Computers and Education Open 9 (2025) 100268

Contents lists available at ScienceDirect

Computers and Education Open

journal homepage: www.sciencedirect.com/journal/computers-and-education-open

Research on the coupling of talent cultivation and reform practice of higher education in architecture

Zhiwu Zhou [a,*], Qiong Tian [a], Julián Alcalá [b], Víctor Yepes [b]

[a] Hunan provincial Key Laboratory of Intelligent Protection and Utilization Technology in Masonry Artifacts, Hunan University of Science and Engineering, Yongzhou Hunan, PR China

[b] Institute of Concrete Science and Technology (ICITECH), Universitat Politècnica de València, València, Spain

ARTICLE INFO

Keywords:
Higher vocational colleges
Discreteness system
Standard technology
Talent development practice
Higher education reform

ABSTRACT

With the sustainable development of the global construction industry and the rapid development of the intelligent building industry, colleges and universities worldwide are stepping up the training of comprehensive talents in intelligent application in the construction profession. Therefore, establishing a cross-regional and perfect construction talent training system has become a critical research and practice topic for university researchers. This study uses computational procedures to fit mathematical theories, coupled model analysis, and other innovative training framework systems. It also analyzes the problems and shortcomings in talent training from three aspects: the current status of industrialization of higher education construction at home and abroad. Combined with the current status of talent training in higher education and the different needs of various countries for architectural talents, a Chinese-style "six-stage multi-module innovation optimization" training framework and a "construction talent training model" are proposed to improve the innovation system. Through in-depth research, a talent training goal system and improvement strategy adapted to the development of China's construction industrialization have been established. The research results effectively compensate for the shortcomings of higher vocational education in this field. The framework of this study can serve as a beacon for deepening education in the construction profession in various countries around the world, guiding higher vocational education to move towards the training of high-tech and high-skilled talents.

1. Introduction

Higher vocational education has significantly contributed to global high-skilled talent training and community welfare. In the 21st century, the main challenge is to meet the intelligent updating of the industry and the movement of high-quality, high-skilled, and lifelong learning talents. Given this, it is urgent to transform the teaching reform models into higher vocational colleges [1]. This paper used Cite space software to analyze the research results published domestically and internationally (Web of Science, Scopus, Google, and CNKI). It could be seen that there needed to be more innovative education models and advanced training systems that integrate the status of global building industrialization and sustainable development, as well as research on future talent demand and interdisciplinary comprehensive training. The purpose of this paper is to fill this gap.

1.1. *Current status of building industrialization at home and abroad*

In the 2030 Agenda for Sustainable Development, the United Nations proposed building resilient infrastructure and promoting inclusive and sustainable industrialization. Building informatization, artificial intelligence, big data, and robot technology have become the economic core for developing the new industrialization strategy [2].

Countries around the world are developing classification systems to support building industrialization; for example, ISO has established the Coclass Building Information Management System and linked it to the global building standard IFC; Denmark has established a building classification system; North American AEC has built the Omni Class platform and the Unclassy system for the UK construction industry. All the above achieve the transfer of data and system management from design to construction management through Cobie. Building SMART has developed the best data dictionary, forming an open international standard component concept attribute library so architects, technical consultants,

* Corresponding author.
E-mail address: zhizh1@huse.edu.cn (Z. Zhou).

https://doi.org/10.1016/j.caeo.2025.100268
Received 15 August 2024; Received in revised form 1 April 2025; Accepted 15 June 2025
Available online 16 June 2025

investors, and operators can exchange and share product information globally [3].

Northern Europe has achieved the digital industrial building model: Finland and Norway enforce model information and specific standard systems in the national structural design [4]; RIBA has identified five stages of building industrialization: manufacturing and assembly design, off-site prefabrication, logistics, on-site assembly and maintenance design [5]; Spain implements a lean building automation construction, applied production, and new engineering product manufacturing model, which achieves the integration of the entire construction process [6], and incorporates all influencing factors of the product lifecycle from conceptual development to operational implementation into the control system. In addition, manufacturers, designers, and participating institutions can share information to achieve precise and flexible supply chain management, data modularization, and automation [2].

China's building industrialization emerged in 1955 and was applied to residential buildings in 1978, which went through three stages: The embryonic stage from 1980 to 1998, Housing industrialization from 1999 to 2013, and Modern automation from 2013 to the present [7].

During this period, the national, provincial, and municipal governments implemented many incentive and mandatory policies, such as the National New Urbanization Plan (2014–2020), Green Building Action Plan, Modernization Construction Industry Development Plan in 2016, etc. As of 2014, China's industrial building area accounted for 77.1 % of the total area, with the prefabricated building area accounting for 30 % [3]. From production PC and construction site management, the building management framework has been tracked and produced with RFID, BIM, cloud computing, GPS, and other information technologies, achieving complete cycle information management of construction sites [8].

Building industrialization is mainly characterized by design standardization, component industrialization, construction mechanization, digital technology, and management informatization, aiming to achieve sustainable development of the entire industrial chain, with design standardization as the core and modular expansion and design, standard integrated assembly of components, production automation, component library informatization, and standardization as the difficulties. Verification techniques include BIM, GIS, DTs, and VI collaborative optimization [9]. Among them, the digital standard building system is the foundation of change, which determines the building business model, protection and new allocation of commercial quotation, risk balance allocation, competitive advantage, and revenue maintenance [3], ultimately forming a combination of industrial integration, technical innovation, and energy efficiency. Technical innovation promotes the integration of the information industry and manufacturing industry, and after integration, new initiatives further stimulate technological innovation. The circulation system began to operate healthily, promoting the rapid high-end development of the building industrialization industry chain [10].

The digitalization and intelligence of the construction industry are future development trends, and high-tech construction has entered every construction industry link.

1.2. Current status of secondary and higher education at home and abroad

Selecting accurate data is the key to the authenticity and scientificity of research results [11]. In this paper, the data updated by the OECD (Organization for Economic Co-operation and Development) were chosen to analyze the high school graduation and university enrollment rates of 16 countries in North America, Europe, and Oceania from 2010 to 2019 and the current status of international secondary and higher education [12].

The conclusion of data analysis shows that, the average high school graduation rate in Israel during the ten years ranked first, reaching 90.06 %, followed by Finland and Latvia, gaining 86.86 % and 86.24 %, respectively. The university enrollment rate in Poland was the highest, reaching 89.95 %, followed by Latvia and Netherlands, going 89.64 % and 87.56 %, respectively. The last-ranked countries were Israel and Mexico, with rates of 43.93 % and 46.14 %, lower than the average of 28.47 % (see Fig. 1a). There are 67 higher education institutions in Israel. According to the statistical data of CHE, there were 320,000 college students (in 2020), including 35,700 majoring in engineering. The main reasons for the large data gap are the limited number of higher education institutions, the enormous wealth gap between domestic families, and the failure of immigrants and other vulnerable groups to continue their university education [13].

China has a large population base, with an average growth rate of 3.75 % for high school students, 3.18 % for enrollment, and 4.94 % for graduation from 2000 to 2020. After the expansion of registration, the increasing rate of college students was 16.38 %, and the growth rate for graduation was 21.26 %. The rising rate of secondary vocational school students was 1.47 %, lower than the graduation rate of 8.28 % (see Fig. 1b). The influencing factors include the regional distribution of education scale, population density, people's quality of life, per capita GDP, tertiary industry, and so on [14].

Performing interpolation and discrete fitting analysis on research data, ranking first with a dispersion interval of −15.68 % to −32.56 % in Mexico. High school education in Mexico was affected by economic, social, and uncertain factors from 2010 to 2019, resulting in various difficulties in sustainable education. The lowest negative range of the university enrollment rate was from −22 % to 31.25 %. According to the analysis of discrete data on high school graduation rate, Portugal ranked first, ranging from −11.36 % to 12.61 %, due to the negative impact of the regulatory and performance evaluation systems in Portuguese secondary education institutions. The discrete range of university enrollment rate in Hungary ranked first, ranging from −5.96 % to 5.93 % (see Fig. 2a), due to Hungary's long-term exposure to severe secularist interference, and religious education in schools coerced by religion, religious institutions, and communist parties [15].

In addition, a polynomial was used to fit and analyze data from 16 countries. It could be seen from the figure that 2015 was at the boundary point position, with a rapid increase in the early stage and a gradual trend towards stability in the later stage (see Fig. 2b). The average growth rates of the two related indexes were 0.71 % and 0.33 %, with a ratio of 2.13. The fitting results were consistent with the OECD data analysis results. The model presents the educational modes of high school students in Europe and the Americas: it is student-centered. Students exhibit proactive learning, and schools focus on cultivating students' transferable skills, problem-solving ability, and critical and reflective thinking. The above teaching ideas must be referenced in Chinese-style education [15].

Chinese vocational colleges have dual attributes of higher education and vocational education. There were about 1468 institutions (in 2020) and 14.595 million college students in China [16]. In 2014, the State Council issued the Decision on Accelerating the Development of Modern Vocational Education, proposing five connections and one innovation guidance suggestion [9]. As specified in the National Medium-and Long-Term Plan for Education Reform and Development (2010–2020), we should promote the diversified development of ordinary high schools and the diversification of educational systems and training models and encourage regular high schools to have their characteristics [17]. It is also clear that the goal of training vocational college talents is to serve regional economic and social construction, build a modern industrial system, meet the talent demand of local economic development and construction, and train many high-quality human resource teams with reasonable structure [18].

Comparative research results indicate significant differences in vocational education among countries. Still, they also need help with common problems, such as slow and partial feedback on labour market demand, difficulty balancing enterprises and meeting student needs, disharmony in industrial modernization development and educational

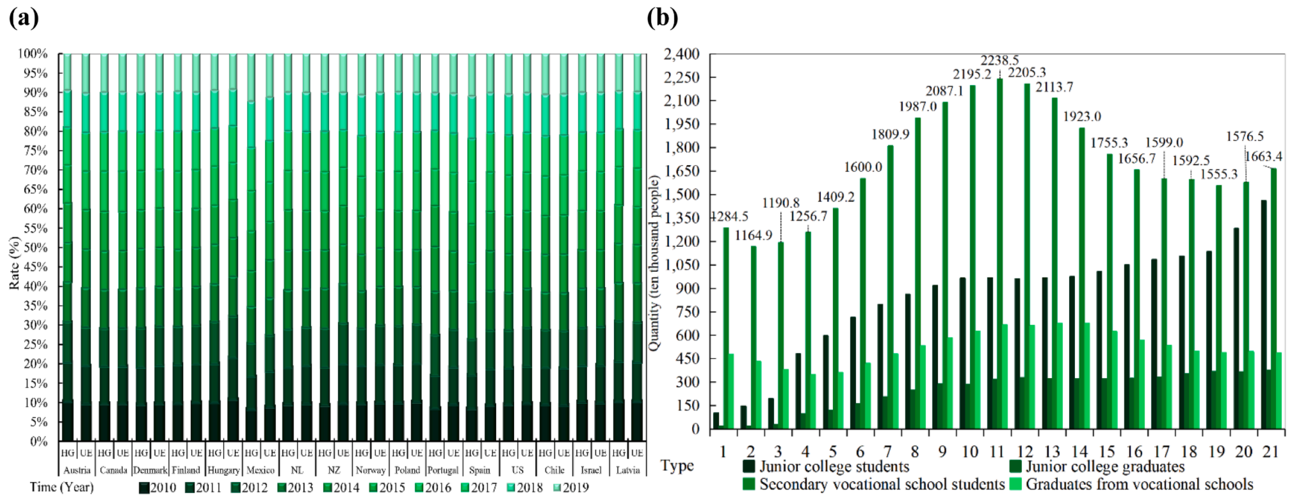

Fig. 1. Data analysis: (a) High school graduation rate and university enrollment rate in 16 countries (2010–2019), (b) Data of high school and university in China (2010–2020).

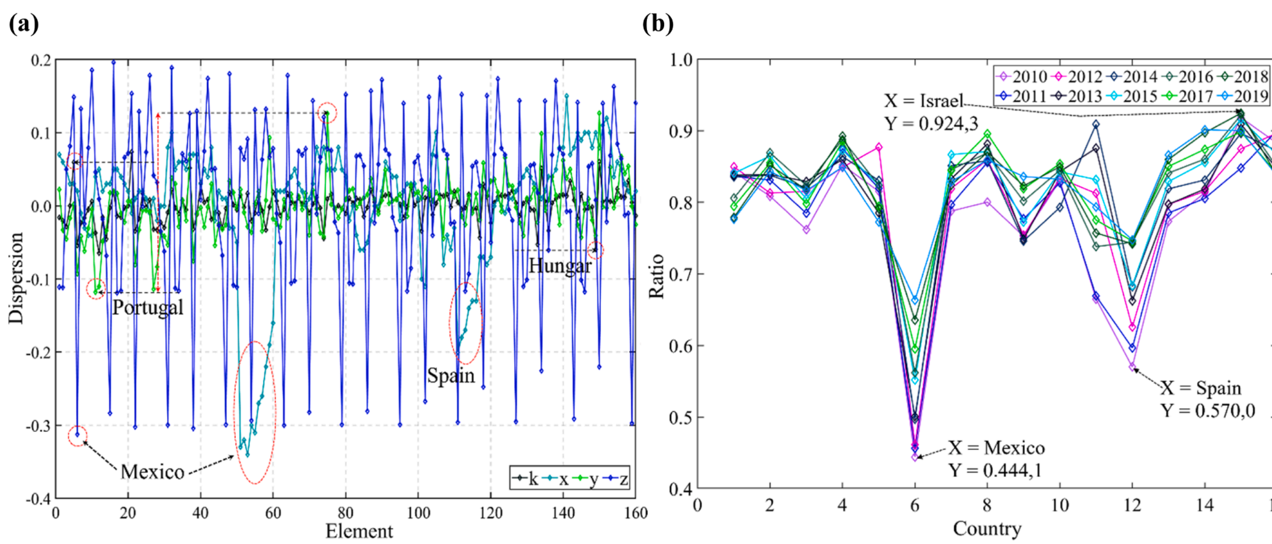

Fig. 2. Rate analysis of 16 countries (2010–2019): (a) Discreteness, X = Vertical Ratio of High School Graduation Rate, Y = Horizontal Ratio of High School Graduation Rate, $K = Z$ = Vertical Ratio of University Enrollment Rate, (b) Data Fitting.

integration, and weak full-time teaching staff [19].

1.3. Evaluation on the demand for chinese architectural professionals (2000–2041)

As a pillar industry of China's economy, the construction industry is essential in promoting rapid economic development. According to the data analysis of the Statistical Bulletin of National Economic and Social Development [20], the amount of China's construction industry in 2010 increased by CNY (Chinese Yuan) 2.64 trillion (see Fig. 3a), accounting for 6.65 % of GDP (Gross Domestic Product). The average growth rate of construction enterprises from 2000 to 2020 was 5.16 %. It can be seen from Fig. 3b that the population in the construction industry continues to show an increasing trend, with an average of 4.66 %. After a turning point in 2002, it maintains a stable growth trend.

In the talent evaluation from 2021 to 2041, the talent structure was analyzed through the MATLAB simulation program, and the sustainable change trend and local optimal parameters were predicted and fitted using the least squares curve model. The predicted data are based on the three centenary plans proposed by the Chinese government and the research results of China's GDP from 2021 to 2041. The mathematical model of GDP ↔ total construction output value ↔ Chinese construction industry employees is established, and biharmonic spline interpolation is used for analysis. The structural goodness of fit is SSE: 7.474e-22 R-square: 1, reflecting the efficiency and optimality of fitting curves (see Fig. 4a). The mathematical model of GDP ↔ real estate investment output value ↔ Chinese real estate construction employees is established. SSE: 1.521e-24, R-square: 1, reflecting the optimal fitting curve model (see Fig. 4b).

The analysis data show that the total investment in the construction industry and the number of employees continuously increase. Among them, investment in the real estate industry continues to grow, while the demand for employees is increasing at a low speed, and the average annual number of employees will be lower than the average value in 2020. Fig. 5a shows 43,916,055 construction employees from 2021 to 2041, with an average annual population of 2091.241, which is 3.89 times that of 2020.

Fig. 5b shows 395,858 Chinese real estate employees from 2021 to 2041, with an average annual population of 18,850, 0.65 times that of 2020. The conclusion is that there should be many innovative

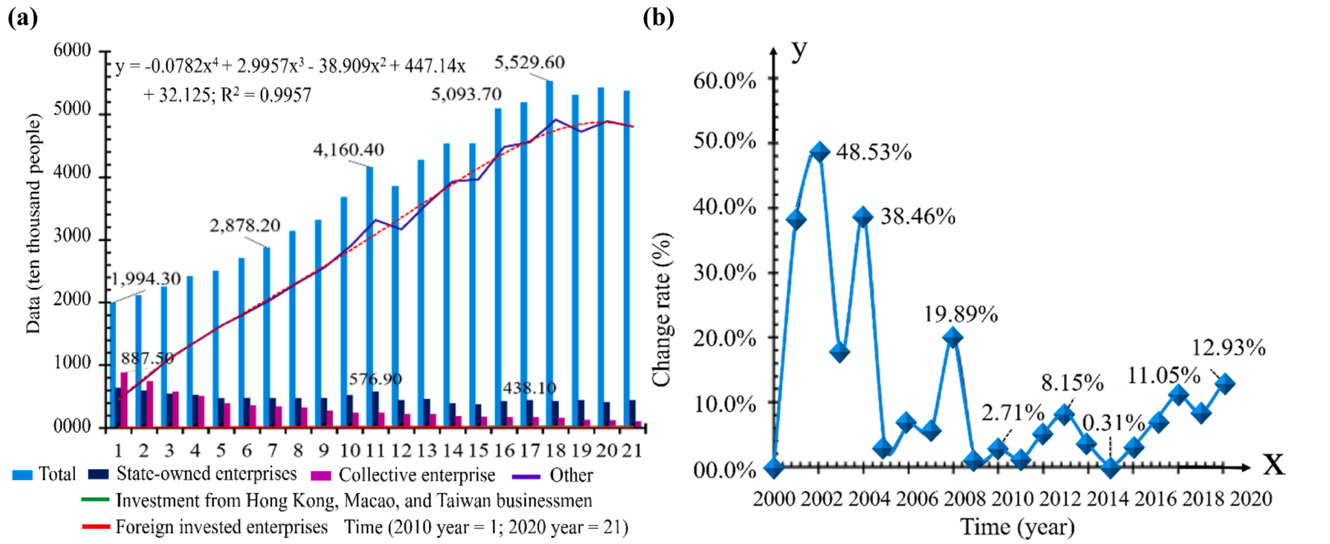

Fig. 3. Analysis of China's construction industry data: (a) Theoretical model and change rate analysis of enterprises, (b) Employee model and growth rate analysis.

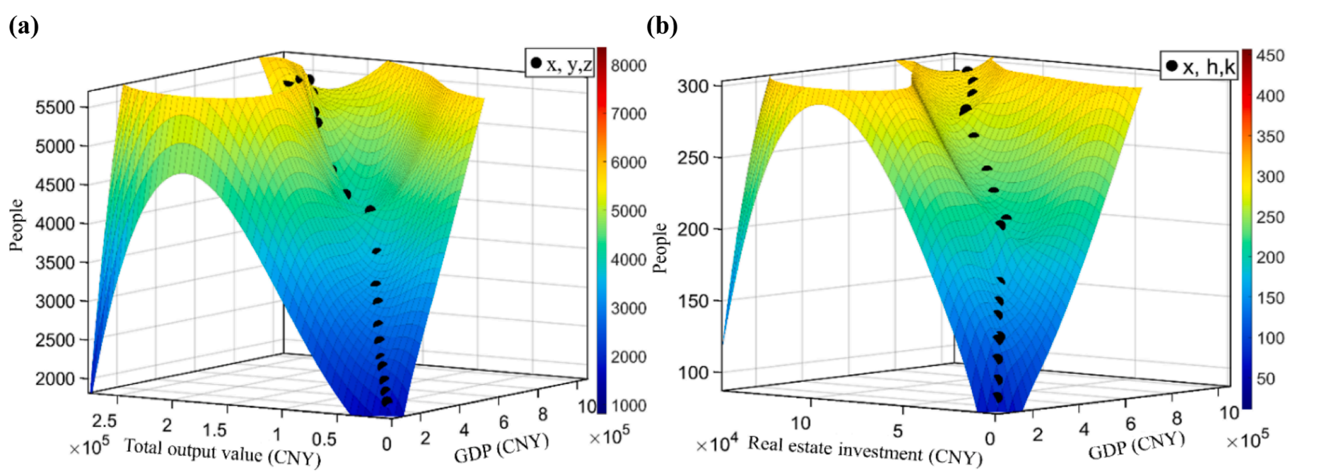

Fig. 4. Mathematical theoretical model: (a) GDP - total output value of the construction industry – employees, (b) GDP - real estate industry investment - real estate employees.

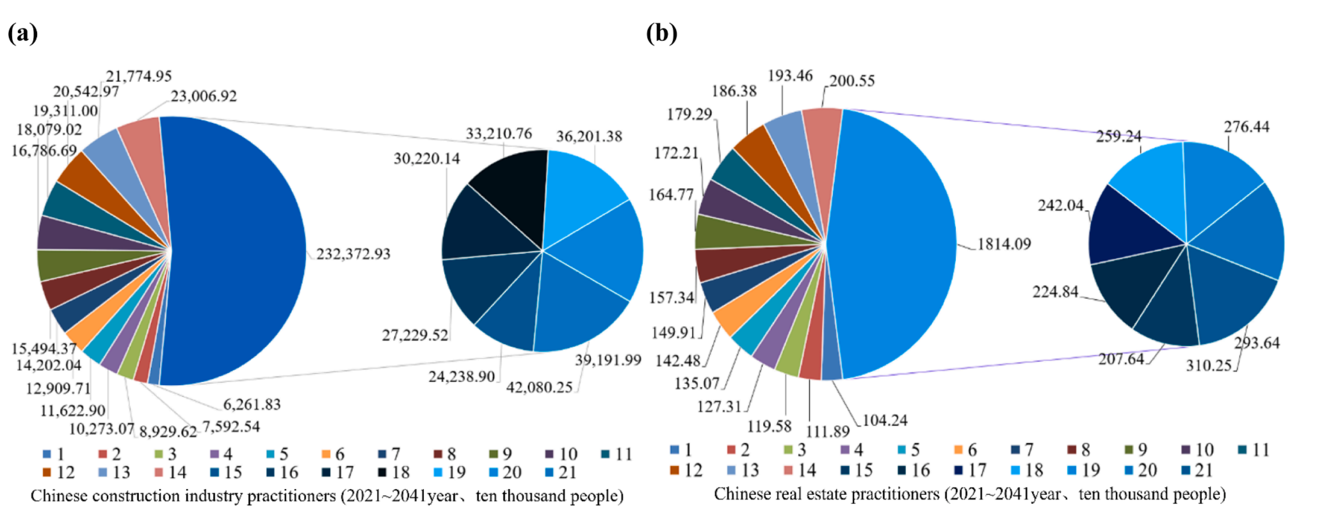

Fig. 5. Evaluation and analysis data (2021–2041): (a) Construction industry employees, (b) Real estate employees.

professionals and human capital resources to achieve sustainable green development and the new concept of "innovation, coordination, green, openness, and sharing" of China's construction industry [17].

The innovation of this paper is: 1. The research thoroughly investigated the status and shortcomings of research in this field in universities around the world, laying the foundation for the urgency of the research direction and the robustness of the research results. 2. The research integrates cross-disciplinary application analysis such as computer science, advanced mathematics, and engineering theory, proving the scientific nature of the article. 3. The research innovates talent training system models such as "six-stage multi-module innovation optimization" and verifies the practical value of the research through practice and follow-up investigation.

This paper is divided into five sections. The first section is Introduction, which analyzes the current status and shortcomings of the research through literature survey; the second section is Methodology, which establishes the talent demand framework and theoretical research model of this paper; the third section is Results, which verifies the robustness of the research through case analysis and employment follow-up investigation; the fourth section is Discussion, which analyzes and discusses the key content of the research and gives methods; the fifth section is Conclusion, which summarizes the key content and shortcomings of the research of this paper, and explains the content and direction of further research.

2. Methodology

In 2004, the Ministry of Education issued the Administrative Measures for the Establishment of Higher Vocational Education Majors in Regular Institutions of Higher Education (Trial), which clarified the concept of industry-oriented and subject-supplemented and divided higher vocational majors into 19 major categories (agriculture, forestry, animal husbandry and fishery, and transportation), 78 secondary categories, with a total of 532 majors. In 2019, the Ministry of Education and Finance implemented the "Double High-levels Plan" [21]. The Ministry of Education selected 197 construction units, totaling 389 significant groups. After >40 years of development, China's higher vocational colleges have achieved many things, but some things could be improved in their operation [19].

2.1. Reform and innovation measures for Chinese higher vocational colleges

The goal of the construction engineering technology major in higher vocational colleges is to train architectural professionals, with graduates mainly engaged in industry-facing physical construction enterprises. There are areas for improvement in positioning talent training goals based on university majors, making it challenging to reflect the educational concept of deep industry-education integration [22].

2.1.1. Analysis of the demand for architectural professionals

There is no dynamic adjustment mechanism for majors, so adjusting traditional majors according to industry needs, establishing digital platforms for practical education, promoting deep cooperation between enterprises and universities, and formulating talent training plans and high-level major group construction plans [23].

Fig. 6 shows higher vocational colleges' current talent training models, with flat, integrated, and skilled demand from employers and enterprises. From the perspective of apparent behaviour, it is a combination of production and education, but in fact, it is two independent social processes that lack authenticity and technical integration [24]. Integrating multiple training modes has promoted higher vocational

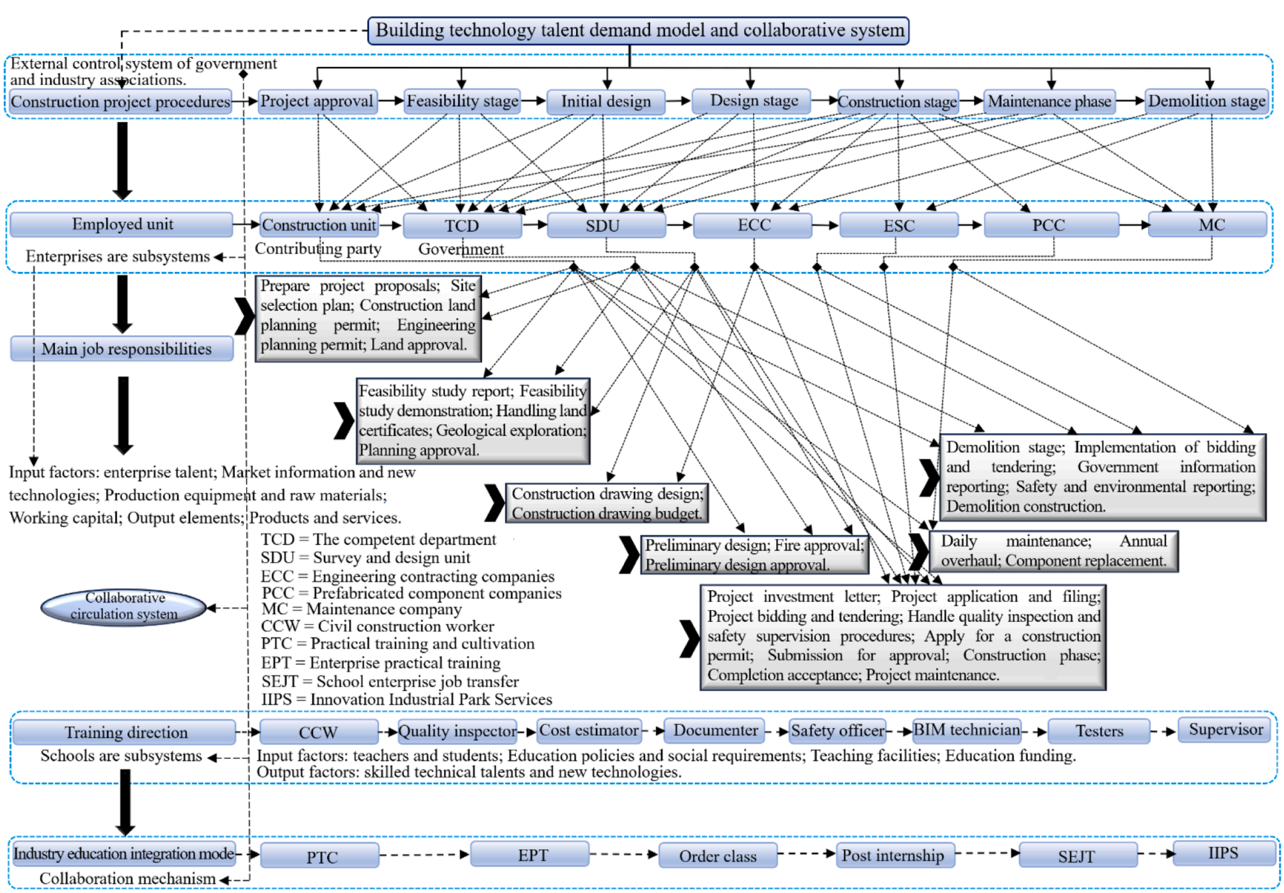

Fig. 6. Analysis of job demand for architectural professionals (Current Operational Model).

colleges' training quality and employment rate. Still, there needs to be more innovative, high-quality professionals combining employment and service orientation, production, learning, and practical research [25].

2.1.2. Evaluation model for talent training results

European higher education has always adopted a binary higher education system, especially in colleges and universities. As the economic development changed, the United Kingdom formulated a post-binary higher vocational education policy in 1965, realizing the interdisciplinary and continuing vocational education through a new institution - the Institute of Technology [26]. The higher education system in China is divided into two major approaches: general higher education and higher vocational education. The latter one started in 1978, which was slightly later than Europe.

2.2. Mathematical evaluation model

In view of the impact of various uncertain factors on higher vocational education, it is crucial to determine multiple indexes based on different dimensions and establish a reasonable talent training evaluation system [27]. In this paper, the core model of educational outcome evaluation proposed by Levin (1974) is introduced [28]:

$$A_{it} = g\left[F_{i(t)} \times S_{i(t)} \times P_{i(t)} \times O_{i(t)} \times I_{i(t)}\right] \tag{1}$$

A_{it} = vector of students' educational outcomes at a certain period; it $F_{i(t)}$ = vector of personal and family characteristics of student i as of time t; $S_{i(t)}$ = vector of school resources related to student i as of time t; $P_{i(t)}$ = vector of peer features of student i as of time t; $O_{i(t)}$ = vector of other external factors related to student i as of time t; $I_{i(t)}$ = initial or innate endowment vector of student i at time t.

Formula (1) is used to evaluate the extent to which the increase in school resources has caused changes in A_{it}. The data differences between the new and old talent training models can be compared and analyzed, which is more representative of the determination criteria. Considering the current situation of colleges and universities, hardware and software facilities, and the discrete influencing factors of regional differences, the sensitivity of Formula (1) was corrected by the entropy weight method to establish an efficient and reasonable model.

Determine the weight of vector matrix elements : $P_i = \frac{\sqrt[n]{M_i}}{\sum_{i=1}^{n}\sqrt[n]{M_i}},\ M_i = \prod_{j=1}^{n} b_{ij}$ (2)

a_j = weight of each index in the analytic hierarchy process; jV_j = information weight of the j^{th} index; S_j = entropy value output by the j^{th} index.

After the S_j value is obtained, normalization is performed to eliminate different interferences of approximate indexes. For positive index:

$$C_{ik}^{*} = \frac{C_{ik} - \min\limits_{1\le i\le s}(C_{ik})}{\max\limits_{1\le i\le S}(C_{ik}) - \min\limits_{1\le i\le S}(C_{ik})} \tag{4}$$

For inverse index:

$$C_{ik}^{*} = \frac{\max\limits_{1\le i\le S}(C_{ik}) - C_{ik}}{\max\limits_{1\le i\le S}(C_{ik}) - \min\limits_{1\le i\le S}(C_{ik})} \tag{5}$$

S = total number of evaluation units; $\max\limits_{1\le i\le S}(C_{ik})$ and $\min\limits_{1\le i\le S}(C_{ik})$ = maximum and minimum values of k indexes in the evaluation unit; C_{ik} = value of the k^{th} index in the i^{th} evaluation unit.

According to the analysis of Formulas (1) - (5), combined with the sensitivity entropy weight analysis formula, it can be corrected as follows:

$$A_{it} = g\left\{\left[F_{i(t)} \times \left(1 \pm S_{ia_j}^{V_j}\right)\right] \times \left[S_{i(t)} \times \left(1 \pm S_{ia_j}^{V_j}\right)\right] \times \left[P_{i(t)} \times \left(1 \pm S_{ia_j}^{V_j}\right)\right] \times \left[O_{i(t)} \times \left(1 \pm S_{ia_j}^{V_j}\right)\right] \times \left[I_{i(t)} \times \left(1 \pm S_{ia_j}^{V_j}\right)\right]\right\} \tag{6}$$

Correction coefficient: C_{ik}^{*}(negative interval index) $\le S_{ia_j}^{V_j} \le C_{ik}^{*}$ (positive interval index).

2.2.1. Influence index evaluation

Five evaluation indexes were formulated in Formula (1), and the model's primary impact evaluation index factors were constructed based on the characteristics of higher vocational college students and infrastructure configuration as the decision structure analysis layer. The index results were analyzed by establishing a theoretical model to find the best evaluation parameter combination. The comprehensive evaluation system indexes of college students were used as $P_{i(t)}$ influence parameters, a matrix-vector was established for six parameters, and each parameter was divided into five evaluation level indexes: poor (0.00), fail (0.40), pass (0.60), good (0.70), excellent (0.80), and total score (1.00) [29].

$$P_{i(t)} = \begin{bmatrix} \text{Student quality} & 0.00 & 0.40 & 0.60 & 0.80 & 1.00 \\ 0.00 & \text{Cultural and sports quality} & 0.40 & 0.60 & 0.80 & 1.00 \\ 0.00 & 0.40 & \text{Psychological quality} & 0.60 & 0.80 & 1.00 \\ 0.00 & 0.40 & 0.60 & \text{Innovative quality} & 0.80 & 1.00 \\ 0.00 & 0.40 & 0.60 & 0.80 & \text{Competency quality} & 1.00 \\ 0.00 & 0.40 & 0.60 & 0.80 & 1.00 & \text{Character} \end{bmatrix}$$

P_i = index weight of vector elements; M_i = determination of the product of elements in the same row of a vector matrix; b_{ij} = element vector.

The entropy weight method is used to correct the weight indexes of analytic hierarchy process:

$$a_j = \frac{V_i \times P_j}{\sum_{j=1}^{n}(V_j \times P_j)},\ V_j = \frac{(1 - S_j)}{\sum_{j=1}^{n}(1 - S_j)},\ S_j = -(\ln n)^{-1} \times \sum_{i=1}^{n}(r_{ij} \times \ln r_{ij}) \tag{3}$$

The family environment has a direct impact on students. Considering the special groups with low social status and economic difficulties, four family influence parameter indexes were proposed for strengthened assessment [30].

$F_{i(t)}$ = Scoring standard

$$\begin{bmatrix} \text{Economic situation} & \text{Poor} & \text{Medium} & \text{Good} \\ \text{Married} & \text{Parental status} & \text{Divorce} & \text{Unmarried} \\ \text{Poor} & \text{Medium} & \text{Parental relationship} & \text{Good} \\ \text{Dissatisfied} & \text{Basically satisfied} & \text{Satisfied} & \text{Major selected} \end{bmatrix}.$$

the scoring criteria are the same as $P_{i(t)}$.

School resources are a multi-factor influence index for higher education evaluation, which determines the overall quality of education and the future employment channels for students. The combination of academic and environmental indexes is a relatively perfect evaluation method [31].

$$S_{i(t)} = \begin{bmatrix} \text{Academic reputation} & 0.00 & 0.40 & 0.60 & 0.80 & 1.00 \\ 0.00 & \text{Employer reputation} & 0.40 & 0.60 & 0.80 & 1.00 \\ 0.00 & 0.40 & \text{Teachers/students} & 0.60 & 0.80 & 1.00 \\ 0.00 & 0.40 & 0.60 & \text{Teacher citation} & 0.80 & 1.00 \\ 0.00 & 0.40 & 0.60 & 0.80 & \text{International teacher ratio} & 1.00 \\ 0.00 & 0.40 & 0.60 & 0.80 & 1.00 & \text{International student ratio} \end{bmatrix}$$

College students are a vulnerable group, influenced by individual and multiple environmental factors. After the career goals are clarified, it is necessary to overcome negative impacts and obtain external support through effective learning strategies [29].

$$Q_{i(t)} = \begin{bmatrix} \text{Personality} & \text{Extremely poor} & \text{Relatively poor} & \text{Poor} & \text{Pass} & \text{Good} & \text{Excellent} & \text{Full score} \\ \text{Extremely poor} & \text{Cognitive model} & \text{Relatively poor} & \text{Poor} & \text{Pass} & \text{Good} & \text{Excellent} & \text{Full score} \\ \text{Extremely poor} & \text{Relatively poor} & \text{Coping style} & \text{Poor} & \text{Pass} & \text{Good} & \text{Excellent} & \text{Full score} \\ \text{Extremely poor} & \text{Relatively poor} & \text{Poor} & \text{Economic situation} & \text{Pass} & \text{Good} & \text{Excellent} & \text{Full score} \\ \text{Extremely poor} & \text{Relatively poor} & \text{Poor} & \text{Pass} & \text{Family situation} & \text{Good} & \text{Excellent} & \text{Full score} \\ \text{Extremely poor} & \text{Relatively poor} & \text{Poor} & \text{Pass} & \text{Good} & \text{Life event} & \text{Excellent} & \text{Full score} \\ \text{Extremely poor} & \text{Relatively poor} & \text{Poor} & \text{Pass} & \text{Good} & \text{Excellent} & \text{Physical conditions} & \text{Full score} \\ \text{Extremely poor} & \text{Relatively poor} & \text{Poor} & \text{Pass} & \text{Good} & \text{Excellent} & \text{Full score} & \text{Social relation} \end{bmatrix}$$

The differences in students' intellectual structure determine the gap in language, perception, and genius abilities. Researchers have identified seven indexes through multiple ability score tests, factor analysis, and uniqueness tests to identify and label genius sample tests [32].

$$I_{i(t)} = \begin{bmatrix} \text{Language ability} & \text{Extremely poor} & \text{Poor} & \text{Pass} & \text{Good} & \text{Excellent} & \text{Full score} \\ \text{Extremely poor} & \text{Reasoning} & \text{Poor} & \text{Pass} & \text{Good} & \text{Excellent} & \text{Full score} \\ \text{Extremely poor} & \text{Poor} & \text{Rotation memory} & \text{Pass} & \text{Good} & \text{Excellent} & \text{Full score} \\ \text{Extremely poor} & \text{Poor} & \text{Pass} & \text{Spatial visualization} & \text{Good} & \text{Excellent} & \text{Full score} \\ \text{Extremely poor} & \text{Poor} & \text{Pass} & \text{Good} & \text{Visual perception} & \text{Excellent} & \text{Full score} \\ \text{Extremely poor} & \text{Poor} & \text{Pass} & \text{Good} & \text{Excellent} & \text{Response time} & \text{Full score} \\ \text{Extremely poor} & \text{Poor} & \text{Pass} & \text{Good} & \text{Excellent} & \text{Full score} & \text{Specialized field information} \end{bmatrix}$$

3. Results

A complete index and evaluation theoretical system was established as a mathematical model in the 3.2 questionnaire survey to conduct in-depth analysis and discussion of the new and old talent training systems.

3.1. Insufficient architectural professionals in higher vocational colleges

Through the analysis and discussion in Sections 2, 3, and 4, the following issues were proposed, which should be urgently considered in the training of architectural professionals in higher vocational colleges:

1. Current situation of high school students and training and improvement of quality: According to China Statistical Yearbook in 2021, the number of high school graduates reached the first peak of 7.271 million in 2006 and remained at 7.757 to 8.361 million from 2007 to 2020; the average annual growth rate within 21 years was 5.64 %; from 2009 to 2020, the average yearly growth rate was −0.50 %. Regarding general undergraduate and junior college enrollment, 5.045 million students were

enrolled in 2005. Afterwards, enrollment expansion was still carried out, reaching a peak of 9.675 million in 2020. The average annual growth rate within 21 years was 9.53 %, and the average enrollment rate was 87.35 %. The above analysis data are among the top in the world, only lower than Poland, Latvia, and Netherlands compared to 16 countries. Since 2018, the number of college enrollments has exceeded that of high school graduates, and the number of higher vocational college students has shown a significant downward trend. The enrollment score for higher vocational colleges from 2010 to 2021 was 180, about 220 points lower than the regular undergraduate enrollment score. In addition, students need more quality [24].

2. Low enrollment rate and lack of learning interest and sense of responsibility: In 2015, the national average net enrollment rate for higher vocational colleges was 38.1 %, lower than 10.4 % for undergraduate colleges. The gross enrollment rate of higher education in OECD countries was 60.45 % [33].
3. Students need a clearer understanding of their central direction and future development and have no interest in hobbies. Learning interest and motivation mainly affect learning effectiveness and enthusiasm. Chinese students are busy with exam-oriented education during their high school stage and follow the arrangements of their parents and teachers, lacking training in personal development direction, industry engagement, and professional interests in the future [34]. However, European and American schools and parents have focused on cultivating children's interest in science, technology, engineering, and essential subject development from kindergartens. Through extensive participation in social, school, and collective activities, students can visit and practice the cognitive world. They can determine their interests and hobbies during the nine-year education stage, with a ratio of 94.7 % in Europe and 93.8 % in the United States [35].
4. A lack of significant financial support and equipment for offering practical training courses in high vocational colleges results in substandard quantity and quality. In 2017, China invested RMB 452.5 billion in higher vocational education, accounting for 10.63 % of national education funds [36].
5. Due to the severe academic procrastination, lack of good restraint ability and learning enthusiasm, and relaxed the learning environment in universities, it is difficult for students to complete their university studies, causing a shortage of professional skills and essential abilities, which is also one of the reasons why state-owned enterprises and well-known enterprises and units refuse to provide internships or employment opportunities for higher vocational college students [14].
6. There is a need for more full-time, double-qualified teachers, and teachers need more comprehensive abilities. Some universities need more apparent concepts and more specific understandings. After vocational training and short-term on-site practice, in-service teachers are recognized as "double-qualified" and hold full-time teaching positions. In 2018, the State Council proposed standards for "double-qualified" teachers. The Ministry of Education has repeatedly clarified the criteria for the recognition of "double-qualified" teachers: Teacher Qualification Certificate and Technical Title Certificate (an intermediate or higher technical title can be obtained after 3–5 years of employment in a specialized unit rather than getting a national industry qualification certificate through examination) [37].
7. The 'university-enterprise cooperation' also has its shortcomings. There is no perfect win-win cooperation path. Most universities offer order-based classes and experimental classes with a - 4-year

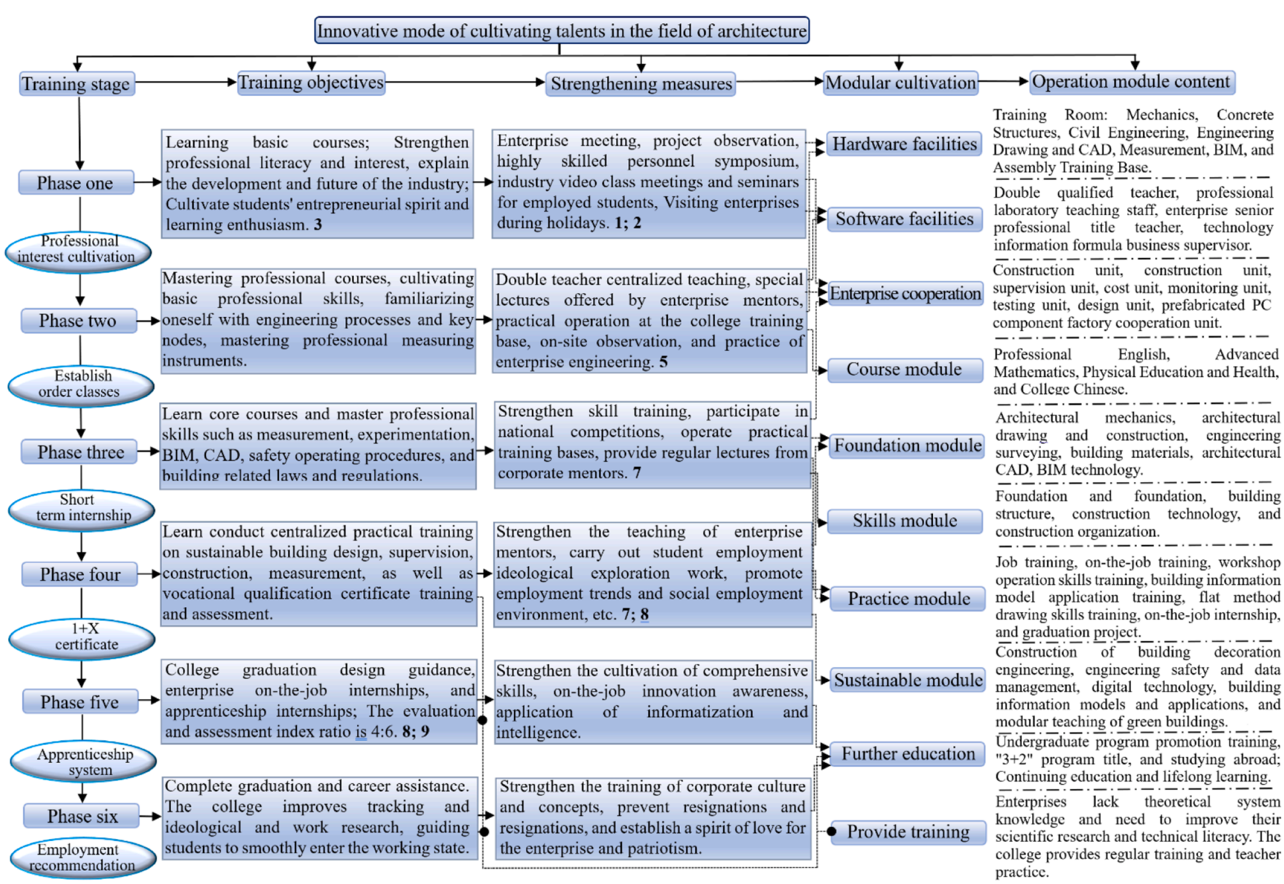

Fig. 7. Innovative training system model for architectural professionals.

training period, and enterprises cannot employ the professionals in the short term, lacking enthusiasm for training. Moreover, engineering enterprises have randomness and discontinuity in project contracting, high mobility of technical management personnel, and need more stable internship bases for replacement and waiting positions. There are management risks in project training, and project leaders are challenged to delegate management authority to interns because they are concerned that safety, quality, and progress accidents may occur, causing losses to both the project and the enterprise.

8. The competition for student employment is fierce, and enterprises are more willing to accept undergraduates under the same recruitment conditions. There are significant differences in basic knowledge and professional skills between junior college students and undergraduates. Undergraduates have higher levels of self-cultivation, corporate culture learning, job skills, innovation, training time, and efficiency creation.
9. Also, undergraduates can contribute to scientific research projects after employment because they have strong analytical and problem-solving abilities, innovative awareness, and outstanding theoretical achievements. In this case, their time and space for promoting technical titles and positions are faster and more extensive. However, it has caused specific stress and impact on junior college students' ideology, work, life, and development, resulting in low enrollment and high turnover rates.
10. Social identity is low, and students experience more stress from society and family. Since it was proposed to gradually improve the management and training system at the Fourth National Conference on Higher Vocational Education in 2000, this issue has been constraining the healthy development of higher vocational education from beginning to end. Higher vocational colleges have hurt society due to their short history, rapid expansion of scale, lack of understanding of culture, low quality of students, and weak educational characteristics [38,39].

3.2. Innovation pattern and improvement strategy

Higher education institutions and universities are the principal places to achieve sustainable talent development goals. In the current era of intelligentization and informatization, the innovative construction of talent training mechanisms and the improvement of students' overall quality are significant. Therefore, it is imperative to deepen the reform of higher vocational education through active and effective measures and strategies, improve the quality of the teaching staff, and establish a talent training system that meets industrial needs and innovation and entrepreneurship development strategies.

A research model for the innovative training system of architectural professionals is established based on the shortcomings mentioned in Section 3 and the characteristics of China's existing vocational talent training system, combined with multiple higher vocational education laws, regulations, and policies issued by China.

1. The training period of high vocational colleges is three years (4 ∼ 5 years for special majors), and there is no defined constraint time for each stage in the model. Given the differences in majors and uncertain interference factors, the teaching cycle can be freely adjusted. Commonly used models include 2 + 1 years, 0.8 + 0.2 + 0.8 + 0.2 + 0.5 + 0.5 years, 2.5 + 0.5 years, and 3 + 1 years. It is unreasonable for students to meet the employment standards of enterprises after one year of on-the-job training. Students need at least two years of work training and exercise to acquire basic and operational skills.

Fig. 7 shows the innovative system model named 'six-stage multi-module innovation optimization'. Before discussing the model, several essential points must be clarified:

2. In the design of the training system, the questions raised in Section 3 are answered and effective solutions are provided, with a calibration of 1 - 10.

3. Regarding education funds, the state, local governments, enterprises, and universities should increase their research funds, support the provision of higher vocational infrastructure, hardware and software, establish high standard vocational education, and cultivate independent innovation. Moreover, the comprehensive quality is based on scientific research and practice.

4. It is essential to emphasize and enhance the practical training at the college base. Most universities need largescale construction, prefabricated training places and equipment, and guidance from highly skilled talents with senior professional titles and long-term work experience. Students need on-site operating conditions and opportunities for practical operations. Therefore, the construction of the architectural professional training base can be funded in batches to ensure the orderly and effective design and overall implementation of the talent cultivation plan.

5. It is essential to conduct joint training of enterprises and mentors. By their high professional title, rich practical experience, and comprehensive management, construction and pricing abilities, enterprise experts have enough on-site teaching and operation skills. In the third stage, it is necessary to strengthen classroom teaching together with enterprise training, and the personnel management department of the university needs to coordinate in the following four aspects:

Senior professional title management personnel in enterprises are usually middle-level and above leaders with busy work and business, whether they have the conditions for long-term teaching.

Enterprise executives have yet to receive formal teacher training, whether they have the conditions for long-term classroom teaching or the quality of the explanation content.

Whether the enterprise agrees to arrange professional mentors to carry out teaching tasks for a long time and whether it affects the enterprise's everyday work and production functions.

Whether the college should pay corresponding remuneration and teaching fees to demonstrate recognition and gratitude for the enterprise.

The college should enhance its external influence and popularity by promoting long-term cooperation with state-owned enterprises, well-known enterprises, and internationally renowned universities to make academic achievements and by transforming innovative achievements into promotional information. In addition, the college should also increase enrollment rates and ensure stable employment quality by promoting the construction of distinctive majors and first-class disciplines.

The college should regularly visit employed students. In the early stages of employment, students may experience immaturity and instability in their thinking, understanding, and concepts, so it is necessary to regularly and frequently visit enterprises and track students' thoughts, work, and life, timely discover and predict unstable factors, and provide assistance and coordination through active communication with project and company department leaders to solve the problem. The college cannot ignore and does not provide service for students after employment but should assist enterprises in utilizing, retaining, and developing talents.

The characteristics of the "six-stage multi-module innovation optimization" model are as follows:

1. Transforming the training of higher vocational college students from passive indoctrination education to an educational model of cultivating a sense of interests, hobbies, and responsibility.
2. Paying more attention to applied and practical teaching and making students learn professional knowledge through hands-on and brainstorming.
3. Fully integrate student training with the enterprise talent demand, cultivate talents who adapt to corporate culture and industry development mission and focus on training high-skilled talents. Loving the enterprise and country will be the goal of the new generation of high-skilled talents.

4. Strengthening the practicality of professional knowledge. Higher vocational colleges' old talent training model requires a six-month or one-year internship in the student's junior year. Most students need clarification about their future work and development direction from the beginning of enrollment. They need to realize what knowledge and skills are required to arm and improve themselves, their future personal development direction, how to do it, and how to achieve it.
5. Training college students out of society is an imperfect and incomplete educational model. Therefore, it is necessary to expose students to enterprise and organisation too early and to learn and practice professional skills, especially for architectural professionals. If they do not go to the site and participate in actual engineering projects, it will become mere paper talk. Therefore, students can only recognise accurate skills and techniques by strengthening project internships, practising, and combining professional knowledge with on-site practice.
6. Through multiple practices, internships, and practical training, students can fundamentally understand the characteristics, rules and risks of their future industry in advance, cultivate and enhance their belief in choosing their future life path, and decide whether to give up or firmly go ahead in advance, eliminating giving up halfway and causing irreparable losses to colleges and enterprises.
7. It is necessary to improve the comprehensive skills of "double-qualified" teachers to allow them to engage in multiple practical activities and communicate with enterprises to grasp the latest building patterns and information technology promptly, improve their practical engineering experience, update educational concepts, and completely eradicate the old educational method.

3.3. Comparative analysis of new and old model data

After the talent training system was determined and the multi-disciplinary demand analysis in the industry was completed, critical talent training was carried out according to the college's overall development plan.

$$F_{i(t)} = \begin{bmatrix} 0.70 & 0.70 & 0.60 & 0.60 \\ 0.60 & 0.70 & 0.60 & 0.60 \\ 0.70 & 0.70 & 0.80 & 0.60 \\ 0.60 & 0.70 & 0.60 & 0.60 \\ 0.80 & 0.80 & 0.60 & 0.60 \\ 0.60 & 0.70 & 0.80 & 0.60 \\ 0.60 & 0.70 & 0.60 & 0.60 \\ 0.70 & 0.70 & 0.60 & 0.60 \\ 0.60 & 0.70 & 0.80 & 0.60 \\ 0.70 & 0.70 & 0.80 & 0.60 \\ 0.70 & 0.70 & 0.80 & 0.60 \\ 0.70 & 0.70 & 0.80 & 0.60 \\ 0.60 & 0.60 & 0.80 & 0.60 \\ 0.60 & 0.70 & 0.80 & 0.60 \\ 0.60 & 0.70 & 0.60 & 0.60 \\ 0.60 & 0.70 & 0.60 & 0.60 \end{bmatrix};$$

$$S_{i(t)} = \begin{bmatrix} 0.40 & 0.40 & 1.00 & 0.01 & 0.01 \\ 0.40 & 0.40 & 1.00 & 0.01 & 0.01 \\ 0.40 & 0.40 & 1.00 & 0.01 & 0.01 \\ 0.40 & 0.40 & 1.00 & 0.01 & 0.01 \\ 0.40 & 0.40 & 1.00 & 0.01 & 0.01 \\ 0.40 & 0.40 & 1.00 & 0.01 & 0.01 \\ 0.40 & 0.40 & 1.00 & 0.01 & 0.01 \\ 0.40 & 0.40 & 1.00 & 0.01 & 0.01 \\ 0.40 & 0.40 & 1.00 & 0.01 & 0.01 \\ 0.40 & 0.40 & 1.00 & 0.01 & 0.01 \\ 0.40 & 0.40 & 1.00 & 0.01 & 0.01 \\ 0.40 & 0.40 & 1.00 & 0.01 & 0.01 \\ 0.40 & 0.40 & 1.00 & 0.01 & 0.01 \\ 0.40 & 0.40 & 1.00 & 0.01 & 0.01 \\ 0.40 & 0.40 & 1.00 & 0.01 & 0.01 \\ 0.40 & 0.40 & 1.00 & 0.01 & 0.01 \end{bmatrix};$$

$$P_{i(t)} = \begin{bmatrix} 0.40 & 0.40 & 0.60 & 0.40 & 0.30 & 0.20 \\ 0.60 & 0.40 & 0.60 & 0.40 & 0.40 & 0.40 \\ 0.70 & 0.40 & 0.70 & 0.50 & 0.60 & 0.70 \\ 0.70 & 0.70 & 0.60 & 0.40 & 0.60 & 0.70 \\ 0.40 & 0.40 & 0.60 & 0.40 & 0.30 & 0.20 \\ 1.00 & 0.40 & 0.60 & 0.40 & 1.00 & 1.00 \\ 0.70 & 0.40 & 0.70 & 0.50 & 0.60 & 0.70 \\ 0.70 & 0.40 & 0.70 & 0.50 & 0.60 & 0.70 \\ 0.40 & 0.40 & 0.70 & 0.50 & 0.30 & 0.20 \\ 0.80 & 0.70 & 0.70 & 0.50 & 0.70 & 0.90 \\ 0.70 & 0.40 & 0.70 & 0.50 & 0.60 & 0.70 \\ 0.60 & 0.70 & 0.60 & 0.40 & 0.40 & 0.40 \\ 0.60 & 0.40 & 0.60 & 0.40 & 0.40 & 0.40 \\ 0.70 & 0.40 & 0.60 & 0.40 & 0.60 & 0.70 \\ 0.40 & 0.70 & 0.60 & 0.40 & 0.30 & 0.20 \\ 0.80 & 0.40 & 0.60 & 0.40 & 0.70 & 0.90 \end{bmatrix},$$

$$Q_{i(t)} = \begin{bmatrix} 0.40 & 0.40 & 0.70 & 0.65 & 0.60 & 0.80 & 0.75 \\ 0.50 & 0.50 & 0.50 & 0.55 & 0.60 & 0.80 & 0.45 \\ 0.60 & 0.60 & 0.70 & 0.65 & 0.60 & 0.80 & 0.75 \\ 0.60 & 0.60 & 0.50 & 0.55 & 0.60 & 0.80 & 0.45 \\ 0.40 & 0.40 & 0.50 & 0.55 & 0.60 & 0.80 & 0.45 \\ 1.00 & 1.00 & 0.50 & 0.55 & 0.60 & 0.80 & 0.45 \\ 0.60 & 0.60 & 0.50 & 0.55 & 0.60 & 0.80 & 0.45 \\ 0.60 & 0.60 & 0.70 & 0.65 & 0.60 & 0.80 & 0.75 \\ 0.40 & 0.40 & 0.50 & 0.55 & 0.60 & 0.80 & 0.45 \\ 0.80 & 0.80 & 0.70 & 0.65 & 0.60 & 0.80 & 0.75 \\ 0.60 & 0.60 & 0.70 & 0.65 & 0.60 & 0.80 & 0.75 \\ 0.50 & 0.50 & 0.70 & 0.65 & 0.60 & 0.80 & 0.75 \\ 0.50 & 0.50 & 0.50 & 0.55 & 0.60 & 0.80 & 0.45 \\ 0.60 & 0.60 & 0.50 & 0.55 & 0.60 & 0.80 & 0.45 \\ 0.40 & 0.40 & 0.50 & 0.55 & 0.60 & 0.80 & 0.45 \\ 0.80 & 0.80 & 0.50 & 0.55 & 0.60 & 0.80 & 0.45 \end{bmatrix};$$

$$I_{i(t)} = \begin{bmatrix} 0.60 & 0.20 & 0.20 & 0.50 & 0.50 & 0.50 & 0.20 \\ 0.60 & 0.50 & 0.50 & 0.55 & 0.55 & 0.55 & 0.50 \\ 0.60 & 0.70 & 0.70 & 0.50 & 0.50 & 0.50 & 0.70 \\ 0.80 & 0.70 & 0.70 & 0.50 & 0.50 & 0.50 & 0.70 \\ 0.60 & 0.20 & 0.20 & 0.70 & 0.70 & 0.70 & 0.20 \\ 0.60 & 1.00 & 1.00 & 0.30 & 0.30 & 0.30 & 1.00 \\ 0.60 & 0.70 & 0.70 & 0.50 & 0.50 & 0.50 & 0.70 \\ 0.60 & 0.70 & 0.70 & 0.50 & 0.50 & 0.50 & 0.70 \\ 0.60 & 0.30 & 0.30 & 0.50 & 0.50 & 0.50 & 0.30 \\ 0.80 & 0.80 & 0.80 & 0.30 & 0.30 & 0.30 & 0.80 \\ 0.60 & 0.70 & 0.70 & 0.50 & 0.50 & 0.50 & 0.70 \\ 0.80 & 0.50 & 0.50 & 0.55 & 0.55 & 0.55 & 0.50 \\ 0.60 & 0.50 & 0.50 & 0.55 & 0.55 & 0.55 & 0.50 \\ 0.60 & 0.70 & 0.70 & 0.50 & 0.50 & 0.50 & 0.70 \\ 0.80 & 0.30 & 0.30 & 0.50 & 0.50 & 0.50 & 0.30 \\ 0.60 & 0.80 & 0.80 & 0.30 & 0.30 & 030 & 0.80 \end{bmatrix}$$

According to Formula (2), calculate P_i,$M_{iF} = \begin{bmatrix} 0.1764 \\ 0.1512 \\ 0.2352 \\ 0.1512 \\ 0.2304 \\ 0.2016 \\ 0.1512 \\ 0.1764 \\ 0.2016 \\ 0.2352 \\ 0.2352 \\ 0.2352 \\ 0.1728 \\ 0.2016 \\ 0.1512 \\ 0.1512 \end{bmatrix}$; $M_{iS} =$

$$\begin{bmatrix}0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\end{bmatrix}; M_{iP}=\begin{bmatrix}0.0023\\0.0092\\0.0412\\0.0494\\0.0023\\0.0960\\0.0412\\0.0412\\0.0034\\0.1235\\0.0412\\0.0161\\0.0092\\0.0282\\0.0040\\0.0484\end{bmatrix}; M_{iQ}=\begin{bmatrix}0.0170\\0.0082\\0.0383\\0.0118\\0.0052\\0.0327\\0.0118\\0.0383\\0.0052\\0.0681\\0.0383\\0.0266\\0.0082\\0.0118\\0.0052\\0.0209\end{bmatrix}; M_{iI}=\begin{bmatrix}0.000600\\0.012478\\0.025725\\0.034300\\0.001646\\0.016200\\0.025725\\0.025725\\0.002025\\0.011059\\0.025725\\0.016638\\0.012478\\0.025725\\0.002700\\0.008294\end{bmatrix};$$

$$P_{iF}=\frac{M_{iF}}{M_{iF}+M_{iS}+M_{iP}+M_{iQ}+M_{iI}}=\begin{bmatrix}0.1764\\0.1512\\0.2352\\0.1512\\0.2304\\0.2016\\0.1512\\0.1764\\0.2016\\0.2352\\0.2352\\0.2352\\0.1728\\0.2016\\0.1512\\0.1512\end{bmatrix}\Bigg/\begin{bmatrix}0.1764\\0.1512\\0.2352\\0.1512\\0.2304\\0.2016\\0.1512\\0.1764\\0.2016\\0.2352\\0.2352\\0.2352\\0.1728\\0.2016\\0.1512\\0.1512\end{bmatrix}+\begin{bmatrix}0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\end{bmatrix}+$$

$$\begin{bmatrix}0.0023\\0.0092\\0.0412\\0.0494\\0.0023\\0.0960\\0.0412\\0.0412\\0.0034\\0.1235\\0.0412\\0.0161\\0.0092\\0.0282\\0.0040\\0.0484\end{bmatrix}+\begin{bmatrix}0.0170\\0.0082\\0.0383\\0.0118\\0.0052\\0.0327\\0.0118\\0.0383\\0.0052\\0.0681\\0.0383\\0.0266\\0.0082\\0.0118\\0.0052\\0.0209\end{bmatrix}+\begin{bmatrix}0.000600\\0.012478\\0.025725\\0.034300\\0.001646\\0.016200\\0.025725\\0.025725\\0.002025\\0.011059\\0.025725\\0.016638\\0.012478\\0.025725\\0.002700\\0.008294\end{bmatrix}$$

$$P_{iS}=\frac{M_{iS}}{M_{iF}+M_{iS}+M_{iP}+M_{iQ}+M_{iI}}=\begin{bmatrix}0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\end{bmatrix}\Bigg/\begin{bmatrix}0.1764\\0.1512\\0.2352\\0.1512\\0.2304\\0.2016\\0.1512\\0.1764\\0.2016\\0.2352\\0.2352\\0.2352\\0.1728\\0.2016\\0.1512\\0.1512\end{bmatrix}+\begin{bmatrix}0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\end{bmatrix}$$

$$+\begin{bmatrix}0.0023\\0.0092\\0.0412\\0.0494\\0.0023\\0.0960\\0.0412\\0.0412\\0.0034\\0.1235\\0.0412\\0.0161\\0.0092\\0.0282\\0.0040\\0.0484\end{bmatrix}+\begin{bmatrix}0.0170\\0.0082\\0.0383\\0.0118\\0.0052\\0.0327\\0.0118\\0.0383\\0.0052\\0.0681\\0.0383\\0.0266\\0.0082\\0.0118\\0.0052\\0.0209\end{bmatrix}+\begin{bmatrix}0.000600\\0.012478\\0.025725\\0.034300\\0.001646\\0.016200\\0.025725\\0.025725\\0.002025\\0.011059\\0.025725\\0.016638\\0.012478\\0.025725\\0.002700\\0.008294\end{bmatrix}=$$

$$P_{iP}=\frac{M_{iP}}{M_{iF}+M_{iS}+M_{iP}+M_{iQ}+M_{iI}}=\begin{bmatrix}0.0023\\0.0092\\0.0412\\0.0494\\0.0023\\0.0960\\0.0412\\0.0412\\0.0034\\0.1235\\0.0412\\0.0161\\0.0092\\0.0282\\0.0040\\0.0484\end{bmatrix}\Bigg/\begin{bmatrix}0.1764\\0.1512\\0.2352\\0.1512\\0.2304\\0.2016\\0.1512\\0.1764\\0.2016\\0.2352\\0.2352\\0.2352\\0.1728\\0.2016\\0.1512\\0.1512\end{bmatrix}+\begin{bmatrix}0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\end{bmatrix}+$$

$$\begin{bmatrix}0.0023\\0.0092\\0.0412\\0.0494\\0.0023\\0.0960\\0.0412\\0.0412\\0.0034\\0.1235\\0.0412\\0.0161\\0.0092\\0.0282\\0.0040\\0.0484\end{bmatrix}+\begin{bmatrix}0.0170\\0.0082\\0.0383\\0.0118\\0.0052\\0.0327\\0.0118\\0.0383\\0.0052\\0.0681\\0.0383\\0.0266\\0.0082\\0.0118\\0.0052\\0.0209\end{bmatrix}+\begin{bmatrix}0.000600\\0.012478\\0.025725\\0.034300\\0.001646\\0.016200\\0.025725\\0.025725\\0.002025\\0.011059\\0.025725\\0.016638\\0.012478\\0.025725\\0.002700\\0.008294\end{bmatrix}=$$

$$P_{iQ}=\frac{M_{iQ}}{M_{iF}+M_{iS}+M_{iP}+M_{iQ}+M_{iI}}=\begin{bmatrix}0.1764\\0.1512\\0.2352\\0.1512\\0.2304\\0.2016\\0.1512\\0.1764\\0.2016\\0.2352\\0.2352\\0.2352\\0.1728\\0.2016\\0.1512\\0.1512\end{bmatrix}\Bigg/\begin{bmatrix}0.1764\\0.1512\\0.2352\\0.1512\\0.2304\\0.2016\\0.1512\\0.1764\\0.2016\\0.2352\\0.2352\\0.2352\\0.1728\\0.2016\\0.1512\\0.1512\end{bmatrix}+\begin{bmatrix}0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\end{bmatrix}+$$

$$\begin{bmatrix}0.0023\\0.0092\\0.0412\\0.0494\\0.0023\\0.0960\\0.0412\\0.0412\\0.0034\\0.1235\\0.0412\\0.0161\\0.0092\\0.0282\\0.0040\\0.0484\end{bmatrix}+\begin{bmatrix}0.0170\\0.0082\\0.0383\\0.0118\\0.0052\\0.0327\\0.0118\\0.0383\\0.0052\\0.0681\\0.0383\\0.0266\\0.0082\\0.0118\\0.0052\\0.0209\end{bmatrix}+\begin{bmatrix}0.000600\\0.012478\\0.025725\\0.034300\\0.001646\\0.016200\\0.025725\\0.025725\\0.002025\\0.011059\\0.025725\\0.016638\\0.012478\\0.025725\\0.002700\\0.008294\end{bmatrix}=$$

$$P_{iI}=\frac{M_{iI}}{M_{iF}+M_{iS}+M_{iP}+M_{iQ}+M_{iI}}=\begin{bmatrix}0.000600\\0.012478\\0.025725\\0.034300\\0.001646\\0.016200\\0.025725\\0.025725\\0.002025\\0.011059\\0.025725\\0.016638\\0.012478\\0.025725\\0.002700\\0.008294\end{bmatrix}\Bigg/\begin{bmatrix}0.1764\\0.1512\\0.2352\\0.1512\\0.2304\\0.2016\\0.1512\\0.1764\\0.2016\\0.2352\\0.2352\\0.2352\\0.1728\\0.2016\\0.1512\\0.1512\end{bmatrix}+\begin{bmatrix}0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\\0.000016\end{bmatrix}$$

$$+\begin{bmatrix}0.0023\\0.0092\\0.0412\\0.0494\\0.0023\\0.0960\\0.0412\\0.0412\\0.0034\\0.1235\\0.0412\\0.0161\\0.0092\\0.0282\\0.0040\\0.0484\end{bmatrix}+\begin{bmatrix}0.0170\\0.0082\\0.0383\\0.0118\\0.0052\\0.0327\\0.0118\\0.0383\\0.0052\\0.0681\\0.0383\\0.0266\\0.0082\\0.0118\\0.0052\\0.0209\end{bmatrix}+\begin{bmatrix}0.000600\\0.012478\\0.025725\\0.034300\\0.001646\\0.016200\\0.025725\\0.025725\\0.002025\\0.011059\\0.025725\\0.016638\\0.012478\\0.025725\\0.002700\\0.008294\end{bmatrix}$$

$$P_{iF}=\begin{bmatrix}2,664,652,567,975.83\\66,394,414,438.15\\1,539,673,094.4091\\3,125,910948.75\\3,173,553,719,008.26\\1,228,983,528.21\\4,997,421,964.86\\1,539,674,102.32\\1,745,454,545,454.55\\671,970,241.32\\1,539,673,094.41\\8,771,439,120.17\\66,395,143,318.22\\7,301,199,844.99\\1,112,582,781,456.95\\7,449,450,159.63\end{bmatrix};\ P_{iS}=\begin{bmatrix}241,691,842.90\\7,025,863.96\\104,739.67\\330,784.23\\220,385,674.93\\97,538.38\\528,827.72\\139,652.98\\138,528,138.53\\45,712.26\\104,739.67\\596,696.54\\6,147,698.46\\579,460.31\\117,733,627.67\\788301.60\end{bmatrix};\ P_{iP}=$$

$$\begin{bmatrix}34,743,202,416.92\\4,039,871,777.98\\269,704,640.69\\1,021,296,302.04\\31,680,440,771.35\\585,230,251.53\\1,361,731,381.96\\359,606,422.99\\29,437,229,437.23\\352,841,517.02\\269,704,640.69\\600,425,892.15\\3,534,926,611.85\\1,021,298,787.84\\29,433,406,916.85\\2,384,612,352.69\end{bmatrix};\ P_{iQ}=\begin{bmatrix}256,797,583,081.57\\3,600,755,280.38\\250,720,576.17\\243,953,367.69\\71,625,344,352.62\\199,344,054.43\\390,010,444.35\\334,294,320.40\\45,021,645,021.65\\194,562,812.22\\250,720,576.17\\992,007,995.73\\3,150,695,458.39\\427,351,975.05\\38,263,428,991.91\\1,029,718,970.48\end{bmatrix};\ P_{iI}=$$

$$\begin{bmatrix}9,063,444,108.76\\5,479,295,657.14\\168,401,744.70\\709,118,687.45\\22,672,176,308.54\\98,757,604.95\\850,255,820.41\\224,535,806.59\\17,532,467,532.47\\31,595,743.62\\168,401,744.70\\620,489,813.27\\4,794,436,332.90\\931,663,521.89\\19,867,549,668.87\\408,635,844.07\end{bmatrix}.$$

According to Formula $S_j = -(\ln n)^{-1} \times \sum_{i=1}^{n}(r_{ij} \times \ln r_{ij})$, calculate each weight index separately.

$$-(log10(n))^{-1} = -(log10(M_{iF}))^{-1} = -(log10 \times \begin{bmatrix}0.1764\\0.1512\\0.2352\\0.1512\\0.2304\\0.2016\\0.1512\\0.1764\\0.2016\\0.2352\\0.2352\\0.2352\\0.1728\\0.2016\\0.1512\\0.1512\end{bmatrix})^{-1} = log10(M_{iF})$$

$$=\begin{bmatrix}1.3271\\1.2188\\1.5909\\1.2188\\1.5686\\1.4378\\1.2188\\1.3271\\1.4378\\1.5909\\1.5909\\1.5909\\1.3116\\1.4378\\1.2188\\1.2188\end{bmatrix};\quad log10(M_{iS})=\begin{bmatrix}0.2085\\0.2085\\0.2085\\0.2085\\0.2085\\0.2085\\0.2085\\0.2085\\0.2085\\0.2085\\0.2085\\0.2085\\0.2085\\0.2085\\0.2085\\0.2085\end{bmatrix};\quad log10(M_{iP})=\begin{bmatrix}0.3790\\0.4911\\0.7220\\0.7655\\0.3790\\0.9826\\0.7220\\0.7220\\0.4051\\1.1009\\0.7220\\0.5577\\0.4911\\0.6453\\0.4170\\0.7604\end{bmatrix};$$

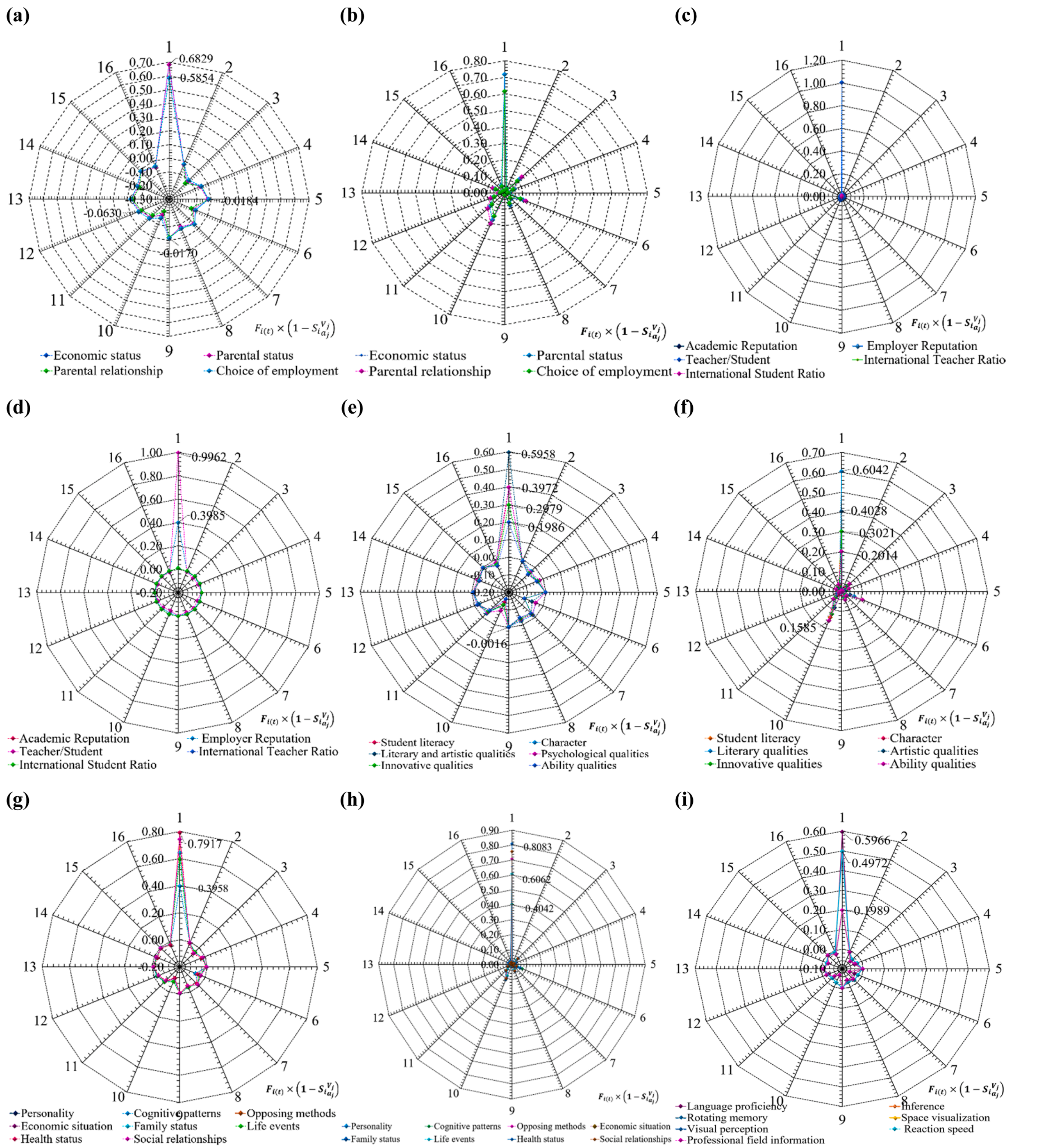

Fig. 8. Comparison of data between new and old talent training models: (a) Analysis of family impact survey (Negative Entropy Value (NEV)), (b) Analysis of family impact survey (Positive Entropy Value (PEV)), (c) Analysis of school resources related to students (NEV), (d) Analysis of school resources related to students (PEV), (e) Analysis of student peer characteristics (NEV), (f) Analysis of student peer characteristics (PEV), (g) Analysis of other external characteristics related to students (NEV), (h) Analysis of other external characteristics related to students (PEV), (i) Analysis of students' initial or innate endowments (NEV).

$$log10(M_{iQ}) = \begin{bmatrix} 0.5651 \\ 0.4793 \\ 0.7058 \\ 0.5186 \\ 0.4378 \\ 0.6732 \\ 0.5186 \\ 0.7058 \\ 0.4378 \\ 0.8570 \\ 0.7058 \\ 0.6349 \\ 0.4793 \\ 0.5186 \\ 0.4378 \\ 0.5953 \end{bmatrix}; \quad log10(M_{iI}) = \begin{bmatrix} 0.3104 \\ 0.5253 \\ 0.6291 \\ 0.6827 \\ 0.3593 \\ 0.5585 \\ 0.6291 \\ 0.6291 \\ 0.3713 \\ 0.5112 \\ 0.6291 \\ 0.5621 \\ 0.5253 \\ 0.6291 \\ 0.3893 \\ 0.4805 \end{bmatrix}; \quad \sum_{i=1}^{n}(r_{ij} \times \ln r_{ij}) = \begin{bmatrix} 0.0184 \\ 0.0314 \\ 0.1063 \\ 0.0689 \\ 0.0195 \\ 0.1108 \\ 0.0599 \\ 0.0887 \\ 0.0197 \\ 0.1600 \\ 0.1063 \\ 0.0660 \\ 0.0338 \\ 0.0631 \\ 0.0181 \\ 0.0553 \end{bmatrix}.$$

$$S_{jF} = \begin{bmatrix} 0.0244 \\ 0.0383 \\ 0.1691 \\ 0.0840 \\ 0.0306 \\ 0.1593 \\ 0.0730 \\ 0.1177 \\ 0.0283 \\ 0.1600 \\ 0.1063 \\ 0.0660 \\ 0.0338 \\ 0.0631 \\ 0.0181 \\ 0.0553 \end{bmatrix}; \quad S_{jS} = \begin{bmatrix} 0.0038 \\ 0.0065 \\ 0.0222 \\ 0.0144 \\ 0.0041 \\ 0.0231 \\ 0.0125 \\ 0.0185 \\ 0.0041 \\ 0.0334 \\ 0.0222 \\ 0.0138 \\ 0.0070 \\ 0.0132 \\ 0.0038 \\ 0.0115 \end{bmatrix}; \quad S_{jP} = \begin{bmatrix} 0.0070 \\ 0.0154 \\ 0.0767 \\ 0.0527 \\ 0.0074 \\ 0.1089 \\ 0.0432 \\ 0.0640 \\ 0.0080 \\ 0.1761 \\ 0.0767 \\ 0.0368 \\ 0.0166 \\ 0.0407 \\ 0.0075 \\ 0.0421 \end{bmatrix};$$

$$S_{jQ} = \begin{bmatrix} 0.0104 \\ 0.0151 \\ 0.0750 \\ 0.0357 \\ 0.0085 \\ 0.0746 \\ 0.0311 \\ 0.0626 \\ 0.0086 \\ 0.1371 \\ 0.0750 \\ 0.0419 \\ 0.0162 \\ 0.0327 \\ 0.0079 \\ 0.0329 \end{bmatrix}; \quad S_{jI} = \begin{bmatrix} 0.0057 \\ 0.0165 \\ 0.0669 \\ 0.0470 \\ 0.0070 \\ 0.0619 \\ 0.0377 \\ 0.0558 \\ 0.0073 \\ 0.0818 \\ 0.0669 \\ 0.0371 \\ 0.0178 \\ 0.0397 \\ 0.0070 \\ 0.0266 \end{bmatrix}.$$

According to Formula $V_j = \frac{(1-S_j)}{\sum_{j=1}^{n}(1-S_j)} =$ Calculate the information weight;

$$V_{jF} = \begin{bmatrix} 0.1971 \\ -0.0077 \\ -0.0342 \\ -0.0170 \\ -0.0062 \\ -0.0322 \\ -0.0148 \\ -0.0238 \\ -0.0057 \\ -0.0514 \\ -0.0342 \\ -0.0212 \\ -0.0090 \\ -0.0183 \\ -0.0045 \\ -0.0136 \end{bmatrix}; \quad V_{jS} = \begin{bmatrix} 0.2013 \\ -0.0013 \\ -0.0045 \\ -0.0029 \\ -0.0008 \\ -0.0047 \\ -0.0025 \\ -0.0037 \\ -0.0008 \\ -0.0067 \\ -0.0045 \\ -0.0028 \\ -0.0014 \\ -0.0027 \\ -0.0008 \\ -0.0023 \end{bmatrix};$$

$$V_{jP} = \begin{bmatrix} 0.2007 \\ -0.0031 \\ -0.0155 \\ -0.0106 \\ -0.0015 \\ -0.0220 \\ -0.0087 \\ -0.0129 \\ -0.0016 \\ -0.0356 \\ -0.0155 \\ -0.0074 \\ -0.0034 \\ -0.0082 \\ -0.0015 \\ -0.0085 \end{bmatrix}; \quad V_{jQ} = \begin{bmatrix} 0.2000 \\ -0.0031 \\ -0.0152 \\ -0.0072 \\ -0.0017 \\ -0.0151 \\ -0.0063 \\ -0.0126 \\ -0.0017 \\ -0.0277 \\ -0.0152 \\ -0.0085 \\ -0.0033 \\ -0.0066 \\ -0.0016 \\ -0.0066 \end{bmatrix}; \quad V_{jI} = \begin{bmatrix} 0.2009 \\ -0.0033 \\ -0.0135 \\ -0.0095 \\ -0.0014 \\ -0.0125 \\ -0.0076 \\ -0.0113 \\ -0.0015 \\ -0.0165 \\ -0.0135 \\ -0.0075 \\ -0.0036 \\ -0.0080 \\ -0.0014 \\ -0.0054 \end{bmatrix}.$$

According to Formula$V_j = a_j = \frac{V_i \times P_j}{\sum_{j=1}^{n}(V_j \times P_j)}$, analyze the index weight.

$$a_{jF} = \begin{bmatrix} 0.8972 \\ -0.0009 \\ -0.0001 \\ -0.0001 \\ -0.0336 \\ -0.0001 \\ -0.0001 \\ -0.0001 \\ -0.0170 \\ -0.0001 \\ -0.0001 \\ -0.0003 \\ -0.0010 \\ -0.0002 \\ -0.0086 \\ -0.0002 \end{bmatrix}; \quad a_{jS} = \begin{bmatrix} 0.0001 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ 0.0000 \end{bmatrix}; \quad a_{jP} = \begin{bmatrix} 0.0119 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ -0.0001 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ -0.0001 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ 0.0000 \\ -0.0001 \\ 0.0000 \end{bmatrix};$$

Table 1
Comprehensive evaluation and analysis data of various indicators for the old talent training model.

	1-S_j	V_j	$V_j \times P$	a_j	1+S_j	$F \times (1+S_j)$	$F \times (1-S_j)$	$\sum A_I$
0.025,52	0.008,51	0.047,87	0.000,74	0.000,00	0.000,00	0.000,00	0.000,00	0.082,60
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
−0.000,00	−0.000,00	−0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00

Table 2
Comprehensive evaluation and analysis data of various indicators for the new talent training model.

	1-S_j	V_j	$V_j \times P$	a_j	1+S_j	$F \times (1 + S_j)$	$F \times (1 - S_j)$	$\sum A_{it}$
0.028,30	0.009,40	0.053,00	0.000,80	0.000,00	0.000,00	0.000,00	0.000,00	0.091,50
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00
0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00	0.000,00

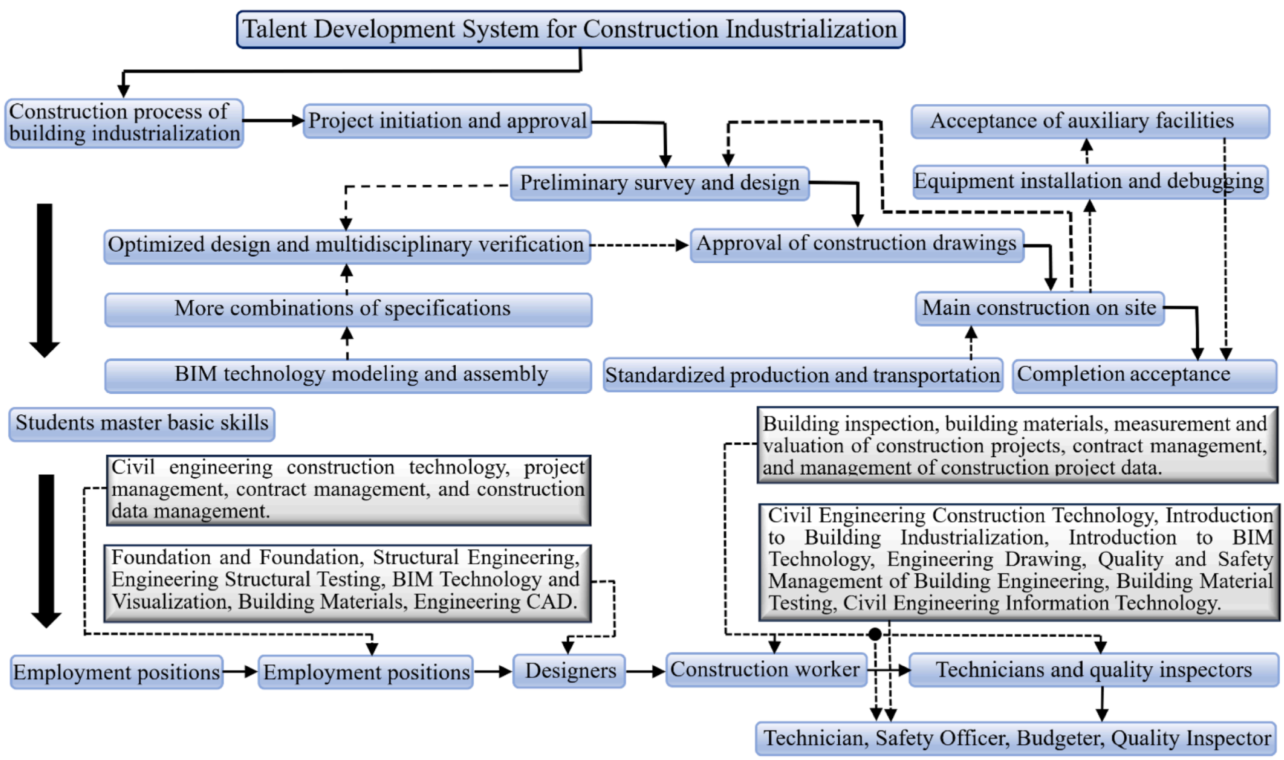

Fig. 9. Talent training and development system for building industrialization.

$$a_{jQ}=\begin{bmatrix}0.0877\\0.0000\\0.0000\\0.0000\\-0.0002\\0.0000\\0.0000\\0.0000\\-0.0001\\0.0000\\0.0000\\0.0000\\0.0000\\0.0000\\-0.0001\\0.0000\end{bmatrix};\ a_{jI}=\begin{bmatrix}0.0877\\0.0000\\0.0000\\0.0000\\-0.0002\\0.0000\\0.0000\\0.0000\\-0.0001\\0.0000\\0.0000\\0.0000\\0.0000\\0.0000\\-0.0001\\0.0000\end{bmatrix}$$

. According to Formula (6), analyze $A_{it} = g$

Four majors in Grade 2021 of the Railway Construction College were selected: a total of 131 students, including 15 in Construction Technology, 20 in Construction Engineering, 48 in Railway Engineering, and 46 in Road and Bridge Engineering. A 100 % questionnaire survey was conducted based on established impact indicators and factors.

The theoretical model for data analysis was analyzed according to Innovation pattern and improvement strategy, and the influence indexes were analyzed according to Discussion. According to the questionnaire survey, a vector matrix equation was established:

According to the analysis of the five indexes in Fig. 8, the data obtained from both talent training models have improved. This once again proves the innovation and superiority of the "six-stage multi-module innovation optimization" model, providing decisive application value for cultivating comprehensive quality and exploiting the potential of higher vocational college students. $A_{it}/A_I = 0.091,6/0.082,6 = 1.109$ times the complete assessment data of the new talent training model was 1.109 times that of the old talent training system (Tables 1 and 2).

The analysis of various indicator data under the new and old talent training programs shows that the new talent training model has improved employment rates and social awareness, enhanced the reputation of the school, and demonstrated the scientific and practical nature of the research model.

4. Discussion

The industrial innovation in the construction industry has brought about substantial changes in talent demand and training, involving building research and development, structural design, prefabricated component manufacturing, logistics transportation, automated installation, and comprehensive management [40,41]. Therefore, there is an urgent need for comprehensive, highly skilled talents and professional industrial workers.

4.1. A new system for training talents in China's building industrialization

As shown in Fig. 9, new and higher professional quality requirements are proposed for students with the change in the construction production mode. Building industrialization and prefabricated building are a new construction mode that achieves the integration, intellectualization, digitalization, and standardization of building procedures, which defines a new measurement standard for the ability and skill level of employment positions, breaks the traditional mode of university-enterprise cooperation, industry-education integration, and post-internship, and requires more refinement, programming, intelligence, and multi-professional coordination.

Reflections on the training for architectural professionals:

1. University-enterprise cooperation should be expanded from simply cooperating with construction enterprises to jointly building and cultivating with design companies, consulting companies, intelligent manufacturing, CNC component prefabrication, high-tech companies, and internet logistics enterprises.
2. The professional course design module should have higher flexibility, multi-disciplinary, selectivity, and pertinence. The employment training of students needs to be investigated and refined in the third stage (Fig. 7).
3. The facilities of the training base should be complete, separated from the pure construction process, while increasing training in testing, mechanical properties, material and component design, BIM optimization, logistics design, and industrial management, improving students' comprehensive quality, innovation, and adaptability.
4. It is necessary to strengthen the practicality of core majors, popularize the training and examination of $1 + X$ certificates and various industry qualification certificates and improve the pass rate. Students should be proficient in national and industry measurement, testing, safety, and quality standards.
5. Higher requirements are put forward for full-time "double-qualified" teachers, with teaching industries spanning design, consulting, supervision, construction, component manufacturing, installation and transportation, information monitoring, and big data intelligence. Full-time teachers should regularly participate in professional training and seminars.

5. Conclusion

Building industrialization is the future of sustainable development and green building development. Higher education institutions are responsible and obligated to cultivate high-skilled talents who adapt to the times and industry development. Lack of progress, international cooperation, and industry dynamics will inevitably affect talent training.

From the analysis of the current situation of building industrialization at home and abroad to the comparative study of training of architectural professionals, it is demonstrated that cultivating interests and hobbies and developing good learning habits are the prerequisites for talent training. Therefore, it is necessary to guide college students to adapt to the rapid development trend of the industry and master basic skills, key technologies, and advanced equipment from an ideological perspective.

Through the comparative analysis of the demand for architectural professionals in China, as well as the data on high school graduation rate and university enrollment at home and abroad, it is found that the demand for architectural professionals in China is enormous, and the number of high school graduates in China is decreasing. However, the university enrollment and graduation rate continue to increase. In the future, Chinese higher vocational colleges will face a shortage of students and increasingly urgent competition for employment among college students, and higher vocational students will face more significant competitive pressure. The European and American educational models mainly cultivate interests and hobbies from a young age; their relaxed atmosphere in schools and China should reference the independent career choice education model for students for education reform.

From the perspective of career development needs, this paper analyzed the training direction of architectural professionals and the shortcomings and measures that need to be improved in current Chinese higher vocational education and created the "six-stage multi-module innovation optimization" training system model to improve the weaknesses of higher vocational education.

Finally, a thorough study was conducted on the demand for architectural professionals, and an "architectural professional training model" system was established, proposing the problems that need to be faced to affect the system's regular operation. However, because higher vocational education in building industrialization is still in the practical stage in China, this paper still has some shortcomings; for example, the scope of application of the established model system has certain limitations. It is suitable for the talent training system of higher vocational universities. Whether it is suitable for the talent training system of research-oriented comprehensive universities needs further practical testing and continuous adjustment and improvement; the different higher education systems in different countries also affect the final effect of talent training, and this direction also needs further research; this research model and results are only applicable to the talent training system in China's construction industrialization, and whether it can be applied to other majors remains to be tested.

The research content that needs to be further strengthened in the future is to promote the use of this talent training program in more classes, summarize and adjust inappropriate links promptly, establish a sustainable development evaluation system to track students' employment and future development, and comprehensively prove the robustness of the talent training system.

CRediT authorship contribution statement

Zhiwu Zhou: Writing – original draft, Software, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization, Investigation. **Qiong Tian:** Resources, Formal analysis, Funding acquisition. **Julián Alcalá:** Validation, Resources, Conceptualization, Writing – review & editing. **Víctor Yepes:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization.

Declaration of competing interest

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

Data availability

Data generated or analysed during the study are available from the

corresponding author by request.

Acknowledgements

The authors gratefully acknowledge the funding received from the following research projects: Grant PID2023–150003OB-100 funded by MCIN/AEI/10.13039/501100011033 and the European Regional Development Fund (ERDF), a program of the European Union (EU).; The newly launched doctoral research project, issued by Xiang Ke University [2023] No. 75; Natural Science Foundation in Hunan Province, Number 2025JJ50288; Teaching Reform Project in Hunan Province, number 24A0586.

References

[1] Ye R, Nylander E. Conventions of skilling: the plural and prospective worlds of higher vocational education. Eur Educ Res J 2024. https://doi.org/10.1177/14749041241262826.
[2] Zhu H, Hong J, Shen GQ, Mao C, Zhang H, Li Z. The exploration of the life-cycle energy saving potential for using prefabrication in residential buildings in China. Energy Build 2018;166:561–70. https://doi.org/10.1016/j.enbuild.2017.12.045.
[3] Andersson N, Lessing J. Industrialization of construction: implications on standards, business models and project orientation. Organization, technology and management in construction. An Int J 2020;12:2109–16. https://doi.org/10.2478/otmcj-2020-0007.
[4] Quinlan KM, Corbin J. How and why do students' career interests change during higher education? Stud High Educ 2023;48:771–83. https://doi.org/10.1080/03075079.2023.2166916.
[5] Zhou ZW, Alcalà J, Yepes V. Carbon impact assessment of bridge construction based on resilience theory. J Civ Eng Manag 2023;29:561–76. https://doi.org/10.3846/jcem.2023.19565.
[6] Goh M, Goh YM. Lean production theory-based simulation of modular construction processes. Autom Constr 2019;101:227–44. https://doi.org/10.1016/j.autcon.2018.12.017.
[7] Liu J-B, Yuan X-Y, Lee C-C. Prediction of carbon emissions in China's construction industry using an improved grey prediction model. Sci Total Environ 2024;938:173351. https://doi.org/10.1016/j.scitotenv.2024.173351.
[8] Clarke L, Gleeson C, Winch C. What kind of expertise is needed for low energy construction? Constr Manag Econ 2017;35:78–89. https://doi.org/10.1080/01446193.2016.1248988.
[9] Ofori-Kuragu JK, Osei-Kyei R. Mainstreaming pre-manufactured offsite processes in construction – are we nearly there? Constr Innovat 2021;21:743–60. https://doi.org/10.1108/CI-06-2020-0092.
[10] Dong F, Li Y, Zhang X, Zhu J, Zheng L. How does industrial convergence affect the energy efficiency of manufacturing in newly industrialized countries? Fresh evidence from China. J Clean Prod 2021;316:128316. https://doi.org/10.1016/j.jclepro.2021.128316.
[11] Leviäkangas P, Mok Paik S, Moon S. Keeping up with the pace of digitization: the case of the Australian construction industry. Technol Soc 2017;50:33–43. https://doi.org/10.1016/j.techsoc.2017.04.003.
[12] Stenzel AG, Osei Kwadwo V, Vincent RC. Free secondary education policy and education attainment. Int J Educ Dev 2024;106:103021. https://doi.org/10.1016/j.ijedudev.2024.103021.
[13] Matos R, Rodrigues H, Costa A, Requejo C, Rodrigues F. Facility manager perspectives on building condition assessment for Portuguese higher education institutions. Build Res Inf 2023;51:949–64. https://doi.org/10.1080/09613218.2023.2204415.
[14] Deng Y, Liu T, Cao B, Li A. Fatigue strengthening for rib-to-deck joint by bonding reinforcing plates on the deck surface. J Bridge Eng 2023;28. https://doi.org/10.1061/JBENF2.BEENG-5617.
[15] Richardson D. Don't dump the didactic lecture; fix it. Adv Physiol Educ 2008;32:23–4. https://doi.org/10.1152/advan.00048.2007.
[16] Müller A. Cooperation between colleges and companies: vocational education, skill mismatches and China's turnover problem. China Q 2024:1–19. https://doi.org/10.1017/S0305741023001868.
[17] Yepes V, Pellicer E, Ortega AJ. Designing a benchmark indicator for managerial competences in construction at the graduate level. J Prof Issues Eng Educ Pract 2012;138:48–54. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000075.
[18] Islam S, Javeed D, Saeed MS, Kumar P, Jolfaei A, Islam AKMN. Generative AI and cognitive computing-driven intrusion detection system in industrial CPS. Cognit Comput 2024;16:2611–25. https://doi.org/10.1007/s12559-024-10309-w.
[19] Khanna K, Pandher JS, Bedi SS. Building students' attachment strength with higher education institutes using intangible resources: role of institutional branding. High Educ Ski Work-based Learn 2023;13:528–59. https://doi.org/10.1108/HESWBL-03-2023-0076.
[20] Wang X, Owusu EK, Ye K. Impacts of external environmental factors on the collusive team scale in bidding: the case of China. J Manag Eng 2023;39. https://doi.org/10.1061/JMENEA.MEENG-5270.
[21] Han Y, Ni R, Deng Y, Zhu Y. Supply and demand of higher vocational education in China: comprehensive evaluation and geographical representation from the perspective of educational equality. PLoS One 2023;18:e0293132. https://doi.org/10.1371/journal.pone.0293132.
[22] Chen X, Chang-Richards AY, Yiu TW, Ling FYY, Pelosi A, Yang N. A multivariate regression analysis of barriers to digital technologies adoption in the construction industry. Eng Const Arch Man 2023. https://doi.org/10.1108/ECAM-11-2022-1051.
[23] Huang Y, Zhang Y, Long Z, Xu D, Zhu R. How to improve entrepreneurship education in "double high-level plan" higher vocational colleges in China. Front Psychol 2021;12. https://doi.org/10.3389/fpsyg.2021.743997.
[24] Zembylas M. The analytical potential of 'affective imaginaries' in higher education research. Educ Inq 2023:1–16. https://doi.org/10.1080/20004508.2023.2223781.
[25] Martinez S, Jardon A, Navarro JM, Gonzalez P. Building industrialization: robotized assembly of modular products. Assem Autom 2008;28:134–42. https://doi.org/10.1108/01445150810863716.
[26] Weng S, Qin Y. Which qualities should built environment possess to ensure satisfaction of higher-education students with remote education during pandemics? Environ Sci Pollut Res 2023;30:102504–18. https://doi.org/10.1007/s11356-023-29118-z.
[27] Chen W, Zheng Q, Liang C, Xie Y, Gu D. Factors influencing college students' Mental health promotion: the mediating effect of online mental health information seeking. Int J Environ Res Public Health 2020;17:4783. https://doi.org/10.3390/ijerph17134783.
[28] Li G, Xu J, Li L, Shi Z, Yi H, Chu J, et al. The impacts of highly resourced vocational schools on student outcomes in China. China & World Economy 2020;28:125–50. https://doi.org/10.1111/cwe.12358.
[29] Cheng P. Employment data screening and destination prediction of college students based on deep learning. Wirel Commun Mob Comput 2022;2022:1–10. https://doi.org/10.1155/2022/7173771.
[30] Zhai H, Chen L, Yang Y, Sun H, Pan H, He J, et al. Family and college environmental exposures mediate the relationship between parental education and depression among college students. PLoS One 2016;11:e0151759. https://doi.org/10.1371/journal.pone.0151759.
[31] Dong P, Tu C-C. Research on the impact of university innovation and entrepreneurship education on university students' Entrepreneurship willingness based on virtual reality technology. Math Probl Eng 2021;2021:1–8. https://doi.org/10.1155/2021/9730705.
[32] Ji Y, Zhu F, Li H, Al-Hussein M. Construction Industrialization in China: current profile and the prediction. Applied Sciences 2017;7:180. https://doi.org/10.3390/app7020180.
[33] Torres-Machí C, Carrión A, Yepes V, Pellicer E. Employability of graduate students in construction management. J Prof Issues Eng Educ Pract 2013;139:163–70. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000139.
[34] Ghadiri Khanaposhtani M, Liu CJ, Gottesman BL, Shepardson D, Pijanowski B. Evidence that an informal environmental summer camp can contribute to the construction of the conceptual understanding and situational interest of STEM in middle-school youth. Int J Sci Educ B: 2018;8:227–49. https://doi.org/10.1080/21548455.2018.1451665.
[35] Xiong Q-Y, Ba J-Y, Duan H-J, Deng M-X, Wang Y-M, Wang R-Q. Optical conductivity and polarization rotation of type-II semi-dirac materials. Phys Rev B 2023;107:155150. https://doi.org/10.1103/PhysRevB.107.155150.
[36] Si H, Wang R, Wang R, He Z. Can the MODIS data achieve the downscaling of GOME-2 SIF? Validation of data from China. Sustainability 2023;15:5920. https://doi.org/10.3390/su15075920.
[37] Ba H, Li J, Ni W, Li Y, Ju Y, Zhao B, et al. Effect of calcium to silicon ratio on the microstructure of hydrated calcium silicate gels prepared under medium alkalinity. Constr Build Mater 2023;379:131240. https://doi.org/10.1016/j.conbuildmat.2023.131240.
[38] Hongxiong Y, Yue Y. Configuration analysis of the influencing factors of design standardization in China's building industrialization —— Qualitative Comparative analysis based on (fsQCA) fuzzy set. J Asian Archit Build Eng 2021:1–12. https://doi.org/10.1080/13467581.2021.1972809.
[39] Yang P, Gao Y, Li X. The effect of supportive mentoring style on innovative behavior of Master's Degree students: evidence from China. Sage Open 2024;14. https://doi.org/10.1177/21582440241233049.
[40] Ebolor A, Agarwal N, Brem A. Sustainable development in the construction industry: the role of frugal innovation. J Clean Prod 2022;380:134922. https://doi.org/10.1016/j.jclepro.2022.134922.
[41] Zhou Z, Zhou J, Alcalá J, Yepes V. Thermal coupling optimization of bridge environmental impact under natural conditions. Environ Impact Assess Rev 2024;104:107316. https://doi.org/10.1016/j.eiar.2023.107316.