



The Construction of the ecosystem of entrepreneurship and Innovation Education in Higher Vocational Colleges from the perspective of "integration of expertise and innovation"

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SUMMARY: *Under the background of the deepening of "the integration of professional and creative", entrepreneurship and innovation education in higher vocational colleges is faced with problems such as insufficient connection between curriculum content and professional scene, scattered resource allocation, poor school-enterprise collaboration, and experiential process evaluation, which restrict the overall effectiveness of education ecology. Around the above practical dilemma, this paper constructs the entrepreneurship and innovation education ecosystem in higher vocational colleges under the perspective of "integration of expertise and innovation", introduces the methods of multi-source data perception, education ecological element identification, analytic hierarchy process evaluation and intelligent recommendation collaborative configuration, and integrates curriculum learning, project practice, competition training, enterprise tasks and platform services into a unified digital framework. By constructing an educational ecological element model and an evaluation model, this study structurally described students' development status, resource supply characteristics and ecological operation quality, and realized the dynamic matching of curriculum resources, practical projects and tutor support with the help of an intelligent recommendation mechanism. The results show that the constructed educational ecosystem has good performance in operation efficiency and application effectiveness. The average response time of the platform is reduced to 1.6 s, the accuracy of resource matching is 91.3%, the task completion conversion rate is increased to 86.1%, and the comprehensive satisfaction is 90.2%. The research shows that the innovation and entrepreneurship education ecosystem supported by computer technology helps to improve the synergy, adaptation and continuous optimization ability of innovation and entrepreneurship education in higher vocational colleges, and can also provide reference for similar colleges to carry out digital innovation and entrepreneurship education reform.*

KEYWORDS: *Integration of expertise and innovation; Higher vocational colleges; Innovation and entrepreneurship education ecology; Intelligent recommendation*

1 Introduction

Under the background of industrial structure adjustment, regional innovation-driven development and vocational education quality improvement training in parallel, entrepreneurship and innovation education is no longer an auxiliary link in talent training in higher vocational colleges, but an important link connecting professional learning, post ability formation and innovative practice transformation. "Integration of expertise and innovation"

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emphasizes that professional knowledge teaching, practical skills training and innovation and entrepreneurship literacy cultivation are integrated into the same education chain, so that students can form composite capabilities in the process of real tasks, project competitions, school-enterprise collaboration and achievement incubation. However, from the current implementation situation of higher vocational colleges, there are still problems such as the disconnection between the course content and the professional scene, the decentralization of resources, the lack of coordination of the main body, and the empirical process evaluation, which make it difficult to form a stable coupling between educational activities. Although there are many ecological elements, they have not really been transformed into ecological advantages.

The emergence of such problems is not so much a lack of ideas as a lack of organizational capacity of the system. Traditional entrepreneurship and innovation education relies more on artificial experience for course arrangement, project matching and student portrait judgment, which is difficult to continuously identify and dynamically interact with students' ability characteristics, teachers' guidance direction, enterprise project needs, platform resource supply and practical feedback results. Especially in higher vocational colleges, there are large differences in students' bases, diverse types of majors, and frequent updates of practical tasks. If there is no data-driven support mechanism, educational resources are prone to the practical dilemma of "a lot of supply and weak adaptation". With the continuous deepening of computer technologies such as learning analysis, analytic hierarchy process, knowledge graph and intelligent recommendation in the education scene, it has become an important direction to use multi-source data to perceive educational ecological elements, construct structured evaluation model, and realize resource collaborative allocation to improve the operation quality of entrepreneurship and innovation education.

Based on this, this paper focuses on the construction of the entrepreneurship and innovation education ecosystem in higher vocational colleges from the perspective of "the integration of expertise and innovation". On the basis of combing the core elements and their relationships of the education ecosystem, the multi-source data modeling, analytic hierarchy process evaluation and intelligent recommendation methods are introduced to try to construct the entrepreneurship and innovation education ecosystem with the functions of structure identification, quality evaluation and resource collaboration. This paper focused on three levels of issues. First, how to identify the ecological elements from the dimensions of curriculum, teachers, students, platforms and enterprise projects and form a computable structural model. The second is how to establish an ecological evaluation mechanism for the quality improvement of "innovation integration"; Thirdly, how to improve the allocation efficiency and application effectiveness of educational resources with the help of intelligent recommendation. Through the above research, it is expected to provide a more operational technical path and practical basis for the innovation and entrepreneurship education in higher vocational colleges from single point promotion to system collaboration.

2 Literature Review

Focusing on the research on the ecological system of entrepreneurship and entrepreneurship education, the existing results generally form two relatively clear lines. One kind focuses on the ecological composition, organizational logic and education mechanism of innovation and entrepreneurship education, emphasizing the collaborative relationship between courses, teachers, systems, platforms, enterprises and regional environment. The other group paid more attention to the embedding way of digital technology in education governance, trying to improve the efficiency of education supply by means of big data analysis, intelligent recommendation, online learning platform and learning behavior mining. The two types of

studies have answered the questions of "what constitutes the ecosystem" and "how to run the ecosystem efficiently" respectively, but there is still a lack of connection between the two in the context of "integration of innovation and innovation" in higher vocational colleges.

From the perspective of ecological research on innovation and entrepreneurship education, Clark et al. put entrepreneurship education into the framework of entrepreneurial ecosystem and believed that the effectiveness of educational activities does not depend on a single course or a single project, but on the linkage degree of organizational resources, external support and learning environment [1]. Wraae and Thomsen further proposed that the learning process of entrepreneurship education is essentially embedded in the multi-agent interaction network, and the formation of students' ability has obvious situational and generative characteristics [2]. Liu et al. sorted out the key elements of entrepreneurship education ecology from the perspective of sustainability, and pointed out that institutional guarantee, resource flow, cooperation network and evaluation feedback were the core variables affecting ecological stability [3]. The studies of Wang et al., Guerrero et al., and Ayala-Gaytan et al., respectively, reveal the coupling relationship between the internal cultivation mechanism and the external innovation network of universities from the perspectives of the influencing factors of the entrepreneurial ecology of universities, the role of incubators and the entrepreneurial behavior of graduates [4-6]. These studies provide a theoretical basis for this paper to understand the "entrepreneurship and innovation education ecosystem", but the research objects are mainly ordinary undergraduate colleges or comprehensive universities, and the discussion of the deep chimerism between professional education and entrepreneurship education in higher vocational colleges is still insufficient.

In the combination of "integration of expertise and innovation" and vocational education, related research has begun to pay attention to the reconstruction of teaching methods and capacity-oriented training. Tan and Du discussed the method improvement of integrating entrepreneurship and entrepreneurship education into higher vocational teaching based on big data analysis, indicating that data analysis can improve the pertinence of teaching content organization and the fineness of teaching decision-making [7, 8]. Mei and Symaco, Wang and Ma, Zhu et al., starting from the reality of the development of entrepreneurship and entrepreneurship education in Chinese universities, pointed out that curriculum homogeneity, resource decentralization and weak coordination mechanism were the persistent problems restricting the improvement of education quality [9-11]. Ibrahim et al., Li, Islam and Cao et al conducted empirical studies on students' entrepreneurial intention and its influencing factors, indicating that learning experience, practical environment, external support and individual cognition have a significant impact on the results of entrepreneurship and innovation [12-14]. However, most of these studies focus on intention recognition, current situation diagnosis and policy analysis, and there is still a lack of in-depth technical paths on how to describe the educational ecological structure through the computable model and how to realize the dynamic matching of resources.

At the same time, the application of computer technology in education platform and resource allocation has accumulated more results. Kuratko, Pittaway and Cope earlier explained from the perspective of entrepreneurship education development and evidence research that entrepreneurship education should not stop at content teaching, but should turn to contextualized, interactive and practice-driven support systems [15, 16]. Linzalone et al. introduced digital learning platform into entrepreneurship education in colleges and universities, emphasizing that the platform should undertake composite functions such as knowledge exchange, resource connection and learning process support [17]. Rosienkiewicz et al. pointed out in their research on technology-oriented entrepreneurship education that the strengthening of innovation ecology in higher education requires the joint participation of modeling tools,

international collaboration projects and digital carriers [18]. Hao introduced analytic hierarchy process and graph attention network into the construction of entrepreneurship and entrepreneurship learning platform for college students, and improved the accuracy of learning task allocation and resource recommendation through the linkage of evaluation modeling and recommendation algorithm [19]. Cui and Bell further explained that the design method of educational activities would directly affect the transformation of students' innovative behaviors and entrepreneurial actions from the perspective of behavioral entrepreneurship mentality [20]. This shows that it is feasible to integrate ecological element identification, quality evaluation and resource allocation into a unified framework by means of analytic hierarchy process, multi-source data fusion, graph model and intelligent recommendation.

Table 1: Main directions and implications of ecological research on entrepreneurship and innovation education

Research Direction	Representative Studies	Main Focus	Main Methods/ Perspectives	Implications for This Study	Existing Limitations
Entrepreneurship Education Ecosystem Research	Clark et al. [1]; Wraae and Thomsen [2]; Liu et al. [3]	Ecosystem elements, interactions, and sustainability	Ecosystem theory; organizational collaboration	Clarifies key actors and relationship boundaries in the innovation and entrepreneurship education ecosystem	Limited focus on higher vocational “specialty–innovation integration” and weak technological pathways
Research on Innovation and Entrepreneurship Education Development in Higher Education	Wang et al. [4]; Guerrero et al. [5]; Ayala-Gaytán et al. [6]; Mei and Symaco [9]	Drivers, support systems, and barriers	Empirical analysis; case studies; policy discussion	Identifies the roles of institutions, platforms, incubators, and external networks	Largely macro-level, lacking computable ecosystem models
Research on Innovation and Entrepreneurship Integration in Higher Vocational Education	Tan and Du [7–8]; Li and Islam [13]; Cao [14]	Integration into vocational education and entrepreneurial intention formation	Big data analysis; surveys; empirical modeling	Connects professional training, student traits, and innovation and entrepreneurship cultivation	Focuses more on status and intention, with insufficient study of resource allocation mechanisms
Research on Digital Platforms and Intelligent Support	Linzalone et al. [17]; Rosienkiewicz et al. [18]; Hao [19]	Platform design, knowledge sharing, and intelligent recommendation	Digital learning platforms; AHP; graph attention networks	Provides technical support for element identification, evaluation, and resource recommendation	Mainly task-specific, lacking a complete ecosystem collaboration framework
Research on Entrepreneurial Behavior and Educational Outcomes	Kuratko [15]; Pittaway and Cope [16]; Cui and Bell [20]	Effects of educational activities on cognition, behavior, and outcomes	Systematic reviews; behavioral studies	Links ecosystem performance with student development outcomes	Limited attention to platform data, process feedback, and dynamic optimization

As shown in Table 1, although the existing research has formed a certain accumulation in

the construction of ecological theory, the reform of entrepreneurship and innovation education and the support of digital platform, there are still three obvious shortcomings. First, many studies emphasize the importance of ecological collaboration, but lack the structural modeling of the "professional-course-project-enterprise" chain in higher vocational colleges. Second, existing research on entrepreneurship and innovation education focuses on explanation and ignores calculation, which is difficult to support dynamic evaluation and precise intervention in complex scenes. Thirdly, although some platform studies introduce recommendation algorithms or data analysis methods, they mostly serve a single learning task, and have not really risen to the level of collaborative configuration mechanism at the level of education ecology. Based on this, this paper intends to combine multi-source data perception, analytic hierarchy process evaluation and intelligent recommendation model under the framework of "innovation and innovation integration", and build an education ecosystem that can reflect the relationship between the elements, operation quality and resource flow characteristics of entrepreneurship and innovation education in higher vocational colleges.

3 Construction scheme of innovation and entrepreneurship education ecosystem in Higher Vocational Colleges from the perspective of "integration of expertise and innovation"

This chapter focuses on the practical needs of the innovation and entrepreneurship education in higher vocational colleges from decentralized promotion to system collaboration, and builds an education ecosystem scheme under the guidance of "integration of innovation and innovation". Firstly, the research builds an overall framework from the dimensions of curriculum, teachers, students, enterprise projects, platform resources and system guarantee, and clarifies the data flow, task flow and feedback relationship between each ecological subject. On this basis, the multi-source data perception method is introduced to structurally identify learning behavior, project participation, competition performance and resource usage, and the educational ecological element model is formed. Furthermore, an ecological evaluation model is constructed by combining the analytic hierarchy process (AHP) to quantitatively judge the degree of integration, collaborative efficiency and education effectiveness, and the dynamic matching of course content, practical projects, mentor resources and entrepreneurial services is realized with the help of intelligent recommendation technology, so as to provide computable, analysiable and iterative technical support for the continuous operation and optimization of the ecology of entrepreneurship and innovation education.

3.1 Overall construction plan of innovation and entrepreneurship education ecosystem in Higher vocational colleges

Under the guidance of "integration of expertise and innovation", the construction of the ecosystem of entrepreneurship and innovation education in higher vocational colleges should not stay at the level of curriculum superposition, activity splicing or platform stacking, but should form an overall mechanism of sustainable operation around "professional learning - practical training - project incubation - results feedback". Based on this idea, this paper builds an entrepreneurship and innovation education ecosystem integrating data collection, process analysis, resource collaboration and result feedback for students, teachers, enterprise mentors, management departments and platform resources. Its business process is shown in Figure 1. The system takes the students' professional growth trajectory as the main line, and integrates curriculum learning, competition training, project practice, innovation activities,

entrepreneurial services and school-enterprise cooperation into the same platform scene, so that the originally separated teaching links are connected at the data level and coordinated at the application level.

As shown in Figure 1, after students enter the platform, they need to complete identity registration, professional label selection, ability feature input and learning preference initialization, and the platform generates basic portraits accordingly. Teachers can publish course tasks, practical projects and competition training content, and corporate tutors provide real cases, job ability requirements and project collaboration resources. The platform continuously collects students' information such as course scores, training records, project participation, competition performance, resource usage frequency and interactive feedback during operation, and forms dynamic learning archives through behavior log analysis, label update and process tracking. Based on these data, the system can complete course resource push, project task matching, team collaboration support, achievement display and process evaluation, so as to make the innovation and entrepreneurship education change from static supply to dynamic adaptation.

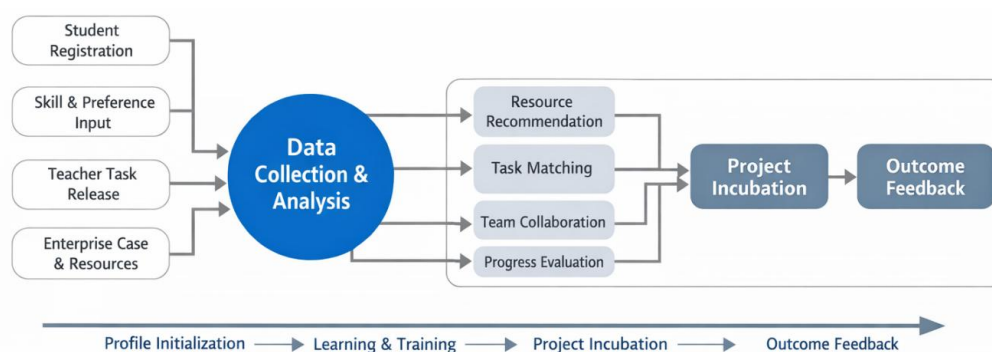


Figure 1: Business flow chart of entrepreneurship and innovation education ecosystem in higher vocational colleges under the guidance of "integration of expertise and innovation"

In order to ensure the stable operation of the system and support multi-role collaboration, this paper adopts B/S architecture to design the overall technical framework of the platform, as shown in Figure 2. On the whole, the system is composed of data support layer, analysis and calculation layer, business service layer and interactive display layer. The data support layer is mainly responsible for storing student portraits, curriculum resources, project cases, competition question databases, enterprise requirements and process evaluation data. MySQL or PostgreSQL can be used to complete structured information management, and Redis is combined to improve the efficiency of high-frequency access. The analysis and calculation layer undertakes tasks such as ecological element identification, learning behavior analysis, fusion evaluation and resource recommendation, and realizes data cleaning, feature extraction, correlation modeling and result output through Python algorithm services. The business service layer is responsible for connecting front-end interaction and back-end analysis, and can build interface services based on Spring Boot or FastAPI to complete task publishing, team management, project flow, achievement archiving and evaluation writeback. The interactive display level provides personalized entry for different users, and uses front-end frameworks such as Vue to realize the visual presentation of learning kanban board, project collaboration page, resource recommendation page and management monitoring page.

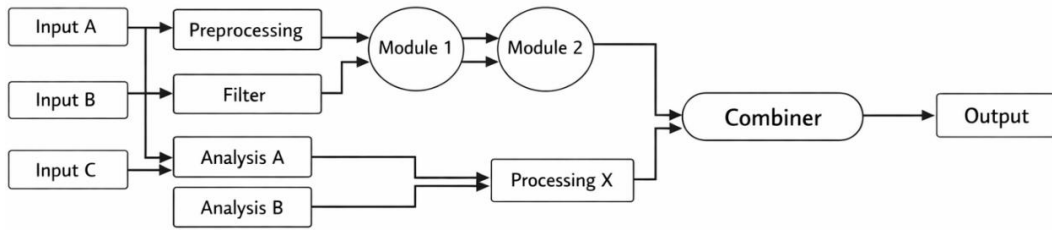


Figure 2: Overall architecture diagram of entrepreneurship and innovation education ecosystem in higher vocational colleges under the guidance of "integration of expertise and innovation"

The value of this overall construction scheme lies in the transformation of "special-purpose" and "creation" from parallel relationship to coupling relationship, and the transformation of students' ability cultivation from result assessment to process-driven. The platform not only serves the vertical promotion of professional courses, but also supports the horizontal expansion of innovation and entrepreneurship activities. It can not only reflect the individual ability difference of students, but also reveal the collaborative state between courses, projects, teachers and enterprises. Therefore, the ecology of entrepreneurship and innovation education in higher vocational colleges is no longer a collection of several single tasks, but a digital education system that can be perceived, analyzed, feedback and optimized.

3.2 Identification and structural modeling of educational ecological elements based on multi-source data perception

In the context of "integration of expertise and innovation", the ecology of entrepreneurship and innovation education in higher vocational colleges is not the mechanical superposition of several teaching links, but a dynamic relationship network composed of students, teachers, courses, projects, enterprises, platforms and institutional environment. If we judge ecological status only by static questionnaires or stage summaries, we often only see local results, and it is difficult to identify the real linkage between elements. Therefore, this paper introduces a multi-source data perception method to hierarchically identify and structure model the educational ecological elements. Its core goal is to transform the heterogeneous information scattered in the teaching process, project training and platform interaction into computable node features and relationship features, which provides basic support for subsequent evaluation and recommendation. Its overall recognition framework is shown in Figure 3.

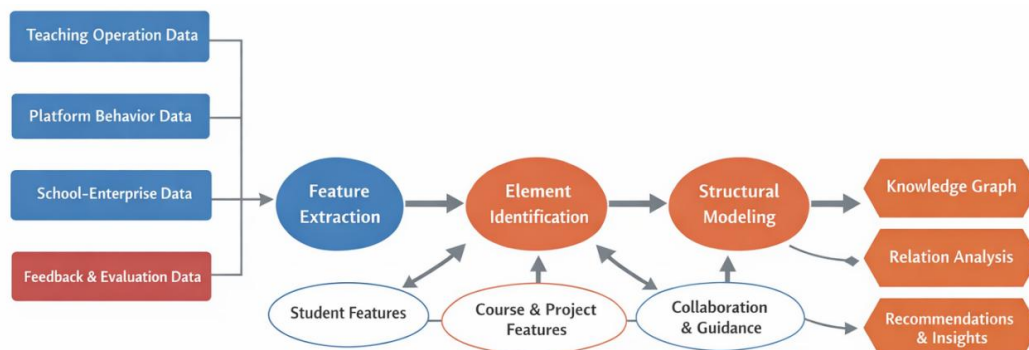


Figure 3: Identification and structure modeling framework of educational ecological elements of "integration of expertise and innovation" based on multi-source data perception

As shown in Figure 3, the data collected by the system mainly comes from four sources: first, teaching operation data, including course grades, training records, assignment submission, competition participation and project completion. The second is platform behavior data, including login frequency, resource click, learning time, collaborative interaction and task response. Third, school-enterprise collaboration data, including enterprise project requirements, tutor guidance times, post ability labels and achievement transformation records; The fourth is feedback evaluation data, including student mutual evaluation, teacher evaluation, enterprise evaluation and process reflection text. In order to reduce the interference caused by the differences of different data scales, this paper uses the range standardization method to uniformly process the original features, and obtains the standardized results of feature x_{ij} :

$$z_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \quad (1)$$

Here, x_{ij} represents the original value of the i th educational subject on the JTH index, and z_{ij} is the normalized result. After processing, subjects such as students, teachers, courses, projects and enterprises can be represented as feature vectors under a unified dimension, thus providing a data basis for ecological node modeling.

Considering that "integration of expertise and innovation" is not just a simple juxtaposition of professional ability and entrepreneurial consciousness, this paper divides the state representation of student nodes into three dimensions: professional foundation, innovation practice and collaborative adaptation. Among them, the professional basis mainly reflects the course mastery, skill training and professional certificate. Innovation practice reflects competition participation, project development, scheme design and achievement expression ability; Co-adaptation reflects team collaboration, task response, resource invocation and cross-role interaction ability. Therefore, the comprehensive state of the student node can be expressed as follows.

$$S_i = \alpha K_i + \beta I_i + \gamma C_i \quad (2)$$

Here, K_i represents the professional learning characteristics of the i th student, I_i represents the innovation and entrepreneurship practice characteristics, C_i represents the collaborative adaptation characteristics, and $\alpha + \beta + \gamma = 1$. This expression can better reflect the integration relationship of "promoting innovation by innovation and strengthening specialty by innovation", and avoid isolating the ability of entrepreneurship and innovation from the professional training system.

At the course and project level, this paper no longer regards course resources as static content collections, but models them as task nodes related to students' abilities, enterprise needs and teacher guidance intensity. The comprehensive adaptation strength of the course-project node is defined as follows.

$$P_m = \lambda_1 R_m + \lambda_2 D_m + \lambda_3 E_m \quad (3)$$

Among them, R_m represents the professional relevance of course or project resources, D_m represents the matching degree of task difficulty and student ability, and E_m represents its fit degree with the real scene of the enterprise. The model can identify which items are more suitable as the training carrier of "innovation integration", and also help to find the disconnection and redundancy points in resource supply.

After completing the node feature construction, this paper further establishes the

educational ecological correlation matrix based on the collaboration, guidance, participation and resource invocation relationships between subjects. The relationship strength of any two nodes u and v is defined as follows.

$$A_{uv} = w_1 H_{uv} + w_2 B_{uv} + w_3 T_{uv} \quad (4)$$

Here, H_{uv} represents the historical collaboration frequency, B_{uv} represents the behavior similarity, T_{uv} represents the task correlation, and $w_1 + w_2 + w_3 = 1$. According to this, the ecology of entrepreneurship and innovation education in higher vocational colleges can be expressed as a weighted graph structure $G = (V, A)$, where V is the set of ecological subjects and A is the set of inter-subject relations. The graph structure can not only show the explicit connections between students and courses, teachers and projects, schools and enterprises, but also find potential collaborative paths through behavioral similarity and task correlation.

In general, the identification of educational ecological elements supported by multi-source data perception is not only to describe the system composition, but more importantly, to reveal the operating logic between "people-study-item-enterprise-platform". Through node modeling and relationship modeling, the originally scattered educational activities were integrated into an ecological network that could be traced, analyzed, and iteratively optimized, which provided a stable data base and structural basis for the construction of subsequent analytic hierarchy process evaluation models and intelligent recommendation models.

3.3 The construction of educational ecological evaluation model of "integration of expertise and innovation" based on analytic hierarchy Process

In order to more accurately judge the operation quality of the ecology of entrepreneurship and innovation education in higher vocational colleges, this paper introduces the analytic hierarchy process (AHP) to construct the "innovation and innovation integration" education ecology evaluation model based on the multi-source data identification results. Different from the way of relying solely on the mean value of the questionnaire or the experience scoring, the ecological evaluation object is decomposed into a number of indicator units with hierarchical relationship, and then the weight is calculated by combining the data collected by the platform and the expert judgment results, so as to transform the originally abstract "integration level", "collaborative state" and "education effectiveness" into computable and comparable evaluation results. Figure 4 shows the evaluation hierarchy.

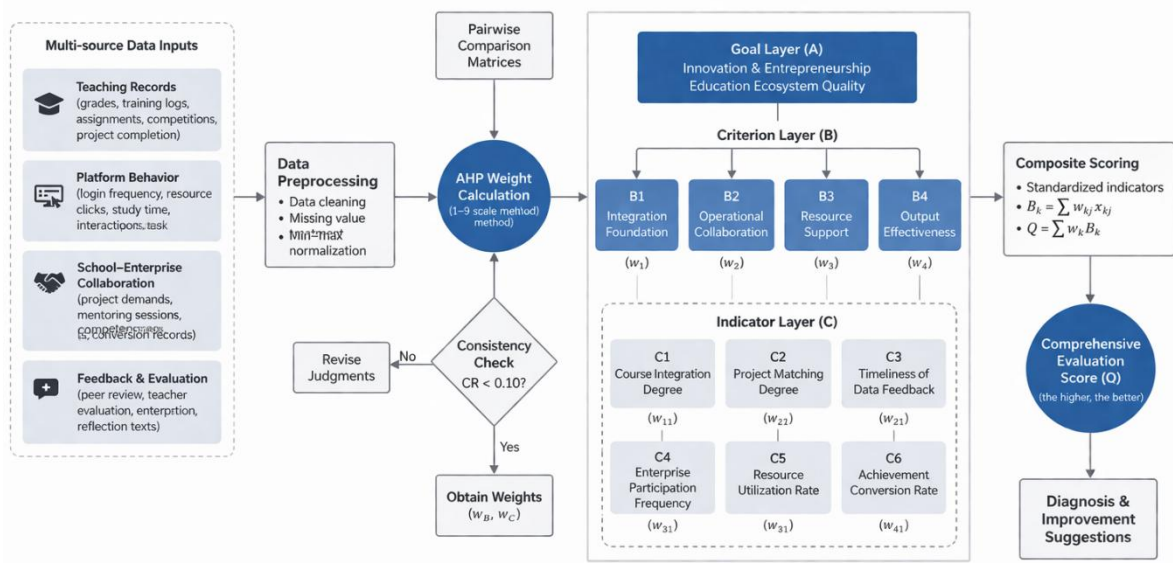


Figure 4: Hierarchy diagram of educational ecological evaluation model of "integration of expertise and innovation"

As shown in Figure 4, the model sets the target layer A as the ecological comprehensive quality of entrepreneurship and innovation education in higher vocational colleges. The criterion layer includes four dimensions: B_1 is the basis of integration, which mainly reflects the embedding degree of professional courses and entrepreneurship and innovation content. B_2 is operational collaboration, which mainly reflects the interaction efficiency between teachers, students, enterprises and platforms. B_3 is resource support, which mainly reflects the supply ability of course resources, project resources, tutor resources and digital platform. B_4 is the output effect, which mainly reflects the students' project completion, competition results, innovation ability improvement and entrepreneurial practice transformation. The index layer was further refined into several observable indicators such as course integration degree, project matching degree, data feedback timeliness, enterprise participation frequency, resource invocation rate, and achievement conversion rate. The significance of this process is that, on the one hand, it can retain the complexity of the "integration of creativity and innovation" problem, and on the other hand, it is easy to complete batch calculation and dynamic update with the help of computer programs.

In the process of weight determination, this paper uses the "1-9 scaling method" to construct the judgment matrix of the same level index. Suppose that a certain layer contains p indicators, then the judgment matrix can be expressed as follows.

$$M = (m_{ij})_{p \times p}, \quad m_{ii} = 1, \quad m_{ij} = \frac{1}{m_{ji}}, \quad m_{ij} > 0 \quad (5)$$

Here, m_{ij} denotes the degree of importance of index i with respect to index j . According to the expert evaluation results and the platform statistical information, the judgment matrix corresponding to each layer can be formed. Then, the maximum eigenvalue λ_{\max} and its corresponding eigenvector w are calculated and normalized to obtain the index weight vector of this layer:

$$Mw = \lambda_{\max} w, \quad \hat{w}_i = \frac{w_i}{\sum_{j=1}^p w_j} \quad (6)$$

Considering the risk of bias caused by subjective comparison in AHP, the model also needs to be checked for consistency. Its consistency index and consistency ratio are as follows.

$$CI = \frac{\lambda_{\max} - p}{p - 1}, CR = \frac{CI}{RI} \quad (7)$$

Here, RI is the random consistency index. When $CR < 0.10$, the judgment matrix can be considered to have acceptable consistency. If the requirements are not met, the pairwise comparison results of the indicators need to be revised again. In this paper, Python and NumPy are used to solve the matrix and check the consistency, so that the evaluation model has good reusability and computational stability.

After obtaining the weights of each layer, the standardized index values are further substituted into the comprehensive evaluation model. Suppose that the KTH criterion layer contains t_k indicators, then its local score is as follows.

$$B_k = \sum_{j=1}^{t_k} \hat{w}_{kj} x_{kj} \quad (8)$$

Here, x_{kj} represents the standardized value of the corresponding index, and \hat{w}_{kj} represents the weight of the index in the subordinate criterion layer. Furthermore, the comprehensive score of educational ecology can be expressed as follows.

$$Q = \sum_{k=1}^4 \hat{w}_k B_k \quad (9)$$

where, \hat{w}_k is the weight of the criterion layer, Q is the comprehensive evaluation value of the education ecology of "integration of expertise and innovation". The higher the Q value, the more stable the performance of the ecosystem in terms of integration depth, operation coordination, resource supply and education effectiveness. Therefore, the evaluation model can not only identify the strengths and weaknesses of the current system, but also provide quantitative basis for subsequent resource recommendation, project adjustment and system optimization.

3.4 Construction of collaborative allocation model of innovation and entrepreneurship education resources based on intelligent recommendation

After completing the identification and level evaluation of educational ecological elements, the system also needs to further answer a more practical question: in the face of multi-type supplies such as curriculum resources, competition projects, enterprise cases, mentor guidance and entrepreneurial services, how to realize more targeted collaborative allocation according to students' professional foundation, innovation potential and development stage. If the manual experience allocation method is still used, it is easy to cause the dislocation of resource allocation and student needs, the mismatch between project difficulty and ability level, and the concentration of high-quality tutor resources in minority groups. Based on this, this paper constructs an intelligent recommendation model for the scenario of "innovation and innovation integration", which uniformly represents students, courses, projects, tutors and enterprise tasks as nodes in heterogeneous graphs, and completes resource matching through representation

learning and relationship aggregation.

Let the set of students be $U = \{u_1, u_2, \dots, u_m\}$, the resource set is $R = \{r_1, r_2, \dots, r_n\}$, the resources include not only professional course development content, but also competition tasks, innovation projects, enterprise cases and entrepreneurial services. Combined with the ecological features constructed in the previous section, the initial representation vector of student u_i is defined as follows.

$$x_{u_i} = [k_{u_i}; i_{u_i}; c_{u_i}; q_{u_i}] \quad (10)$$

Among them, k_{u_i} represents the professional learning feature, i_{u_i} represents the innovative practice feature, c_{u_i} represents the collaborative adaptation feature, and q_{u_i} is the ecological evaluation score obtained in Section 3.3. The initial representation of resource nodes is composed of resource topics, capability requirements, application scenarios and implementation difficulties:

$$x_{r_j} = [d_{r_j}; s_{r_j}; t_{r_j}; h_{r_j}] \quad (11)$$

Here, d_{r_j} is the professional direction label, s_{r_j} is the dual innovation ability requirement, t_{r_j} is the task type feature, and h_{r_j} is the difficulty representation. The platform uses the embedding layer to map the above features into a unified latent space, and obtains the low-dimensional representations e_{u_i} and e_{r_j} of students and resources.

Considering that the resource allocation in the education ecology is not a single point of matching, but is affected by the multiple relationships of "students-courses-project-tutors - enterprises", this paper introduces the graph attention aggregation mechanism after representation learning to perform weighted integration of node neighborhood information. For the student node u_i , its neighborhood aggregation representation at level l can be written as follows.

$$h_{u_i}^{(l+1)} = \sigma \left(\sum_{v \in \mathcal{N}(u_i)} \alpha_{iv}^{(l)} W^{(l)} h_v^{(l)} \right) \quad (12)$$

where $\mathcal{N}(u_i)$ is the set of course, project, tutor and enterprise nodes associated with the student, $W^{(l)}$ is the trainable parameter matrix, $\sigma(\cdot)$ is the activation function, and $\alpha_{iv}^{(l)}$ is the attention weight. The weight is determined by the relationship strength between nodes and the feature similarity:

$$\alpha_{iv}^{(l)} = \frac{\exp \left(\text{LeakyReLU} \left(a^\top [W^{(l)} h_{u_i}^{(l)} \| W^{(l)} h_v^{(l)}] \right) \right)}{\sum_{z \in \mathcal{N}(u_i)} \exp \left(\text{LeakyReLU} \left(a^\top [W^{(l)} h_{u_i}^{(l)} \| W^{(l)} h_z^{(l)}] \right) \right)} \quad (13)$$

After this process, the model can distinguish between "highly relevant resources" and "weakly relevant resources", and avoid simply relying on click frequency or popularity to complete extensive recommendation.

Since the needs of students in different learning cycles will change, this paper further introduces a gated update mechanism to dynamically modify their stage behaviors. Let $g_{u_i}^{(t)}$ be the state representation of the student at time t . Then the update process can be expressed as

follows.

$$\mathbf{g}_{u_i}^{(t)} = \text{GRU}\left(\mathbf{g}_{u_i}^{(t-1)}, \mathbf{h}_{u_i}^{(l+1)}\right) \quad (14)$$

The process can incorporate time series information such as course completion, project participation, competition performance and resource feedback into a unified representation, so as to enhance the stage adaptability of recommendation results. Based on the updated student representation $\mathbf{g}_{u_i}^{(t)}$ and resource representation \mathbf{e}_{r_j} , the platform calculates the matching score between them:

$$\hat{y}_{ij} = (\mathbf{g}_{u_i}^{(t)})^\top \mathbf{e}_{r_j} + b_{u_i} + b_{r_j} \quad (15)$$

Among them, the larger \hat{y}_{ij} is, the more fit the resource r_j is with the current development needs of the student u_i . According to the score, the system can output the Top-N resource list, and jointly push the course reinforcement content, competition training items, enterprise practice tasks and mentor guidance opportunities. In order to optimize the training effect of the model, the ranking loss function is used to constrain the relative order between positive and negative samples:

$$\mathcal{L} = - \sum_{(u,i,j) \in \Omega} \ln \sigma(\hat{y}_{ui} - \hat{y}_{uj}) + \lambda \|\Theta\|_2^2 \quad (16)$$

Here, Ω is the set of training samples, i represents the resources that students actually participate in or prefer, j represents the resources that are not selected, λ is the regularization coefficient, Θ is the set of model parameters.

The significance of this model is not to simply improve the accuracy of recommendation, but more importantly to establish a resource collaborative configuration mechanism under the framework of "innovation integration". It can link the learning results of professional courses, the practice trajectory of entrepreneurship and innovation, and the interactive behavior of the platform with the task needs of enterprises, so that the resource supply changes from static listing to dynamic adaptation, and also makes the entrepreneurship and innovation education ecology in higher vocational colleges truly have the ability to respond to demand and continue to optimize.

4 Operation and application analysis of innovation and entrepreneurship education ecosystem in Higher Vocational Colleges under the guidance of "integration of specialty and innovation"

4.1 Operation efficiency analysis of educational ecosystem

In order to test the stability and collaborative efficiency of the innovation and entrepreneurship education ecosystem in higher vocational colleges under the guidance of "integration of expertise and innovation" in the trial operation stage, this paper analyzes the processing ability, response level and resource scheduling effect of the system in real teaching scenarios based on the trial operation data of an innovation and entrepreneurship platform in a higher vocational college from March 2024 to January 2025. The test environment is based on the deployment of

campus private network, and the platform accesses four roles: student end, teacher end, enterprise mentor end and management end, and continuously collects behavioral data such as course learning, project training, resource access, task flow and process evaluation. The trial data covers March 2024 to January 2025, mainly used for system operation efficiency test, involving a total of 2146 students, 128 full-time teachers, 41 enterprise mentors, 32 entrepreneurship courses, 186 practical projects, 74 competition tasks and 128,436 platform interaction logs." To ensure the comparability of the analysis, this paper compares the traditional manual allocation mode, the resource allocation mode based on rule matching and the intelligent collaborative ecosystem constructed in this paper as three types of operation schemes, and the relevant test environment and sample size are shown in Table 2.

Table 2: Education Ecosystem running test environment and sample data

Item	Parameter
Operating System	Windows Server 2019 / Ubuntu 22.04
Server Memory	32 GB
CPU	Intel Xeon Silver 4310
Storage	1 TB SSD
Development Environment	Python 3.10, PyCharm, Anaconda
Backend Framework	FastAPI + Spring Boot
Database	MySQL 8.0 + Redis
Frontend Framework	Vue 3
Number of Participating Students	2,146
Number of Full-time Teachers	128
Number of Enterprise Mentors	41
Number of Innovation and Entrepreneurship Courses	32
Number of Practical Projects	186
Number of Competition Tasks	74
Number of Platform Logs	128,436
Dataset Split	70% Training Set, 20% Test Set, 10% Validation Set

From the perspective of the system operation process, the effectiveness of the platform is not only reflected in whether the page is accessible, but also reflected in whether different educational elements can be identified, matched and fed back within a limited time. Table 2 shows that the proposed system can still maintain a relatively stable processing capacity when the data scale continues to expand, which indicates that the collaborative chain between multi-source data access, ecological evaluation calculation and recommendation call is loadable. Especially in the case of high frequency access by students, centralized application of projects and batch push of competition resources, there is no obvious congestion in the system, indicating that the hierarchical architecture and asynchronous processing mechanism have good adaptability in education scenarios.

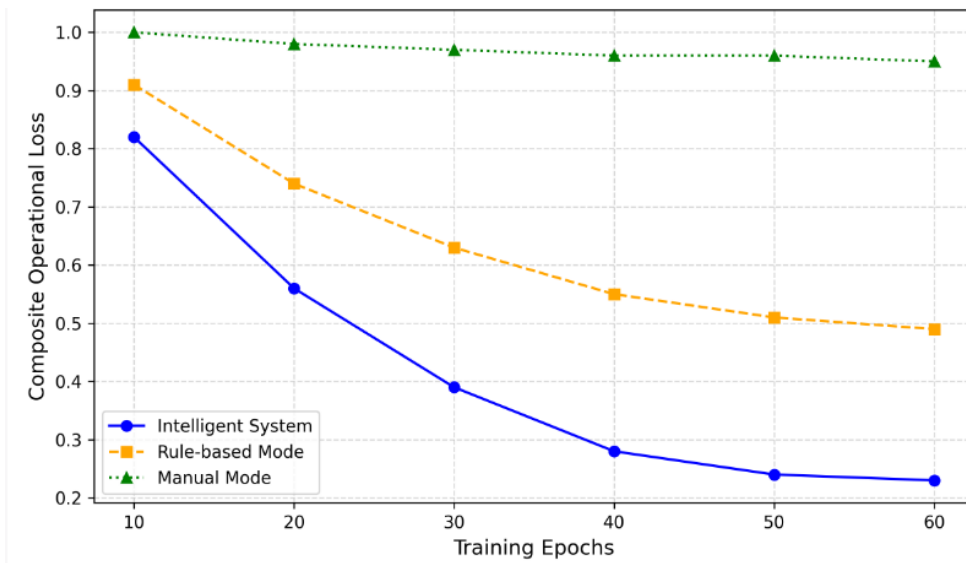


Figure 5: System convergence performance for different operation schemes

As shown in Figure. 5, with the increase of training rounds, the integrated running convergence value of the proposed system decreases faster and becomes stable after the 42nd round. In contrast, although the rule matching mode can quickly enter the stationary region, the optimization space is limited in the later stage, and the traditional manual mode has almost no convergence process in a computable sense. The "convergence" here does not only refer to the decline of the loss function of the algorithm, but also reflects the process of gradually stabilizing the resource allocation results and weakening the fluctuation of the evaluation results after the platform continues to absorb behavioral data. This shows that the ecosystem based on the linkage of multi-source data perception, analytic hierarchy process evaluation and dynamic recommendation is not simply a superposition of several modules, but a relatively complete feedback loop is formed in the operation.

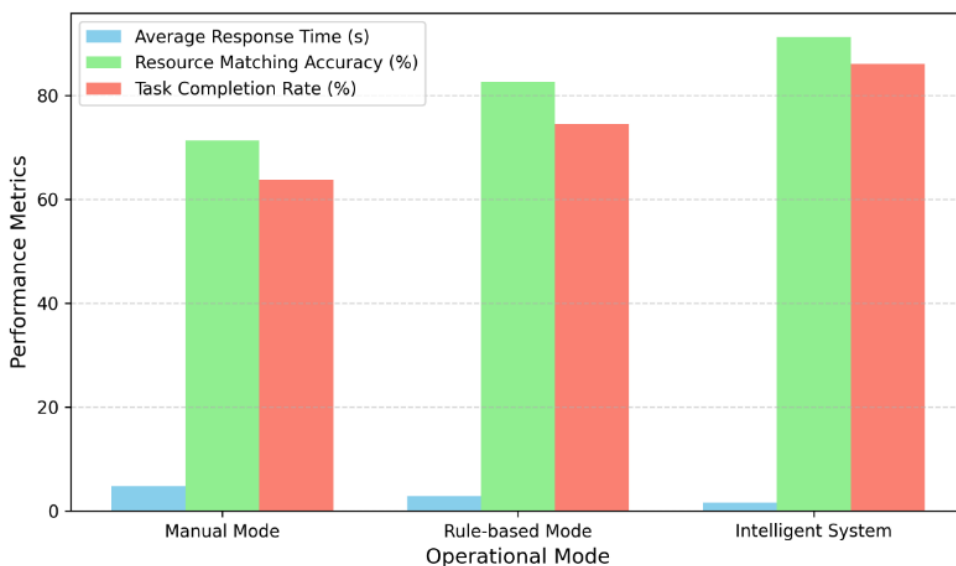


Figure 6: Comparison of core performance indicators for different operation schemes

From the perspective of core operation indicators, the system in this paper shows better results in the three dimensions of average response time, resource matching accuracy and task

completion conversion rate. As shown in Figure 6, the average response time of the traditional manual mode is 4.8 s, the rule matching mode drops to 2.9 s, and the proposed system is further compressed to 1.6 s. In terms of resource matching accuracy, the three methods are 71.4%, 82.7% and 91.3%, respectively. The task completion conversion rates were 63.8%, 74.5% and 86.1%, respectively. This result shows that when the system can comprehensively use information such as students' professional foundation, innovation participation record, project difficulty characteristics and tutor support intensity, the resource allocation will be closer to the actual needs of students, and the platform operation is no longer just "pushing resources out", but really promoting learning tasks to be accepted, executed and produce results. The improvement of simultaneous operation efficiency does not come entirely from the algorithm itself, but from the reorganization of the relationship between ecological elements. In the traditional model, courses, projects, competitions and enterprise resources are often scattered in different management units, and information updates are not synchronized, resulting in students need to retrieve and compare repeatedly, and teachers are difficult to grasp students' participation status in time. Through unified data entry and structured modeling, the system puts student portraits, resource labels, evaluation results and process feedback into the same computing framework, so that task assignment, resource collaboration and result reflux can occur continuously. In other words, the improvement of platform operation efficiency is essentially the improvement of internal connection efficiency of education ecology.

4.2 Application effect analysis of educational ecosystem

After completing the platform trial operation and system efficiency test from March 2024 to January 2025, this paper further connected the system to the entrepreneurship and innovation practice platform of a higher vocational college in the fall semester of 2025, and selected 1000 newly registered users as application observation objects. After balanced grouping according to professional category, grade distribution and existing entrepreneurship and entrepreneurship participation experience, 1000 newly registered users were divided into intelligent ecosystem group, rule matching group and conventional platform group, and their platform use results for 8 consecutive weeks were tracked and analyzed. In the process of operation, the system synchronously records the behavior data such as resource call, project participation, task completion, feedback evaluation and result submission, and makes a comprehensive analysis of the application effect combined with the student satisfaction questionnaire.

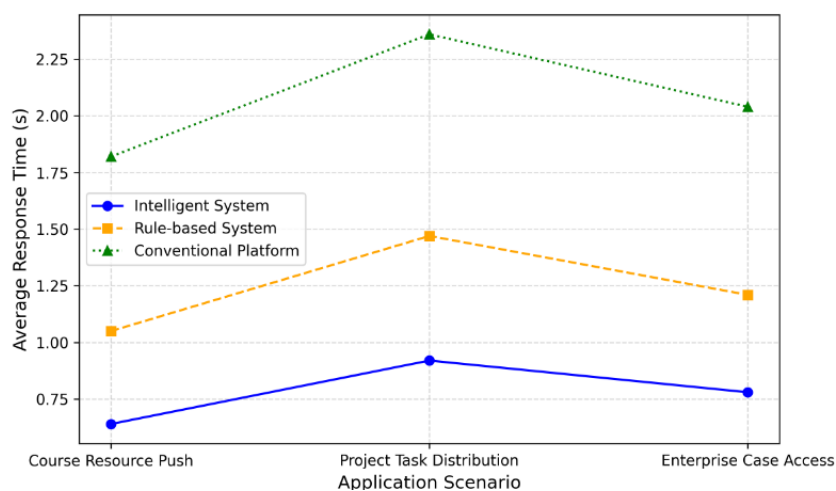


Figure 7: Average response time of different platforms in main application scenarios

From the perspective of platform resource response and task reach effect, the intelligent

ecosystem shows higher scene adaptation ability in the application stage. As shown in Figure 7, in the three links of course resource push, project task distribution and enterprise case call, the average response time of the intelligent ecosystem is lower than that of the other two groups. The response time of the project task distribution is compressed to 0.92s, which is significantly better than that of the rule matching group (1.47s) and the conventional platform group (2.36s). This shows that when the platform can make dynamic judgments by comprehensively using student profiles, course tags, project difficulty and behavior feedback, the redundant retrieval and repeated waiting in the process of resource flow will be significantly reduced, and the path for students to enter the task scene is shorter. For higher vocational colleges, this efficiency improvement is not a simple technical optimization, but the optimization of the connection between professional learning and entrepreneurship and innovation practice.

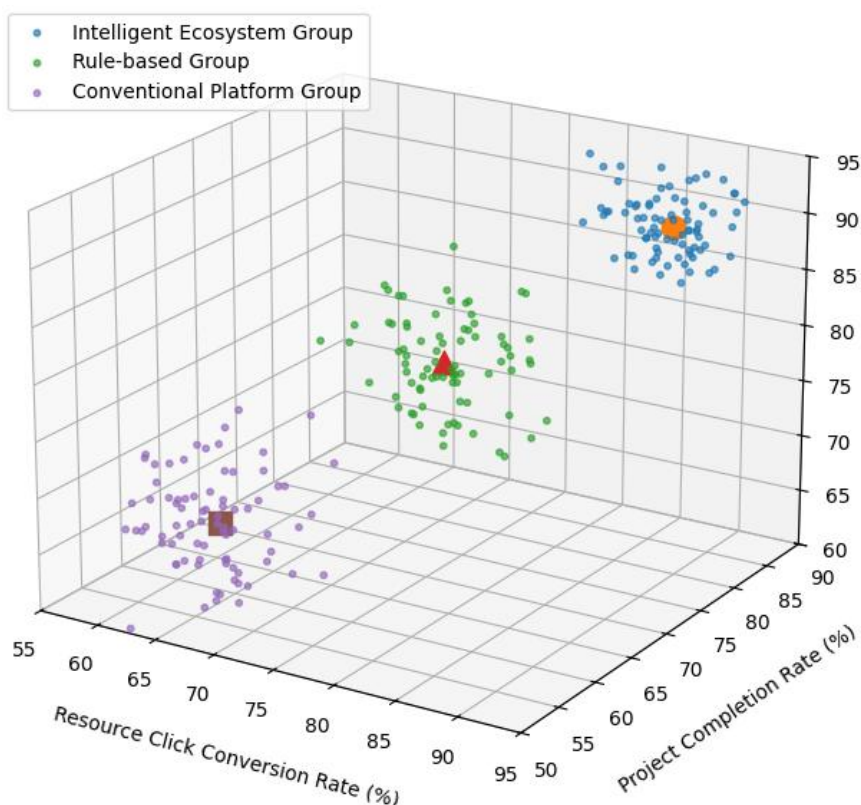


Figure 8: Comparison of application effects of different platforms

From the application results, the value of the system is more concentrated on the depth of participation and the quality of transformation. As shown in Figure 8, after 8 weeks of observation, the three indicators of resource click conversion rate, project completion rate and comprehensive satisfaction rate of the intelligent ecosystem group reached 88.6%, 81.4% and 90.2%, respectively, which were higher than those of the rule matching group and the conventional platform group. Especially in the project completion rate, the intelligent ecosystem group was 22.9 percentage points higher than the conventional platform group, indicating that the intelligent collaborative configuration did not stay at the level of "recommending more resources", but more effectively guided students to practical tasks that were executable, complete and feedbackable. This result mutually corroborated with the previous operation efficiency analysis, indicating that once the education ecology had the ability of data perception, relationship recognition and dynamic recommendation, it was easier for the entrepreneurship and innovation education to shift from active participation to

substantive output. The improvement of student satisfaction comes not only from the improvement of platform interface, but also from the improvement of resource matching accuracy. In conventional platforms, students often face a large number of homogeneous content and need to filter course, project and competition information by themselves, which is easy to form a "lot of information but difficult to choose" experience. By jointly modeling the professional direction, ability basis and stage needs, the intelligent ecosystem makes the platform recommendation more targeted, and students can quickly find the task units and support resources that are consistent with their own development path. Therefore, the platform is no longer just an information display terminal, but has gradually evolved into a digital collaborative center connecting curriculum learning, practical training and achievement incubation.

5 Discussion

Existing research on entrepreneurship education mostly focuses on curriculum reform, institutional guarantees, or students' entrepreneurial intentions. Although there has been some discussion on the overall operational mechanism of the education ecosystem in the context of vocational colleges' integration of specialization and entrepreneurship, there are still significant gaps in technological implementation. One type of research emphasizes that the entrepreneurship education ecosystem should be composed of curriculum, faculty, platforms, and external environment in collaboration, which provides a foundation for understanding the systematic attributes of entrepreneurship education; However, such research often remains at the level of conceptual interpretation and structural description, making it difficult to answer how ecological elements are continuously identified, dynamically evaluated, and how resource linkage can be achieved in platform scenarios. Another type of research introduces big data analysis, online learning platforms, or recommendation algorithms into educational settings to improve resource distribution efficiency, but often focuses on optimizing a single function and neglects the continuous relationship between "professional learning innovative training project practice achievement transformation". Compared with the above path, this article emphasizes more on reconstructing the connection between "specialization" and "creativity" through computer technology. The multi-source data perception module is not only used to collect student behavior information, but also attempts to incorporate course learning records, project participation trajectories, enterprise task requirements, and process feedback results into a unified data space, so that key entities in the education ecosystem can be structurally expressed. The introduction of the Analytic Hierarchy Process (AHP) model is not simply to generate a comprehensive score, but to use hierarchical indicator weights to reveal the inherent differences between fusion basis, operational synergy, resource support, and output effectiveness, gradually shifting management decision-making from empirical judgment to quantitative identification. As for the intelligent recommendation module, its significance is not only reflected in the technical aspect of "pushing more accurately", but also in promoting a more reasonable collaborative relationship between course resources, practical projects, mentor support, and enterprise tasks, thereby reducing resource mismatches and participation fractures.

Of course, our approach is not without limitations. On the one hand, some variables in the education ecology have strong context dependence, such as students' innovation willingness, teachers' investment intensity and enterprise cooperation stability, which are still difficult to completely describe by only using platform logs. On the other hand, the current model still takes the single school scene as the main verification object. Although it can better reflect the operation characteristics of entrepreneurship and innovation education within higher vocational colleges, it is necessary to further consider the practical problems such as the differences in

professional categories, the differences in platform foundation and the non-unity of data standards when promoting across colleges and regions. On this basis, subsequent research can introduce longer period longitudinal tracking data, and combine methods such as knowledge graph, causal inference and federated learning to further improve the explanatory power and transfer ability of educational ecological analysis. In this way, the construction of the entrepreneurship and innovation education ecosystem can truly move from local experiments to stable operation.

6 Conclusions

Under the background of the continuous advancement of "integration of expertise and innovation", entrepreneurship and innovation education in higher vocational colleges can no longer rely on curriculum splicing, activity superposition or experience management to maintain operation, but need to form a more stable ecological support with the help of digital technology. Around this demand, this paper constructs an entrepreneurship and innovation education ecosystem composed of multi-source data perception, education ecological element identification, analytic hierarchy process evaluation and intelligent recommendation collaborative configuration, and integrates professional courses, project practice, competition training, enterprise tasks and platform services into a unified computing framework. The research results show that the system shows good adaptability in system operation and scene application: the average response time of the platform is reduced to 1.6 s, the resource matching accuracy is 91.3%, the task completion conversion rate is increased to 86.1%, and the comprehensive satisfaction is 90.2%. These results show that the closed-loop mechanism of "data perception - evaluation analysis - dynamic recommendation" can effectively alleviate the problems of resource mismatch, feedback lag and lack of collaboration in entrepreneurship and innovation education in higher vocational colleges. At the same time, this paper does not regard entrepreneurship and innovation education as an additional module besides professional teaching, but connects "specialty" and "innovation" at the process level through computer technology, so as to form a closer linkage relationship between students' development trajectory, curriculum resources supply and enterprise practice needs. Of course, the current research still takes the single-school platform scenario as the main verification object, and some hidden variables such as students' innovation motivation and teachers' guidance investment differences have not been fully described. In the future, it is still necessary to combine longer period samples and cross-calibration data to further improve the migration ability, interpretation ability and continuous optimization mechanism of the model.

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