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Research on the Cultivation of Top-notch Innovative Talents in Universities from the Perspective of the Integration of Education, Science and Technology, and Talent

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Abstract: To better clarify the impact of the integration of education, science and technology, and talent on the cultivation of top-notch innovative talents in universities, this study adopts the fuzzy-set Qualitative Comparative Analysis (fsQCA) method. Using 23 universities in China as the research sample, the findings reveal that: (1) none of the three individual factors, education, science and technology, or talent can independently constitute either a necessary or sufficient condition for high-quality cultivation of top-notch innovative talents; (2) the sufficient condition for achieving high-quality cultivation lies in specific configurations of multiple condition variables; (3) five configurations were identified, from which three distinct paths toward achieving high-quality cultivation were derived. Accordingly, different universities can, based on their own resource endowments and local contexts, select appropriate cultivation paths to effectively enhance the quality of top-notch innovative talent training.

Keywords: Top-notch innovative talents; Cultivation quality; Education–science–talent integration; Qualitative comparative analysis; Configuration

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1. Problem statement

Several problems remain in the cultivation of top-notch innovative talents. First, the adaptability of cultivation models to university-specific contexts is limited, with a notable trend of homogenization. Huang Luhan's analysis revealed both imitative and normative convergence in cultivation practices [1]. Under policy and evaluation pressures, universities often replicate existing models rather than exploring innovative approaches tailored to their unique conditions. However, due to variations in institutional positioning and resource allocation, this imitation often fails to achieve the intended effect, leading to the paradox of "good methods applied to excellent students with limited success." Second, universities often emphasize foundational training

but lack sufficient focus on cultivating innovation capabilities. Tan Zhixiong and colleagues found that institutions emphasized comprehensive knowledge and solid disciplinary foundations through curriculum design and pedagogical strategies [2]. Third, insufficient resource support poses significant challenges. According to a survey by An Guoyong and colleagues, issues such as ambiguous standards, inadequate resources, limited curriculum development, underdeveloped faculty teams, and insufficient teaching resources negatively affect cultivation quality [3]. Since talent cultivation is influenced by universities' educational capacity, scientific development, and talent team support, disparities in resource security result in uneven development and prominent shortcomings across institutions.

Based on this, the present study focuses on three key factors influencing the cultivation of top-notch innovative talents in universities: educational resources, scientific development and talent quality. By analyzing the intrinsic relationships between education, science, talent, and the quality of talent cultivation in universities, this study develops a conditional configuration model, thereby providing theoretical support for different types of universities to explore characteristic pathways for cultivating top-notch innovative talents.

2. Research design

2.1. Research method

In the 1980s, American sociologist Charles C. Ragin proposed the Qualitative Comparative Analysis (QCA) method. QCA enables the in-depth analysis of multiple cases, capturing the complex structural relationships between conditions and outcomes. By integrating qualitative and quantitative approaches, QCA identifies how outcomes are influenced under different combinations of conditions [4,5]. Depending on the type of variables, QCA is categorized into three types: crisp-set QCA (csQCA), multi-value QCA (mvQCA), and fuzzy-set QCA (fsQCA), csQCA and mvQCA are suitable for analyzing dichotomous or multi-value categorical variables, i.e., problems addressed through crisp sets and truth tables. In contrast, fsQCA converts fuzzy-set data into truth tables, enabling the analysis of degrees of variation and partial membership. It combines the strengths of qualitative and quantitative analysis [6]. Therefore, this study adopts fsQCA for the empirical analysis.

2.2. Data sources

The data for this study were drawn from multiple sources, including the 2022 departmental final accounts published by universities, the CUAA 2020 China First-Class University and Double First-Class Construction Evaluation Report, the iResearch 360-Degree University Panorama Data Monitoring Report (October 2023), and the China University Ranking (CNUR) 2022 Student Quality Report. Considering data completeness, 23 universities were ultimately selected as the research sample: Peking University, Tsinghua University, Beijing Institute of Technology, China Agricultural University, Beijing Normal University, Nankai University, Tianjin University, Jilin University, Fudan University, Tongji University, Shanghai Jiao Tong University, East China Normal University, Southeast University, Zhejiang University, University of Science and Technology of China, Shandong University, Ocean University of China, Wuhan University, South China University of Technology, Chongqing University, Sichuan University, Xi'an Jiaotong University, and Lanzhou University.

2.3. Variable design

2.3.1. Outcome variable

The ranking of Chinese universities in innovative talent cultivation quality, as reported in the CUAA 2020 China First-Class University and Double First-Class Construction Evaluation Report, was selected as the outcome

variable.

2.3.2. Condition variables

(1) Educational level

This dimension includes funding input, talent cultivation, discipline construction, and international exchange and cooperation. Funding input includes five indicators including curriculum and teaching materials, teaching projects, teaching achievement awards, teaching bases and program construction. Discipline construction includes national key disciplines, and those recognized by the Ministry of Education. International exchange and cooperation were measured by three indicators including Sino-foreign cooperative education institutions and programs, visits from foreign political leaders and the number of honorary doctoral degrees awarded.

(2) Scientific development

This dimension includes scientific research and social services. Scientific research is measured by three aspects: research bases, research projects, and research achievements. Social services include three aspects: service bases, patents/standards/popular science outputs, and the monetary value of technology transfer.

(3) Talent team

This dimension includes student quality and faculty strength. Student quality is measured using two indicators: science or engineering students and liberal arts students. Faculty strength is measured across four aspects, including role models in moral education, leading top-level talents, outstanding mid-career talents, and promising young talents.

2.3.3. Variable calibration

In accordance with the characteristics of the case study and the actual data distribution, the direct calibration method was employed. Following the calibration criteria of Lu Yu et al. and Zhang Lingang et al., the upper quartile, median, and lower quartile were selected as the three anchor points, corresponding to full membership, the crossover point, and full non-membership, respectively, for data calibration [7,8].

3. Empirical results analysis

3.1. Necessity analysis

Using the fsQCA software, we conducted a necessity analysis of the conditional variables to determine whether a single condition constitutes a necessary prerequisite for the outcome. The two key indicators in necessity analysis are consistency and coverage, where a consistency threshold higher than 0.9 is typically required, along with an adequate level of coverage [9]. The consistency values of the eight conditional variables for both high and non-high training quality of top-notch innovative talents are all below 0.9. This indicates that the cultivation quality of top-notch innovative talents does not rely on any single condition.

3.2. Configuration analysis

Using fsQCA 3.0 software, the truth table was analyzed to obtain the “complex solution,” “parsimonious solution,” and “intermediate solution.” Core conditions are those that appear in both the parsimonious and intermediate solutions, while peripheral conditions are those present only in the intermediate solution [5]. As shown in **Table 1**, the consistency values of these five configurations are all exceeding the theoretical threshold

of 0.8. This indicates that each configuration meets the consistency requirement across all cases in this study. The overall consistency of the model is 0.959036, again surpassing the threshold of 0.8, further confirming that these five configurations are sufficient conditions for high-quality cultivation. In addition, the model solution coverage is 0.70318, suggesting that the conditional variables explain a substantial proportion of the reasons behind high-quality cultivation of top-notch innovative talents.

Table 1. Configuration results of high-quality training of top innovative talents in universities

Condition Variable	Configuration 1a	Configuration 1b	Configuration 2a	Configuration 2b	Configuration 3
Funding Input	●	×	●	●	×
Talent Cultivation		×		●	●
Discipline Construction	●	×	●	×	●
International Exchange & Cooperation	●	●	×	●	×
Scientific Research	●	●	×	×	●
Social Services	●	●	×	×	●
Quality of Student Sources	●	●	●	●	×
Faculty Team	●		●	●	●
Raw Coverage	0.532	0.101	0.087	0.116	0.103
Unique Coverage	0.423	0.049	0.047	0.051	0.016
Consistency	0.989	0.974	0.873	0.949	0.867
Overall Coverage			0.703		
Overall Consistency			0.959		

Note: (1) A solid dot in the table indicates the presence of a conditional variable. Among them, "●" denotes a core condition, while "●" denotes a peripheral condition; (2) The symbol "×" indicates the absence of a conditional variable; (3) A blank space represents a fuzzy condition, meaning that the condition may either be present or absent.

3.2.1. Configuration 1a

This configuration takes scientific research, social services, and student quality as the core conditions, and funding input, discipline construction, international cooperation, and faculty strength as the peripheral conditions. Approximately 98.9% of the cases with high-quality cultivation of top-notch innovative talents can be explained by this configuration, and about 42.3% of the cases can only be explained by this path. Representative universities include Peking University, Tsinghua University, Shanghai Jiao Tong University, Zhejiang University, and Fudan University.

3.2.2. Configuration 1b

This configuration takes scientific research, social services, and student quality as the core conditions, and international cooperation as the peripheral condition. Approximately 97.4% of the cases with high-quality cultivation of top-notch innovative talents were explained by this configuration, and about 4.9% of the cases can only be explained by this path. The representative university is Nankai University.

3.2.3. Configuration 2a

This configuration takes student quality as the core condition, and funding input, discipline construction, and

faculty strength as the peripheral conditions. Approximately 86.8% of the cases with high-quality cultivation of top-notch innovative talents can be explained by this configuration, and about 4.7% of the cases can only be explained by this path. The representative university is the University of Science and Technology of China (USTC).

3.2.4. Configuration 2b

This configuration takes student quality as the core condition, and funding input, talent cultivation, international cooperation, and faculty strength as the peripheral conditions. Approximately 94.9% of the cases with high-quality cultivation of top-notch innovative talents were explained by this configuration, and about 5.1% of the cases can only be explained by this path. The representative university is Sichuan University.

3.2.5. Configuration 3

This configuration takes scientific research and social services as the core conditions, and talent cultivation, discipline construction, and faculty strength as the peripheral conditions. Approximately 86.7% of the cases with high-quality cultivation of top-notch innovative talents were explained by this configuration, and about 1.6% of the cases were explained by this path. The representative university is Tongji University.

3.3. Reduction effects and substitution relationships of conditional variables

3.3.1. Reduction effects of funding input, discipline construction and faculty strength

By comparing Configuration 1a and Configuration 1b, both paths include four conditional variables including international cooperation, academic research, social services, and student quality. On this basis, Configuration 1a additionally passes through three conditional variables: funding input, discipline construction, and faculty strength. This indicates that when universities already possess strong international cooperation, academic research, social services, and student quality, the effects of funding input, discipline construction, and faculty strength on the cultivation of top-notch innovative talents can be reduced.

3.3.2. Substitution relationship between discipline construction and talent cultivation, international cooperation

By comparing Configuration 2a and Configuration 2b, it can be seen from **Figure 2** that both paths include three conditional variables: funding input, student quality, and faculty strength. On this basis, Configuration 2a additionally passes through the conditional variable discipline construction, while Configuration 2b passes through talent cultivation and international cooperation. This indicates that when universities possess strong funding input, student quality, and faculty strength, discipline construction and talent cultivation with international cooperation can act as substitutes.

3.3.3. Substitution relationship between international cooperation, student quality and talent cultivation, discipline construction, faculty strength

By comparing Configuration 1b and Configuration 3, it can be seen that both paths include two conditional variables, scientific research and social services. On this basis, Configuration 1b additionally passes through international cooperation and student quality, while Configuration 3 additionally passes through talent cultivation, discipline construction, and faculty strength. This indicates that when universities possess strong scientific research and social services, international cooperation and student quality can act as substitutes for talent cultivation, discipline construction, and faculty strength.

3.4. Robustness test

In this study, robustness tests were conducted by adjusting the analysis thresholds and randomly deleting cases. The resulting configuration paths remained consistent with the original ones, and the consistency and coverage values indicated that the configuration results are robust.

4. Conclusions

Using the fsQCA method and taking 23 universities as cases, this study explored the impact of education–science–talent integration on the quality of cultivating top-notch innovative talents. It revealed the essential influences of educational level, scientific development, and faculty strength, as well as their reduction and substitution effects. The conclusions are as follows.

Overall, the cultivation of top-notch innovative talents in universities is influenced by multiple factors. None of the three dimensions, educational level, scientific development, or talent team, can independently constitute either a necessary or sufficient condition for high-quality cultivation. When all conditional variables occur simultaneously, up to 98.9% of the high-quality cases can be explained, with 42.3% of the cases uniquely explained by this path. This initially indicates that the integration of education, science, and talent is conducive to the cultivation of top-notch innovative talents in universities.

From the perspective of the five configurations, the sufficient condition for high-quality cultivation lies in combinations of multiple conditional variables. Different configurations of multiple factors present reduction and substitution effects. This initially suggests that universities with varying levels of education, science, and talent integration can choose differentiated cultivation paths for top-notch innovative talents. Moreover, among the five configurations, student quality appeared as a core condition in four configurations, while faculty strength appeared as a peripheral condition in four configurations, making them the two most frequently occurring factors.

From the reduction and substitution relationships among the five configurations and conditional variables, the following conclusions can be drawn, including high-quality scientific research, social services, student quality, and international cooperation, supplemented by high-quality funding input, discipline construction, and faculty strength, are conducive to improving the quality of cultivating top-notch innovative talents. Besides that, high-quality student quality, funding input, and faculty strength, supplemented by high-quality discipline construction or high-quality talent cultivation and international cooperation, are also conducive to improving cultivation quality. Other than that, high-quality scientific research and social services, supplemented by high-quality talent cultivation, discipline construction, and faculty strength, are beneficial to enhancing the quality of cultivating top-notch innovative talents.

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Disclosure statement

The author declares no conflict of interest.

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