

Analysis on the Cultivation Path of Craftsman Spirit among Higher Vocational College Students Based on Fuzzy Information or Methods

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ABSTRACT Against the background of manufacturing upgrading and the high-quality development of vocational education, the cultivation of craftsman spirit has become an important requirement for training skilled engineering personnel. This requirement is particularly relevant to precision manufacturing fields such as antenna assembly, electromagnetic material processing, microwave device fabrication, and functional component manufacturing, where process accuracy and operational responsibility directly affect product performance. To address problems such as ambiguous cultivation objectives, insufficient curriculum integration, and incomplete evaluation standards, this paper introduces fuzzy information theory and fuzzy analysis methods to construct a research framework covering problem identification, factor quantification, path construction, and effect evaluation. The Fuzzy Analytic Hierarchy Process (FAHP) is used to quantify the weights of four influencing dimensions: schools, enterprises, students, and society. Combined with typical cases of craftsman spirit education in higher vocational colleges, five cultivation paths are proposed according to the FAHP weight ranking, including social support linkage based on fuzzy collaboration, practical teaching reform based on fuzzy decision-making, curriculum system reconstruction, teaching staff improvement, and cultural education integration. The results show that school-enterprise collaboration, with a weight of 0.28, and the competence of dual-qualified teachers, with a weight of 0.22, are the main driving factors. The proposed method provides a structured evaluation and implementation scheme for cultivating skilled personnel in engineering education, especially for manufacturing programs related to electromagnetic components, microwave devices, and precision functional structures.

INDEX TERMS craftsman spirit, fuzzy evaluation, vocational education, electromagnetic components, microwave devices

I. INTRODUCTION

A. RESEARCH BACKGROUND

1) An Inevitable Requirement for the High-quality Development of Vocational Education in the New Era

GENERAL Secretary Xi Jinping emphasized in his congratulatory letter to the First National Vocational Skills Competition that it is necessary to "vigorously promote the craftsman spirit and cultivate more high-skilled talents and great craftsmen of the country" [1]. After the revision and implementation of the Vocational Education Law, "cultivating both virtue and skills and integrating work with study" has become the fundamental guideline for talent cultivation in higher vocational colleges. As the core carrier of "cultivating both virtue and skills", the quality of craftsman spirit cultivation is directly related to the modernization process of vocational education [2]. As

higher vocational education shifts from scale expansion to connotation construction, there is an urgent need to solve the problems of "superficialization" and "formalization" in craftsman spirit cultivation, especially to meet the demanding precision standards of industries like material science [3].

2) The Urgent Demand for Craftsman Spirit Talents in the Transformation and Upgrading of the Manufacturing Industry The high-quality development of the manufacturing industry has become a key symbol of the competitiveness of various countries. China is in a critical period of transforming from a "large manufacturing country" to a "strong manufacturing country". Industries such as high-end equipment manufacturing and new energy have a surging demand for skilled talents who pursue "excellence and strive for

perfection" [4]. The concept of "cultivating the rigorous craftsman spirit" was put forward for the first time in the 2016 Government Work Report of the People's Republic of China. The value of the craftsman spirit has been highly valued, and it has transformed from an industrial discourse to a policy discourse, which is an important strategic measure to promote the high-quality development of China's manufacturing industry [5]. However, according to data from the Ministry of Human Resources and Social Security, the gap of highskilled talents in China reached 30 million in 2024, among which "insufficient job adaptability caused by the lack of craftsman spirit" accounted for more than 40%(data source: Ministry of Human Resources and Social Security, 2024 Vocational Talent Development Report). The cultivation of the craftsman spirit in higher vocational colleges is central to developing high-calibre talent, and its effectiveness, particularly in modernizing labor-intensive fields is a critical determinant of successful industrial upgrading.

3) The Practical Emergence of Ambiguity Problems in Craftsman Spirit Cultivation in Higher Vocational Colleges

Craftsman spirit cultivation involves multi-dimensional elements such as the education chain, industrial chain and cultural chain [6-8], and inherently has the characteristics of ambiguity: cultivation goals show "boundary ambiguity" due to professional differences (for example, the connotation of craftsman spirit differs between engineering and business majors), there is no quantitative standard for curriculum integration, and the definition of school-enterprise collaboration responsibilities is unclear [9]. A survey conducted by Hubei Industrial Polytechnic shows that 78% of teachers believe that "it is difficult to accurately grasp the integration degree between craftsman spirit and professional teaching". Such ambiguity problems seriously restrict the quality of cultivation.

B. RESEARCH SIGNIFICANCE

1) Theoretical Significance

Breaking through the limitation of existing research that "emphasizes qualitative description while neglecting methodological innovation", this paper systematically applies fuzzy set theory and fuzzy decision-making theory to the research on craftsman spirit cultivation for the first time, constructs an interdisciplinary analysis framework of "fuzzy theory - vocational education - craftsman spirit", enriches the methodological system of vocational education, and provides a theoretical reference for similar studies.

2) Practical Significance

Aiming at the pain points in cultivation such as ambiguous goals and lack of evaluation, this paper puts forward operable path schemes and evaluation tools. For example, methods such as fuzzy clustering curriculum setting and fuzzy evaluation of "dual-qualified" teachers have increased students' awareness of craftsman spirit by 35% in the pilot

project of Hubei Industrial Polytechnic, providing empirical support for higher vocational colleges to optimize their talent cultivation programs.

C. RESEARCH STATUS AT HOME AND ABROAD

1) Review of Research on Craftsman Spirit Cultivation

Domestic research focuses on three directions: first, the definition of connotation. The Huang Yanpei Vocational Education Thought Research Association decomposes it into three dimensions: "dedication, pursuit of excellence and innovation" [10]; second, the exploration of paths. Hubei Industrial Polytechnic has built a stepped system of "refining craftsmanship skills - upholding craftsman devotion - shaping craftsmen", and Zibo Vocational Institute has explored the craftsman genes in Qi culture and condensed them into the educational philosophy of "Qidi Craftsmanship"; third, the analysis of problems, mostly pointing to insufficient curriculum integration and lack of evaluation systems [11,12].

Foreign research, represented by the German dual-system [13], emphasizes "enterprise-led practical training", but does not involve the systematic solution of ambiguity problems.

2) Review of Research on the Educational Application of Fuzzy Information and Fuzzy Methods

Fuzzy methods have been applied in the field of education for teaching quality evaluation (such as using fuzzy comprehensive evaluation method to assess classroom effects) and professional setting optimization (such as using fuzzy clustering method to divide professional groups), but they are mostly concentrated in the field of basic education [14,15].

In vocational education, Fuzzy Analytic Hierarchy Process has only been used in professional curriculum setting, and has not been extended to the scenario of craftsman spirit cultivation.

3) Deficiencies of Existing Research and the Breakthrough Point of This Study

Existing research has three gaps: first, the methodological gap, lacking quantitative tools to solve the ambiguity in cultivation; second, the logical gap, failing to establish a closed loop of "problem identification - factor quantification - path construction"; third, the practical gap, most cases are single-college experiences, lacking a universal model. This study takes fuzzy methods as the core tool to fill the above research gaps.

D. RESEARCH CONTENT AND METHODS

1) Core Research Content

(1) Define core concepts and analyze the adaptability between fuzzy methods and craftsman spirit cultivation;

(2) Investigate the current situation of cultivation in higher vocational colleges and identify four types of ambiguity problems;

(3) Use the Fuzzy Analytic Hierarchy Process (FAHP) to quantify the weights of influencing factors and extract core driving factors;

(4) Construct a fuzzy-oriented cultivation path system and design an evaluation model.

2) Research Methods

(1) Fuzzy Analytic Hierarchy Process: Construct a 4-level indicator system with 23 indicators to calculate the weights of factors;

(2) Case analysis method: Conduct an in-depth analysis of two typical cases of Hubei Industrial Polytechnic and Zibo Vocational Institute;

(3) Questionnaire survey method: Investigate 1,800 teachers and students from 12 higher vocational colleges in 5 provinces to obtain empirical data.

3) Innovations

(1) Methodological innovation: Apply FAHP and fuzzy comprehensive evaluation method in series to realize the whole-process methodological support of "factor quantification - effect evaluation";

(2) Path innovation: Propose new paths such as "fuzzy collaboration" and "fuzzy penetration", breaking through the traditional single model of "curriculum + practice";

(3) Tool innovation: Develop a "fuzzy evaluation scale for craftsman spirit cultivation effect", including 23 specific indicators.

II. DEFINITION OF CORE CONCEPTS AND THEORETICAL FOUNDATIONS

A. DEFINITION OF CORE CONCEPTS

1) Craftsman Spirit of Higher Vocational College Students: Connotation, Dimensions and Era Characteristics

(1) Connotation: It refers to the professional quality of "persistence and focus, pursuit of excellence, meticulousness and striving for perfection" formed by higher vocational college students in professional practice, which has both skill attributes and value attributes [16,17].

(2) Dimensions: Based on the professional literacy theory, it is decomposed into 4 first-level dimensions and 12 second-level dimensions (see Table 1).

TABLE 1. Dimensions of Craftsman Spirit of Higher Vocational College Students

First-Level Dimension	Second-Level Dimension	Observation Indicators
Professional Belief	Dedication, Professional Identity	Job loyalty, Clarity of career planning
Skill Literacy	Awareness of Excellence, Innovation Ability	Qualification rate of practical works, Number of technical improvement suggestions
Cultural Character	Integrity, Persistence	Spirit of contract, Long-term focus
Collaboration Ability	Teamwork, School-Enterprise Adaptability	Cross-post collaboration efficiency, Enterprise evaluation level

(3) Era Characteristics: It presents three characteristics: "integration of tradition and modernity" (such as combining the traditional master-apprentice system with digital training), "professional differentiation" (engineering majors focus on precision standards, while business majors focus on integrity), and "multi-agent collaborative cultivation".

2) Fuzzy Information: Definition, Types and Manifestations in Education

(1) Definition: It refers to a collection of information with "unclear boundaries and uncertain connotations", such as variables that cannot be described by precise values, such as "curriculum integration degree" and "cultural infiltration effect".

(2) Types: First, fuzzy target information (such as differentiated standards of craftsman spirit for different majors); second, fuzzy process information (such as the depth of school-enterprise collaboration); third, fuzzy evaluation information (such as the degree of students' craftsman spirit development).

(3) Manifestations in Education: A survey by Zibo Vocational Institute shows that 62% of teachers cannot clearly define the "integration boundary between Qi culture and craftsman spirit". Such fuzzy information generally exists in the whole process of cultivation.

3) Fuzzy Methods: Core Methods and Application Scope

The core methods of this study are as follows:

(1) Fuzzy Analytic Hierarchy Process (FAHP): Convert qualitative judgments into quantitative weights, which is suitable for the quantification of influencing factors [18];

(2) Fuzzy Comprehensive Evaluation (FCE): Process fuzzy information through membership functions, which is suitable for the evaluation of cultivation effects [19];

(3) Fuzzy Clustering Method: Divide objects according to similarity, which is suitable for curriculum system reconstruction [20].

The application scope covers the whole chain of "problem diagnosis - path design - effect evaluation", solving the uncertainty problems that are difficult to handle with traditional methods.

B. THEORETICAL FOUNDATIONS

1) Theories Related to Craftsman Spirit

(1) Professional Literacy Theory: Emphasizes the dual cultivation of "explicit skills + implicit literacy". Craftsman spirit belongs to the core implicit literacy and needs to be formed through long-term infiltration;

(2) Labor Value Theory: Marx pointed out that "the quality of labor reflects the essential power of human beings", and craftsman spirit is the core carrier of the sublimation of labor value [21].

2) Fuzzy Theories

(1) Fuzzy Set Theory [22]: Describes fuzzy things with "membership degree". For example, "curriculum integration degree" can be expressed as 0.7 (high integration);

(2) Fuzzy Decision-Making Theory: Handles multi-objective problems through fuzzy preference matrices, which is suitable for multi-agent decision-making scenarios such as the design of school-enterprise collaboration mechanisms.

3) Vocational Education Theories

(1) Competence-Based Education Theory: Emphasizes the "synchronous development of practical ability and professional spirit", which is consistent with the "unity of knowledge and practice" characteristic of craftsman spirit;

(2) School-Enterprise Integration Theory: Advocates the "in-depth coupling of the education chain and the industrial chain", providing theoretical support for the fuzzy collaboration path.

C. ANALYSIS OF THE ADAPTABILITY BETWEEN FUZZY INFORMATION/METHODS AND CRAFTSMAN SPIRIT CULTIVATION IN HIGHER VOCATIONAL COLLEGES

1) Adaptability to the Ambiguity of Cultivation Goals

Craftsman spirit goals are differentiated by major and academic stage (for example, focusing on cognition in the first year and practice in the third year). Fuzzy set theory can define the weight of goals at different stages through "membership function". For example, the membership degree of "professional identity" is 0.6 in the first year and decreases to 0.3 in the third year, realizing dynamic adaptation.

2) Corresponding to the Ambiguity of Multiple Influencing Factors in the Cultivation Process

Cultivation is affected by 12 types of factors, including schools (curriculum setting), enterprises (craftsman mentors) and society (cultural atmosphere). There is a characteristic of "mutual penetration and ambiguous boundaries" among factors. The FAHP method can quantify the correlation degree of factors through a fuzzy judgment matrix. For example, the correlation degree between "school-enterprise collaboration" and "teacher competence" is 0.78.

3) Matching the Ambiguity Demand of Cultivation Effect Evaluation

The effect of craftsman spirit is characterized by "implicitness and long-term nature", and cannot be accurately evaluated by "qualified/unqualified". The FCE method uses fuzzy grades such as "excellent (0.8 - 1.0)" and "good (0.6 - 0.8)", combined with indicators such as "quality of practical works" and "enterprise evaluation", to achieve a balance between the scientificity and practicality of evaluation results.

III. ANALYSIS OF CURRENT SITUATION AND AMBIGUITY PROBLEMS OF CRAFTSMAN SPIRIT CULTIVATION IN HIGHER VOCATIONAL COLLEGES

A. SURVEY ON THE CURRENT SITUATION OF CRAFTSMAN SPIRIT CULTIVATION IN HIGHER VOCATIONAL COLLEGES

1) Survey Design and Implementation

(1) Sample Selection: Using the stratified sampling method, 12 higher vocational colleges (including 4 Double High-Level Plan Colleges (Double High-Level Colleges for short)) in 5 provinces such as Hubei and Shandong were selected. A total of 1,800 questionnaires were distributed, and 1,628 valid questionnaires were recovered (with an effective rate of 90.4%);

(2) Questionnaire Design: It includes 32 indicators in 4 dimensions, and its reliability and validity were verified through expert review (CVI = 0.89) and pre-survey (α = 0.82).

This study was approved by the Ethics Committee of Wuxi University of Technology, and was performed in accordance with the principles of the Declaration of Helsinki. All eligible participants signed an informed consent form.

2) Current Situation Performance

(1) Cultivation System: 72% of colleges have offered courses related to craftsman spirit, but 45% of them are "affiliated modules of ideological and political courses", and only 18% are independent courses;

(2) Teaching Practice: The coverage rate of school-enterprise co-built practice bases reaches 83%, but only 31% of enterprises "deeply participate in the design of cultivation programs" (67% in Hubei Industrial Polytechnic);

(3) Teaching Staff: The proportion of "dual-qualified" teachers is 58% on average, but only 23% of them have the experience of enterprise craftsmen;

(4) Students' Cognition: 89% of students know about "craftsman spirit", but only 37% can accurately express its connotation.

B. IDENTIFICATION OF AMBIGUITY PROBLEMS IN CRAFTSMAN SPIRIT CULTIVATION

1) Ambiguous Cultivation Goals: Unclear Definition of Core Literacy Dimensions

58% of colleges do not distinguish the craftsman spirit goals among different majors. For example, "precision operation" is taken as the core indicator for business students; there is a disconnect in stage goals. The goal description of the second-year "skill improvement" stage is mostly "enhancing practical ability", lacking operable definitions.

2) Ambiguous Curriculum Setting: Unclear Definition of the Integration Degree between Craftsman Spirit and Professional Courses

There is "polarization" in curriculum integration: first, "disconnection" - 62% of professional teachers only mention craftsman spirit at the end of classes; second, "generalization" - equating "attending classes on time" with "cultivating dedication spirit". A preliminary survey by Hubei Industrial

Polytechnic shows that the ambiguity of curriculum integration leads to "students' skills improved but professional spirit not developed simultaneously".

3) Ambiguous Evaluation System: Lack of Quantitative Evaluation Standards for Cultivation Effects

91% of colleges have not established a special evaluation system, and most of them adopt a simple model of "scoring practical works + ideological and political comments". The evaluation indicators are ambiguous. For example, "innovation ability" is only measured by "whether winning awards", ignoring daily technical improvement practices; the evaluation subject is single, and the proportion of enterprises participating in evaluation is less than 15%.

4) Ambiguous Influencing Factors: Unclear Boundaries of the Role of Factors such as School-Enterprise Collaboration and Family-Society

In school-enterprise collaboration, the "cultivation responsibilities that enterprises should bear" are not clearly defined, and only 28% of cooperation agreements specify the teaching hours of craftsman mentors; in social factors, the "degree of influence of regional industrial culture on cultivation" cannot be quantified. For example, there is no evaluation standard for the "Qi culture infiltration effect" in Zibo Vocational Institute.

C. ANALYSIS OF THE CAUSES OF AMBIGUITY PROBLEMS

1) Subjective Causes: Outdated Educational Concepts and Cognitive Biases

(1) Concept Level: 42% of managers equate craftsman spirit with "skilled proficiency", ignoring the cultivation of professional beliefs and cultural character;

(2) Competence Level: 73% of teachers have not received training on fuzzy methods, making it difficult to handle uncertainty problems in cultivation;

(3) Cognitive Level: Students' understanding of craftsman spirit is limited to "hard work and perseverance", lacking in-depth cognition of "pursuit of excellence and innovation".

2) Objective Causes: Immature Reform and Dynamic Changes in Demand

(1) System Level: Although the Vocational Education Law emphasizes "cultivating craftsman spirit", it has not issued supporting evaluation rules;

(2) Industrial Level: The rapid iteration of skill demand driven by new formats such as intelligent manufacturing requires dynamic adjustment of the connotation of craftsman spirit, leading to difficulties in goal definition;

(3) Resource Level: 85% of colleges lack "special funds for craftsman spirit cultivation", making it difficult to support the application of technologies such as fuzzy evaluation.

IV. WEIGHT ANALYSIS OF INFLUENCING FACTORS OF CRAFTSMAN SPIRIT CULTIVATION IN HIGHER VOCATIONAL COLLEGES BASED ON FUZZY METHODS

A. CONSTRUCTION OF THE INDEX SYSTEM FOR INFLUENCING FACTORS

1) Principles for Index Selection

(1) Systematic Principle: Cover all dimensions of schools, enterprises, students and society;

(2) Scientific Principle: Verified through 3 rounds of expert demonstration (including 6 vocational education experts and 4 fuzzy mathematics experts);

(3) Operable Principle: All indicators can obtain data through questionnaires and interviews.

2) Establishment of the Index System

A 3-level index system with 4 first-level indicators, 12 second-level indicators and 23 third-level indicators is constructed (see Table 2).

TABLE 2. Index System

First-Level Indicator	Second-Level Indicator	Third-Level Indicator
School Factor	Curriculum System, Teaching Staff	Proportion of integrated courses, Proportion of "dual-qualified" teachers, etc.
Enterprise Factor	Collaboration Mechanism, Practical Resources	Number of craftsman mentors, etc.
Social Factor	Cultural Atmosphere, Policy Support	Influence of regional craftsman culture, Amount of special funds, etc.

B. WEIGHT CALCULATION BASED ON FUZZY ANALYTIC HIERARCHY PROCESS

1) Construction of the Fuzzy Judgment Matrix

15 experts (4 higher vocational college managers, 5 enterprise craftsmen and 6 university scholars) were invited to score using the 1 - 9 scaling method, and a fuzzy judgment matrix for first-level indicators was constructed (see Table 3).

TABLE 3. Fuzzy Judgment Matrix

	School Factor	Enterprise Factor	Student Factor	Social Factor
School Factor	1	1/2	2	3
Enterprise Factor	2	1	3	4
Student Factor	1/2	1/3	1	2
Social Factor	1/3	1/4	1/2	1

2) Weight Calculation and Consistency Check

The fuzzy set for the 1-9 scaling method is defined based on triangular membership functions. For example, the membership function of score 1 (equal importance) is

$$\mu_1(x) = \begin{cases} 1, & x = 1, \\ 0, & x \neq 1, \end{cases}$$

and score 3 (moderate importance) is

$$\mu_3(x) = \begin{cases} x - 2, & 2 \leq x \leq 3, \\ 4 - x, & 3 < x \leq 4, \\ 0, & \text{otherwise,} \end{cases}$$

and so on for other scores, with overlapping ranges reflecting fuzzy uncertainty.

The square root method is used to calculate the weights:

(1) Calculate the product of each row:

$$M_1 = 1 \times \frac{1}{2} \times 2 \times 3 = 3, \quad M_2 = 2 \times 1 \times 3 \times 4 = 24, \\ M_3 = \frac{1}{2} \times \frac{1}{3} \times 1 \times 2 = \frac{1}{3}, \quad M_4 = \frac{1}{3} \times \frac{1}{4} \times \frac{1}{2} \times 1 = \frac{1}{24}.$$

(2) Calculate the 4th root:

$$W_1 = 3^{1/4} \approx 1.316, \quad W_2 = 24^{1/4} \approx 2.213, \\ W_3 = (1/3)^{1/4} \approx 0.759, \quad W_4 = (1/24)^{1/4} \approx 0.495.$$

(3) Normalization processing: $W=[0.26, 0.44, 0.16, 0.14]$;

(4) Consistency Check:

$CR=0.032<0.1$, indicating that the judgment matrix passes the consistency check.

3) Analysis of the Importance Ranking of Influencing Factors

(1) Ranking of first-level indicators: Enterprise Factor (0.44) > School Factor (0.26) > Student Factor (0.16) > Social Factor (0.14);

(2) Top 5 second-level indicators: School-Enterprise Collaboration Mechanism (0.28), Competence of "Dual- Qualified" Teachers (0.22), Quality of Craftsman Mentors (0.15), Professional Identity (0.11), Influence of Regional Culture (0.08).

Key Finding: Enterprise factors are the core driving force. In particular, "school-enterprise collaboration mechanism" and "quality of craftsman mentors" account for more than 40%, which confirms the effectiveness of the "industrial college + craftsman mentor" model of Hubei Industrial Polytechnic.

V. CONSTRUCTION OF THE CULTIVATION PATH OF CRAFTSMAN SPIRIT AMONG HIGHER VOCATIONAL COLLEGE STUDENTS BASED ON FUZZY INFORMATION

A. PRINCIPLES FOR PATH CONSTRUCTION

1) Principle of Ambiguity Adaptation

Aiming at the fuzzy information in cultivation, the strategy of "fuzzy definition + dynamic adjustment" is adopted. For example, the curriculum integration degree is divided into three fuzzy levels: high (0.8 - 1.0), medium (0.5 - 0.8) and low (0 - 0.5).

2) Principle of Unity of Knowledge and Practice

Following the logic of "cognition implantation - practical training - value externalization", Hubei Industrial Polytechnic realizes the internalization of spirit through "ideological and political courses in curriculum + industrial practice".

3) Principle of School-Enterprise Collaboration

Taking enterprise factors as the core, a collaborative mechanism of "enterprise-led, school-based and government-supported" is constructed.

4) Principle of Dynamic Optimization

The path parameters are adjusted through fuzzy comprehensive evaluation every semester. For example, the proportion of practice bases is optimized according to changes in enterprise demand.

B. SPECIFIC CULTIVATION PATHS

1) Fuzzy Collaboration-Based Social Support Linkage (Priority 1, Aligned with Enterprise Factor Weight 0.44)

(1) Five-agent Collaboration Mechanism: Clarify the fuzzy responsibility boundaries of "teachers (teaching leadership, weight 0.3), enterprises (practice leadership, 0.4), students (subject, 0.1), government (policy, 0.1) and society (culture, 0.1)";

(2) Policy Collaboration: Promote the government to include craftsman spirit cultivation in the evaluation indicators of "Double High-Level" colleges (weight 0.2);

(3) Case Support: Shiyan Municipal Government has invested 20 million yuan of special funds to support the construction of the industrial college of Hubei Industrial Polytechnic, where enterprises participate in formulating 60% of the practical training curriculum and arrange 40% of the practical teaching hours.

2) Fuzzy Decision-Making-Based Practical Teaching Reform (Priority 2, Aligned with School-Enterprise Collaboration Mechanism Weight 0.28)

(1) Fuzzy Division of Base Functions: Set up flexible functional areas according to "basic training (membership degree 0.7), technical improvement practice (membership degree 0.5) and innovation incubation (membership degree 0.3)" to adapt to the needs of different stages;

(2) Detailed Fuzzy Decision-Making Process for Practice Hour Adjustment: Construct a fuzzy decision indicator system including 3 first-level indicators (enterprise production demand, student skill level, teaching plan progress) and 8 second-level indicators. For example, enterprise production demand is divided into "peak season (membership degree 0.9)", "flat season (membership degree 0.5)" and "off season (membership degree 0.2)". The membership function for practice hour adjustment is

$$y = 0.3x_1 + 0.4x_2 + 0.3x_3,$$

where x_1 , x_2 , and x_3 are normalized values of the three first-level indicators. When the comprehensive membership

degree is ≥ 0.7 , practice hours are increased by 20-30%; when 0.4-0.7, hours remain unchanged; when < 0.4 , hours are reduced by 10-20%.

(3) Case Support: Hubei Industrial Polytechnic has co-built a flexible base with Dongfeng Motor, increasing the qualification rate of students' practical works from 78% to 92%.

3) Fuzzy-Oriented Curriculum System Reconstruction: Modular Curriculum + Fuzzy Clustering Setting (Priority 3, Aligned with School Factor Weight 0.26)

(1) Core Curriculum Modularization: Set up three modules of "craftsmanship foundation, craftsmanship skill improvement and craftsmanship inheritance", and adjust the weights according to academic stages (the proportion of the foundation module is 0.6 in the first year, and the proportion of the craftsmanship inheritance module is 0.5 in the third year);

(2) Detailed Fuzzy Clustering Process for Professional Courses: Select 3 core clustering attributes (skill precision requirement, craftsman spirit cultural content, industry practice relevance) and quantify them on a 1-5 scale. Construct a fuzzy similarity matrix using the cosine similarity method:

$$r_{ij} = \frac{\sum_{k=1}^3 x_{ik}x_{jk}}{\sqrt{\sum_{k=1}^3 x_{ik}^2} \sqrt{\sum_{k=1}^3 x_{jk}^2}},$$

where x_{ik} and x_{jk} are attribute values of course i and course j . Use the transitive closure method for clustering, dividing 120 professional courses into three categories: "technical skill (high skill precision, weight 0.4)", "cultural literacy (rich cultural content, weight 0.3)" and "collaborative innovation (strong industry relevance, weight 0.3)". Each category integrates corresponding craftsman spirit dimensions (e.g., technical skill courses focus on excellence awareness);

(3) Case Support: Zibo Vocational Institute clusters courses according to the above attributes, increasing professional adaptability by 42%.

4) Fuzzy Evaluation-Based Teaching Staff Construction (Priority 4, Aligned with Dual-Qualified Teacher Competence Weight 0.22)

(1) Evaluation Index System: Construct a three-dimensional evaluation model of "teaching ability (0.3), enterprise experience (0.4) and craftsmanship literacy (0.3)", and score using the FCE method;

(2) Cultivation Mechanism: Implement the "craftsman mentor pairing" training for teachers at the "good (0.6 - 0.8)" level, and set up "craftsmanship studios" for those at the "excellent (0.8 - 1.0)" level;

(3) Case Support: Through this mechanism, the proportion of teachers with craftsman experience in Hubei Industrial Polytechnic has increased from 23% to 41%.

5) Fuzzy Penetration-Based Cultural Education Construction (Priority 5, Aligned with Social Factor Weight 0.14)

(1) Clear Boundary Definition of Fuzzy Penetration Path: Different from other paths focusing on curriculum, prac-

tice and management, this path takes "invisible cultural infiltration" as the core, with the boundary defined as "no mandatory participation requirements, no unified evaluation standards, and voluntary participation of students". It achieves spiritual edification through implicit carriers

(2) Fuzzy Design of Cultural Carriers: Build a three-in-one carrier of "professional cultural festivals (such as automobile/Luban cultural festivals) + craftsman lectures + experience halls" to realize "boundaryless" cultural infiltration;

(3) Integration of Regional Culture: Explore local resources. For example, Zibo Vocational Institute integrates the "pursuit of excellence" concept of Qi culture, and Hubei Industrial Polytechnic implants the "Ma Deng Spirit" of Dongfeng Motor;

(4) Effect Improvement: The participation rate of cultural activities reaches 89%, and students' professional identity increases by 37%.

C. IMPLEMENTATION PROCESS AND KEY POINTS OF THE PATH

1) Implementation Process

(1) Preparation Stage (Months 1 - 2): Establish a school-enterprise expert team and conduct a fuzzy demand survey;

(2) Construction Stage (Months 3 - 6): Complete core tasks such as curriculum clustering and base construction;

(3) Pilot Stage (Months 7 - 12): Select 2 majors for the pilot project and collect fuzzy evaluation data; (4) Promotion Stage (Months 1 - 6 of the next year): Optimize the path based on the pilot results and promote it in an all-round way.

2) Key Control Points

(1) Factor Control: Focus on the two core factors of "school-enterprise collaboration" and "teacher competence", with resource investment accounting for no less than 60%;

(2) Method Control: The FAHP weight calculation needs to be verified by 3 rounds of experts, with CR value < 0.1 ;

(3) Feedback Control: Collect enterprise evaluation data monthly and adjust path parameters quarterly.

VI. IMPLEMENTATION GUARANTEE AND EFFECT PROSPECT OF THE CULTIVATION PATH

A. IMPLEMENTATION GUARANTEE MEASURES

1) System Guarantee

(1) Formulate the Detailed Rules for the Implementation of Craftsman Spirit Cultivation to clarify fuzzy standards for curriculum integration and practical assessment;

(2) Establish a school-enterprise collaboration charter to define the responsibility ratio of both parties in craftsman mentors and base construction (enterprises account for no less than 50%);

(3) Incorporate it into the school quality evaluation system, with the weight of craftsman spirit cultivation no less than 0.2.

2) Resource Guarantee

(1) Teaching Staff Guarantee: Every year, select 30% of teachers to take temporary positions in enterprises, and hire enterprise craftsmen as part-time teachers (the teacher-student ratio is no less than 1:50);

(2) Fund Guarantee: Set up special funds (no less than 500 yuan per student per year) for the development of fuzzy evaluation tools and the construction of practice bases;

(3) Venue Guarantee: The per-student area of school-enterprise co-built practice bases is no less than 20 square meters.

3) Technical Guarantee

(1) Develop a "craftsman spirit cultivation management platform", integrating fuzzy evaluation modules and data visualization functions;

(2) Construct a fuzzy database, including 100 typical cases and 20 sets of evaluation index systems;

(3) Conduct training on fuzzy methods to ensure that 80% of teachers master the basic application of FAHP.

B. FUZZY COMPREHENSIVE EVALUATION OF CULTIVATION EFFECTS

1) Construction of the Evaluation Index System

Based on the previous factor analysis, a four-dimensional evaluation system of "professional belief (0.3), skill literacy (0.4), cultural character (0.2) and collaboration ability (0.1)" is constructed, including 23 third-level indicators.

2) Application of the Fuzzy Comprehensive Evaluation Model

Taking the 2023 pilot class (120 students) of the Mechanical Manufacturing major in Hubei Industrial Polytechnic as the evaluation object, a full-process evaluation is implemented:

(1) Data Sources: Practical evaluation scores from 30 enterprise craftsmen; quality inspection data of students' practical works (including 12 indicators such as qualification rate and precision error); questionnaire survey of teachers and students based on the "fuzzy evaluation scale for craftsman spirit cultivation effect" (effective recovery rate 92%).

(2) Construction of Membership Matrix: Use the trapezoidal membership function to convert the third-level indicator data into a fuzzy matrix. Taking the "skill literacy" dimension as an example, the 92% qualification rate of practical works in the pilot class corresponds to a membership degree of 0.8 for "excellent" and 0.2 for "good", forming the following partial matrix:

$$R_{\text{Skill Literacy}} = \begin{bmatrix} 0.8 & 0.2 & 0 & 0 \\ 0.7 & 0.3 & 0 & 0 \\ 0.6 & 0.3 & 0.1 & 0 \end{bmatrix}$$

The rows of $R_{\text{Skill Literacy}}$ correspond to:

[0.8, 0.2, 0, 0]	# Qualification rate of practical works,
[0.7, 0.3, 0, 0]	# Number of technical improvement suggestions,
[0.6, 0.3, 0.1, 0]	# Operation standardization.

(3) Weight Synthesis and Result Calculation: Combined with the four-dimensional indicator weight vector ($W = [0.3, 0.4, 0.2, 0.1]$), the comprehensive evaluation vector is calculated through the $M(\cdot, \oplus)$ model:

$$B = W \cdot R = [0.72, 0.25, 0.03, 0].$$

According to the maximum membership degree principle, the cultivation effect of the pilot class is rated as "excellent" (membership degree 0.72), among which the skill literacy dimension has the highest score (0.78), and the cultural character dimension needs to be improved (0.65).

(4) Validity Verification: The evaluation results are highly consistent with the 2024 graduate quality report of the college - the enterprise satisfaction rate of the graduates from the pilot class reaches 95%, which is 3 percentage points higher than the average level of the college, confirming the effectiveness of the model.

3) Feedback and Path Optimization of Evaluation Results

A "three-level feedback - iteration" mechanism is established based on the fuzzy evaluation results:

(1) First-level Feedback (Monthly): Aiming at the problem of "low score in the cultural character dimension", strengthen the implementation of the fuzzy penetration path - integrate the "Ma Deng Spirit" cases into the weekly craftsman lectures, increasing the coverage rate of cultural carriers from 89% to 100%;

(2) Second-level Feedback (Quarterly): It is found that the membership degree of the "collaboration ability dimension" is 0.68, which is lower than expected. Adjust the weight of enterprise participation in the fuzzy collaboration path (from 0.4 to 0.45) and add a new "cross-post practical training in enterprises" module;

(3) Third-level Feedback (Annual): Recalculate the weights of influencing factors through the FAHP method and find that the weight of "influence of regional culture" has risen to 0.11. Based on this, add the "crossregional exchange project of Qi culture - automobile culture" (implemented in conjunction with Zibo Vocational Institute).

In the evaluation of the pilot class in the following year after optimization, the membership degrees of the cultural character and collaboration ability dimensions increased to 0.76 and 0.75 respectively, verifying the necessity of dynamic path optimization.

C. RESEARCH LIMITATIONS AND FUTURE PROSPECTS

1) Research Limitations

(1) The sample coverage is limited, mainly focusing on majors related to the manufacturing industry, with insufficient data from higher vocational colleges of the service industry;

(2) The subjectivity of fuzzy weights is relatively strong, and there are still deviations despite expert verification;

(3) The path implementation cycle is short (1 year), and the long-term effect needs further tracking.

2) Future Research Directions

(1) Expand the sample scope to include higher vocational colleges of service industry and art, and construct a professional-specific evaluation model;

(2) Optimize fuzzy methods by combining big data technology to reduce subjective deviations;

(3) Conduct long-term tracking for more than 3 years to verify the sustainability of the path;

(4) Explore the integrated application of "fuzzy methods + artificial intelligence" to realize the intelligent regulation of the cultivation process.

VII. CONCLUSION

This study systematically applied fuzzy information theory and fuzzy analysis methods to construct a cultivation framework for the craftsman spirit—covering "problem identification–factor quantification–path construction–effect evaluation"—and explicitly tailored this research approach for students in higher vocational college programs. The research identifies core issues such as ambiguous goal definitions and a lack of quantitative evaluation standards in current cultivation efforts. Utilizing the Fuzzy Analytic Hierarchy Process (FAHP), the analysis determined that enterprise factors are the core driving force, with the school-enterprise collaboration mechanism (weight 0.28) and the competence of "dual-qualified" teachers (weight 0.22) being the most critical factors. Five distinct cultivation paths were proposed to address the ambiguity, including fuzzy-oriented curriculum reconstruction and fuzzy decision-making-based practical reform. The subsequent establishment and application of a Fuzzy Comprehensive Evaluation (FCE) model demonstrated that these fuzzy methods can effectively solve uncertainty problems in the cultivation process, achieving a scientifically quantifiable and dynamically optimizable effect assessment. This approach enriches the methodological system for craftsman spirit cultivation and provides actionable, precision-focused schemes for higher vocational colleges.

AUTHOR CONTRIBUTIONS

Hao Wang designed, collected and analyzed the data, and drafted the manuscript. Hao Wang conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Hao Wang participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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HUMAN RESEARCH SUBJECTS

This study was approved by the Ethics Committee of Wuxi University of Technology, and was performed in accordance with the principles of the Declaration of Helsinki. All eligible participants signed an informed consent form.

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