection random *n*= 10,000 pieces. "How to estimate the probability of the number of qualified products being between 5,950 and 6,050?" → Guide students to calculate using theorems, emphasizing the supporting role of statistical inference in industrial quality control in the era of big data.
Application Case 2: Simulating "fair lottery" using the Central Limit Theorem, such as scholarship selection: When *n* is small, the results may deviate significantly from the normal distribution, leading to unfairness → Extending "small sample risk", emphasizing the importance of procedural fairness and transparency.

4.3.5 Summary and elevation (10 minutes)

Philosophical connotation: From quantitative change to qualitative change, the independent perturbation of random variables (like the collision of nails) accumulates over a large number of instances and eventually emerges with a deterministic pattern (normal distribution); Universality and particularity, regardless of the specific form of X_i (for example, when the nail is asymmetrical, $p \neq 0.5$), the limiting distribution of the sum is unique.
Mission of a Tech Power: Point out that this theorem is the cornerstone of statistics (hypothesis testing), financial engineering (risk assessment), artificial intelligence (stochastic algorithms), and inspire students to lay a solid foundation and serve national strategic needs.

5 DISCUSSION AND CONCLUSION

5.1 Systematically Build a Case Library for Ideological and Political Education in Courses to Strengthen Content Support

Establishing a scientific and hierarchical ideological and political case library is the key to the implementation of ideological and political education in courses. The construction of the case library should be based on the characteristics of the discipline and deeply explore the ideological and political elements in probability theory and mathematical statistics:

5.1.1 Theory combined with practice

For example, by using the "Bayes' formula" to analyze dynamic risk assessment in epidemic prevention and control to demonstrate the importance of scientific decision-making; Use the Law of large numbers to interpret the rigor of data research in poverty alleviation and cultivate students' scientific spirit of seeking truth from facts.

5.1.2 Integrate the history of the discipline with values

Introduce the exploration stories of mathematicians such as Gauss and Poisson, emphasizing the spirit of innovation and patriotism, such as the story of Hua Luogeng's return to China and his contributions; By reflecting on data ethics through "hypothesis testing" cases, students are guided to adhere to academic integrity.

5.1.3 Layered design of cases

Basic concepts are associated with life integrity education, and the statistical inference section focuses on social responsibility, such as the impartiality of public opinion polls; The integrated application module incorporates national strategies such as big data for rural revitalization. The case library should be accompanied by a user guide, with clear ideological and political goals and teaching entry points to ensure that teachers "use it well and integrate it skillfully".

5.2 Enhance the Ideological and Political Teaching Capabilities of the Teaching Team in Multiple Dimensions and Consolidate the Foundation of the Teaching Staff

Teachers are the main implementers of ideological and political education in the curriculum and need to enhance team capabilities through the "training-collaboration-reflection" trinity mechanism:

5.2.1 Professional training

Organize ideological and political teaching seminars and invite experts from the School of Marxism to jointly analyze philosophical ideas in statistics to help teachers master values guidance skills; Carry out "course-based ideological and political demonstration classes" observation activities, focusing on how to naturally incorporate ideological and political elements rather than mechanically graft them.

5.2.2 Interdisciplinary collaboration

Establish collective lesson preparation groups of math teachers + ideological and political teachers + industry experts to jointly develop cases, such as the cultivation of legal awareness in financial risk models; Encourage teachers to participate in social science projects to enhance their sensitivity to real-world problems.

5.2.3 Dynamic reflection

Implement teaching logs to record the effectiveness of ideological and political education, and continuously optimize cases through student feedback and peer review; Establish an "Innovation Award for Ideological and Political Teaching" to stimulate teachers' intrinsic motivation and achieve a shift from "passive transmission" to "active design"[10].

5.3 Innovate Teaching Models and Methods to Achieve Organic Integration of Ideological and Political Elements

Break away from the traditional "single knowledge transmission" model and build a three-dimensional teaching objective of "knowledge - ability - value".

5.3.1 Contextualized teaching

Design project-based learning tasks, such as analyzing the statistical significance of environmental pollution data in a certain area, to guide students to understand the development concept that "green mountains and clear waters are as valuable as mountains of gold and silver"; Use Monte Carlo simulations to predict the effects of policies and cultivate a sense of patriotism and responsibility.

5.3.2 Technology-enabled interaction

Carry out data mining practices with tools such as R language and Python, and strengthen the scientific attitude of "speaking with data" in analyzing social hotspots; Deepen the values of technology for good by setting up ethical debates on online platforms, such as "The Causes and Countermeasures of Algorithmic Discrimination".

5.3.3 Multiple evaluation mechanisms

Incorporate ideological and political literacy into the assessment, such as marking data sources for report writing to reflect academic norms, and group defense to evaluate their analytical stance on public issues; Use "learning portfolios" to record the growth trajectory of students' values and achieve long-term ideological and political education.

COMPETING INTERESTS

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