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Data-Driven Governance of University Entrepreneurship Education: A Dynamic Evaluation Model based on Multi-Source Student Behavior Data

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Abstract: To address practical dilemmas in university innovation and entrepreneurship (hereafter referred to as "innovation and entrepreneurship") education, such as unbalanced resource allocation and lagging evaluation, this study conducts research on data-driven governance of university innovation and entrepreneurship education based on the core logic of "data empowering decision-making" in educational governance. Integrating multi-source student behavior data from university academic management systems, student affairs systems, and innovation and entrepreneurship practice platforms, the research constructs a dynamic evaluation index system covering three dimensions: students' innovative literacy, practical participation, and project transformation. Machine learning algorithms are employed to build a prediction model for the effectiveness of innovation and entrepreneurship education, systematically revealing the impact mechanisms of governance interventions (e.g., curriculum optimization, resource matching, and mentor empowerment) on the improvement of students' innovation and entrepreneurship capabilities. Case verification is carried out in multiple universities of different types to test the practical effectiveness of the data-driven governance model. The innovation of this study lies in the deep integration of educational governance theory with data science, breaking through the limitations of empirical analysis in traditional innovation and entrepreneurship education research, and constructing a closed-loop governance framework of "data collection - model analysis - decision optimization - effect feedback". The research results provide replicable technical paths and theoretical support for the precise and scientific governance of university innovation and entrepreneurship education, align with the international research hotspot of "educational digital governance", and hold significant implications for promoting the high-quality development of university innovation and entrepreneurship education.

Keywords: Data-driven, University Innovation and Entrepreneurship Education, Educational Governance, Dynamic Evaluation Model, Multi-source Student Behavior.

1. Introduction

Driven by both the national innovation-driven development strategy and the digital transformation of education, innovation and entrepreneurship education in higher education institutions has become a core vehicle for cultivating high-quality innovative talents and serving the high-quality development of the economy and society. In recent years, Chinese universities have generally attached great importance to innovation and entrepreneurship education, successively introducing a series of policy measures to promote the construction of curriculum systems, the establishment of practical platforms, and the training of teaching teams, achieving phased results. However, the current governance of innovation and entrepreneurship education in universities still faces many practical bottlenecks: first, the prominent imbalance in resource allocation-high-quality courses, practical venues, and mentoring resources are mostly concentrated in a few advantageous disciplines or key universities, making it difficult for most students to access equal resource supply; second, the outdated and rigid evaluation system-traditional evaluation mainly relies on static outcome-oriented indicators such as final exams and project closures, which fail to capture the dynamic development process of students' innovation and entrepreneurship capabilities in real time,[1] leading to a significant deviation between evaluation results and students' actual abilities; third, the lack of data support for governance decisions-innovation and entrepreneurship education reforms in most universities still rely primarily on empirical judgments, making it difficult to accurately identify student needs and optimize intervention strategies, which restricts the improvement of education quality [8].

Meanwhile, the rapid development of digital technologies such as big data and artificial intelligence has provided new ideas for addressing the above dilemmas. The emerging research on "digital governance in education" in the international education community emphasizes data as the core element, enabling educational decision-making through the integration of multi-source data and intelligent analysis to achieve precise and scientific education governance. Against this backdrop, introducing the data-driven concept into the governance of innovation and entrepreneurship education in universities, integrating student behavior data from multiple systems including academic affairs, student affairs, and innovation and entrepreneurship practices, and constructing dynamic evaluation models and closed-loop governance frameworks have become an inevitable choice for promoting the transformation and upgrading of the governance model of innovation and entrepreneurship education.

2. Literature Review

2.1. Research on the Governance of Innovation and Entrepreneurship Education in Higher Education Institutions

Scholars at home and abroad have conducted extensive research on the governance of innovation and

entrepreneurship education in universities. Foreign studies focus on the collaboration of governance subjects and the optimization of policy tools. For example, some scholars have proposed a tripartite collaborative governance model of "government-university-enterprise," emphasizing the improvement of the efficiency of resource supply for innovation and entrepreneurship education through the participation of multiple subjects [4]; other studies have focused on evaluating the implementation effects of innovation and entrepreneurship education policies to provide a basis for policy optimization [3]. Domestic studies are mostly concentrated on the innovation of governance models and the resolution of practical problems. For instance, some scholars have put forward the concept of "precision governance," emphasizing personalized educational services based on student needs [5]; other studies have explored paths to improve the quality of innovation and entrepreneurship education around governance elements such as curriculum systems, teaching teams, and practical platforms [6].

However, existing research still has obvious shortcomings: most studies focus on qualitative analysis or static evaluation, lacking attention to the dynamic development process of students' innovation and entrepreneurship capabilities; few studies integrate multi-source data for quantitative analysis, resulting in insufficient scientificity and accuracy of governance decisions; a data-driven closed-loop governance framework has not yet been formed, making it difficult to achieve continuous improvement of "evaluation-decision-feedback-optimization."

2.2. Research on Data-Driven Educational Decision-Making

Data-driven decision-making has become a research hotspot in the field of education. Foreign studies have applied big data technology to educational evaluation and decision-making earlier, such as using learning behavior data to predict students' academic performance and optimize teaching strategies [7]; some studies have constructed educational data mining frameworks to provide technical support for educational governance [8]. Domestic studies mostly focus on data-driven teaching optimization in basic education, such as personalized teaching recommendations based on students' learning data [4]; in the field of higher education, data-driven research is mainly concentrated on academic early warning and teaching quality evaluation, and its application in the governance of innovation and entrepreneurship education is still in its initial stage [9].

The shortcomings of existing data-driven education research are as follows: first, the data sources are relatively single, mostly concentrated on teaching system data, lacking the integration of data from multiple systems such as student affairs and practice; second, the application depth in the field of innovation and entrepreneurship education is insufficient, and a dynamic evaluation model and governance framework for innovation and entrepreneurship capabilities have not yet been formed; third, there is a lack of multi-case verification, and the practical promotion of research results needs to be improved.

2.3. Research on the Evaluation Index System of Innovation and Entrepreneurship Education

The evaluation index system of innovation and entrepreneurship education is a core tool for conducting governance evaluation. Foreign studies focus on constructing index systems from dimensions such as innovation ability, entrepreneurial intention, and practical achievements. For example, some index systems include outcome-oriented indicators such as students' patent applications and the number of entrepreneurial projects, as well as process-oriented indicators such as course participation and team collaboration [3]. Domestic studies mostly combine the actual situation of Chinese universities to construct multi-dimensional evaluation index systems. For instance, some scholars have proposed a three-dimensional index system covering "knowledge, ability, and quality" [10]; other studies have added governance element indicators such as resource allocation and policy support [11].

The problems of existing index systems are: first, most indicators are statically designed, which are difficult to adapt to the dynamic development of students' innovation and entrepreneurship capabilities; second, data acquisition is difficult, and some indicators (such as innovative thinking and entrepreneurial intention) are difficult to quantify; third, there is a lack of integrated application of multi-source data, and the comprehensiveness and accuracy of indicators need to be improved.

2.4. Research Commentary

Overall, existing research provides a theoretical basis and reference for this paper, but there are still obvious research gaps: first, the integration of educational governance theory and data science is insufficient, and there is a lack of a data-driven governance framework for innovation and entrepreneurship education; second, the evaluation index system lacks dynamics and multi-source data support; third, the practical verification and promotion of research results are insufficient. Addressing the above gaps, this study integrates multi-source student behavior data to construct a dynamic evaluation model and a closed-loop governance framework, aiming to fill the deficiencies of existing research and promote the theoretical innovation and practical upgrading of the governance of innovation and entrepreneurship education.

3. Integration of Multi-Source Student Behavior Data and Construction of a Dynamic Evaluation Index System

3.1. Sources and Characteristics of Multi-Source Student Behavior Data

The multi-source student behavior data integrated in this study are mainly derived from three core systems of higher education institutions. The sources and characteristics of each data type are as follows:

(1) Academic Affairs Management System: Primarily includes data such as students' enrollment records of innovation and entrepreneurship courses, course grades, professional backgrounds, and credit completion status. This type of data is highly structured and accurate, reflecting students' foundational knowledge of innovation and entrepreneurship and their learning attitudes.

(2) Student Affairs System: Covers data such as students' reward and punishment records, club participation (especially innovation and entrepreneurship-related clubs), volunteer services, and social practice experiences. This data can reflect students' comprehensive quality, teamwork capabilities, and sense of social participation, serving as an important basis for

evaluating students' innovative literacy.

(3) Innovation and Entrepreneurship Practice Platform: Includes data such as students' participation records in innovation and entrepreneurship competitions (e.g., the "Internet Plus" College Student Innovation and Entrepreneurship Competition), information on entrepreneurial projects settled in incubation bases, project financing status, patent application and authorization records, and registration information of start-up enterprises. This data directly reflects students' practical innovation and entrepreneurship capabilities and the level of achievement transformation, acting as the core data for evaluating the effectiveness of innovation and entrepreneurship education.

In addition, supplementary data are obtained from questionnaires and in-depth interviews, mainly including qualitative data such as students' entrepreneurial intentions, satisfaction with mentor guidance, and resource needs. These data are used to enrich evaluation dimensions and enhance the comprehensiveness of the model.

3.2. Construction of the Dynamic Evaluation Index System

(1) Construction Principles: The evaluation index system is constructed following the principles of comprehensiveness, dynamics, operability, and scientificity. The comprehensiveness principle requires indicators to cover the entire process of students' innovation and entrepreneurship capacity development; the dynamics principle emphasizes that indicators can reflect real-time changes in students' abilities; the operability principle demands that indicator data are easy to collect and quantify; the scientificity principle requires that indicator design aligns with the laws of innovation and entrepreneurship education and evaluation theories.

(2) Framework of the Index System: Based on three core dimensions-"Innovative Literacy-Practical Participation-Project Transformation"-a multi-level dynamic evaluation index system is constructed, as detailed below:

Innovative Literacy Dimension: Reflects students' innovative thinking, knowledge reserves, and comprehensive quality, including 3 first-level indicators: Course Learning Effectiveness (second-level indicators: innovation and entrepreneurship course grades, number of courses enrolled, learning duration), Innovative Thinking Performance (second-level indicators: number of patent applications, number of papers published, number of creative proposals), and Comprehensive Quality (second-level indicators: club participation, reward and punishment status, volunteer service duration).

Practical Participation Dimension: Reflects students' enthusiasm and abilities in participating in innovation and entrepreneurship practices, including 3 first-level indicators: Competition Participation (second-level indicators: number of competition participations, competition level, award status), Project Practice (second-level indicators: number of settled projects, project roles, practice duration), and Team Collaboration (second-level indicators: number of team participations, role contribution, team evaluation).

Project Transformation Dimension: Reflects the commercial and social value of students' innovation and entrepreneurship practice achievements, including 2 first-level indicators: Achievement Transformation (second-level indicators: number of authorized patents, technical transfer amount, number of registered start-up enterprises) and Project Benefits (second-level indicators: project financing amount, number of jobs created, revenue scale).

(3) Determination of Indicator Weights: A combined weighting method integrating the Analytic Hierarchy Process (AHP) and the Entropy Weight Method is adopted to determine indicator weights. First, subjective weights are determined using AHP through expert scoring (inviting innovation and entrepreneurship education managers, mentors, and industry experts from universities); second, objective weights are calculated using the Entropy Weight Method based on preprocessed multi-source data; finally, comprehensive weights are derived by combining subjective and objective weights to ensure the scientificity and rationality of the indicator weights.

4. Construction of an Innovation and Entrepreneurship Education Effectiveness Prediction Model Based on Machine Learning

4.1. Model Construction

(1) Data Partitioning: The preprocessed dataset is divided into a training set (for model training), a validation set (for hyperparameter optimization), and a test set (for model performance evaluation) in a ratio of 7:2:1. To avoid data bias, stratified sampling is adopted to ensure the distribution consistency of each dataset.

(2) Hyperparameter Optimization: For different candidate algorithms, a combined method of Grid Search and Cross Validation is used to optimize hyperparameters. For example, for the Random Forest algorithm, the optimized hyperparameters include the number of decision trees, maximum depth, and minimum number of samples required to split a node; for the Neural Network algorithm, the optimized hyperparameters include the number of hidden layers, number of neurons, learning rate, and number of iterations.

(3) Model Training and Validation: Each optimized algorithm model is trained using the training set, and model parameters are adjusted in real time through the validation set. Mean Squared Error (MSE), Mean Absolute Error (MAE), and Coefficient of Determination (R^2) are used as model performance evaluation indicators. The prediction accuracy of each model is compared to select the optimal model.

(4) Feature Importance Analysis: Based on the optimal model, feature importance analysis (e.g., Gini coefficient for Random Forest, gain value for XGBoost) is conducted to identify key features that significantly affect the effectiveness of innovation and entrepreneurship education (such as innovation and entrepreneurship course grades, competition award status, and project incubation cycle), clarifying the key directions for governance intervention.

4.2. Model Optimization and Validation Results

(1) Model Optimization: Through hyperparameter optimization and cross-validation, the prediction accuracy of all candidate models is improved. Comparative results show that the XGBoost model has the best comprehensive performance, with the smallest MSE and the largest R^2 (R^2=0.85), which can accurately predict students' innovation and entrepreneurship education effectiveness. Therefore, this study ultimately adopts the XGBoost algorithm to construct

the prediction model.

(2) Model Validation: The XGBoost model is validated on the test set. The results show that the model's MSE is 0.032, MAE is 0.125, and R^2 is 0.83, indicating that the model has good prediction accuracy and generalization ability. Meanwhile, the feature importance analysis results show that competition award status, innovation and entrepreneurship course grades, project incubation cycle, and number of mentor guidance sessions are the four key factors affecting the effectiveness of innovation and entrepreneurship education, with a cumulative contribution rate of 68%, providing a clear direction for subsequent governance decisions.

5. Design of a Data-Driven Closed-Loop Governance Framework for Innovation and Entrepreneurship Education in Higher Education Institutions

5.1. Objectives and Principles of Framework Construction

(1) Construction Objectives: The core objective of this framework is to achieve "data-empowered precise governance of innovation and entrepreneurship education." By integrating multi-source data, dynamic evaluation, and intelligent prediction, it optimizes resource allocation and intervention strategies, addresses issues such as resource imbalance and outdated evaluation, and promotes the continuous improvement of the quality of innovation and entrepreneurship education.

(2) Construction Principles: First, the data-driven principle-taking multi-source student behavior data as the core element to ensure the scientificity and accuracy of decision-making; second, the closed-loop optimization principle-forming a continuous improvement mechanism of "collection-analysis-decision-feedback-optimization"; third, the collaborative governance principle-integrating resources from multiple university departments including academic affairs, student affairs, and innovation and entrepreneurship centers to achieve collaborative linkage [2]; fourth, the personalized service principle-providing precise resource supply and mentor empowerment based on individual student differences.

5.2. Structure of the Closed-Loop Governance Framework

The constructed "data collection-model analysis-decision optimization-effect feedback" closed-loop governance framework consists of four core modules. The functions and collaborative relationships of each module are as follows:

(1) Data Collection Module: As the foundation of the framework, it is responsible for integrating multi-source student behavior data from the academic affairs system, student affairs system, and innovation and entrepreneurship practice platform. Through preprocessing such as data cleaning, integration, and transformation, a standardized dataset is formed. Meanwhile, a data privacy protection mechanism is established to ensure the compliance of data collection and use.

(2) Model Analysis Module: Based on the dynamic evaluation index system and the XGBoost prediction model, it analyzes the standardized data and outputs evaluation results of students' innovation and entrepreneurship capabilities, effectiveness prediction values, and identification results of key influencing factors. This module provides core data support for decision optimization, enabling dynamic tracking and precise judgment of the development of students' innovation and entrepreneurship capabilities.

(3) Decision Optimization Module: Led by the university's innovation and entrepreneurship education governance leading group, it collaborates with departments such as academic affairs, student affairs, and innovation and entrepreneurship centers to formulate personalized governance strategies based on model analysis results. Specifically, it includes: optimizing the curriculum system for students' knowledge gaps (e.g., pushing personalized course packages); matching high-quality practical resources based on student needs (e.g., competition registration recommendations, project incubation venue allocation); and allocating mentor resources according to students' ability characteristics (e.g., one-on-one guidance, industry mentor matching).

(4) Effect Feedback Module: It tracks student behavior data after the implementation of governance strategies, re-inputs them into the model analysis module for evaluation, and compares changes in the effectiveness of innovation and entrepreneurship education before and after the implementation of the strategies. If the effectiveness fails to meet expectations, the governance strategies are adjusted; if the effectiveness is significant, the strategies are solidified and promoted. Through continuous feedback and optimization, a closed-loop governance mechanism is formed to continuously improve the level of innovation and entrepreneurship education governance.

6. Conclusion and Policy Recommendations

6.1. Research Conclusion

Based on the core logic of "data-empowered decision-making," this study conducts research on data-driven governance of innovation and entrepreneurship education in higher education institutions. The main conclusions are as follows:

(1) Integrating multi-source student behavior data from academic affairs, student affairs, and innovation and entrepreneurship practice platforms can comprehensively reflect the development of students' innovation and entrepreneurship capabilities, providing a data foundation for precise governance.

(2) The constructed dynamic evaluation index system of "Innovative Literacy-Practical Participation-Project Transformation" features comprehensiveness and dynamics, effectively making up for the deficiencies of traditional static evaluation.

(3) The innovation and entrepreneurship education effectiveness prediction model based on the XGBoost algorithm has high prediction accuracy and strong generalization ability. It can accurately identify key factors affecting innovation and entrepreneurship effectiveness, providing a basis for formulating intervention strategies.

(4) The closed-loop governance framework of "data collection-model analysis-decision optimization-effect feedback" can effectively address issues such as unbalanced resource allocation and outdated evaluation in university innovation and entrepreneurship education, improve

governance efficiency and quality, and has good universality.

6.2. Policy Recommendations

(1) Strengthen top-level design and promote the construction of university data sharing platforms: Introduce relevant national policies to guide universities to break data silos and build cross-departmental data sharing platforms for innovation and entrepreneurship education. Meanwhile, formulate standards and norms for data collection, use, and privacy protection to ensure data security and compliance.

(2) Increase technical and financial investment to enhance universities' data application capabilities: Encourage universities to introduce technologies such as big data and artificial intelligence, and strengthen the construction of data mining and analysis capabilities; establish special funds to support the construction of innovation and entrepreneurship education data platforms, model development, and personnel training, so as to improve the digital literacy of governance teams.

(3) Promote the data-driven governance model and improve differentiated support policies: Summarize the practical experience of this study, and guide universities of different types across the country to apply the data-driven governance model through special training, case promotion, and other methods. Introduce differentiated support policies for local general universities and characteristic institutions to help them improve their data governance capabilities.

(4) Establish a multi-department collaborative governance mechanism and strengthen effect evaluation and feedback: Promote universities to establish a collaborative governance mechanism among academic affairs, student affairs, and innovation and entrepreneurship centers, clarify the division of responsibilities, and realize resource integration and linkage. Establish a regular effect evaluation and feedback mechanism to continuously optimize governance strategies and promote the continuous improvement of the quality of innovation and entrepreneurship education.

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