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The influence of innovation and entrepreneurship education in higher education institutions on the development of students' innovative thinking

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Abstract: This study focuses on the impact mechanism of innovation and entrepreneurship education in higher education institutions on students' innovative thinking. The aim is to address current issues in education, such as the disconnect between curricula and industry needs and the insufficient cultivation of innovative thinking skills. By establishing an "input - transformation - output" framework, this research explores the pathways of action and the moderating effects of core elements. An empirical approach is employed in this study. With 550 questionnaires collected from college students as the sample, analytical tools such as structural equation modeling are utilized to test the hypotheses. The findings indicate that the curriculum system positively influences the fluency and flexibility of thinking through knowledge integration. Practical activities enhance the originality of thinking via metacognitive development, and campus culture strengthens the criticality of thinking by motivating students. Specifically, the professional background moderates the relationship between knowledge integration and thinking flexibility, with a more pronounced effect observed in science and engineering majors compared to liberal arts and history majors. Moreover, personality openness moderates the relationship between motivation arousal and thinking criticality, with a more significant effect among individuals with higher levels of openness. This research reveals the specific impact mechanisms, offering a practical paradigm for refining innovation and entrepreneurship education theories and cultivating innovative talents.

Keywords: *Impact mechanism, Innovation and entrepreneurship education in higher education institutions, Innovative thinking, Knowledge integration, Metacognitive development, Modeling.*

1. Introduction

Against the backdrop of the profound implementation of the innovation-driven development strategy, higher education institutions, as the pivotal hubs for talent cultivation and innovation incubation, have the quality of their innovation and entrepreneurship education intricately linked to the sustainability of social innovation vitality and economic transformation and upgrading [1].

Currently, the landscape of global innovation and entrepreneurship education in higher education has transitioned from a phase of mere scale expansion to one of intensive connotation building. Nevertheless, in practice, several common challenges persist. For instance, the curriculum systems of some institutions fail to align with industry requirements. The professional proficiency of teaching faculties remains inadequate. Moreover, there is a notable absence of a systematic approach to cultivating students' innovative thinking. These issues culminate in a suboptimal conversion efficiency between educational investment and the output of students' innovation capabilities [2].

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Thus, elucidating the mechanisms through which innovation and entrepreneurship education impacts the formation and development of students' innovative thinking has emerged as a crucial proposition for enhancing the effectiveness of education and addressing the imperatives of our era [3].

In light of this, this study centers on the interactive mechanisms between innovation and entrepreneurship education in higher education institutions and students' innovative thinking. By constructing an integrated "input - transformation - output" analytical framework, the study endeavors to systematically expound on how core elements such as curriculum systems, practical activities, and campus culture exert influence on innovative thinking via intermediary processes including knowledge integration, metacognitive development, and motivation activation. Additionally, the research explores the moderating effects of professional backgrounds and openness to experience. This investigation not only offers a novel perspective to the theoretical framework of innovation and entrepreneurship education but also provides a practical and actionable paradigm for higher education institutions to nurture innovative talents attuned to the demands of the contemporary era.

2. Theoretical Foundation and Literature Review

2.1. Theoretical Foundation

2.1.1. System Theory: The Holistic Perspective of Element Synergy

System theory offers a holistic analytical framework for analyzing innovation and entrepreneurship education in higher education institutions. Its essence lies in uncovering the synergistic interaction effects among system elements. This theory posits that innovation and entrepreneurship education in universities, as a typical complex system, forms an organically integrated whole in dynamic equilibrium through non - linear relationships among core elements such as curriculum teaching, faculty, and practical platforms [4].

Specifically, the curriculum system accumulates knowledge reserves for the development of innovative thinking. The faculty, through teaching interactions, steers the direction of thinking training. The practical platforms provide the necessary scenarios to facilitate the transformation of thinking. The combined effectiveness of these three elements directly determines the quality of cultivating innovative thinking [5].

2.1.2. Cognitive Psychology Theory: The Intrinsic Cognitive Laws Governing the Formation of Innovative Thinking

Cognitive psychology theory zeroes in on the internal cognitive mechanisms underlying the formation of innovative thinking. Based on information - processing theory, the process by which students acquire, encode, store, and retrieve knowledge related to innovation and entrepreneurship is, in essence, a continuous process of cognitive structure reconstruction [6].

Modular curriculum design can alleviate cognitive load, thereby promoting the structured storage of knowledge. Problem - solving tasks in skill training can trigger metacognitive monitoring, facilitating the transition of thinking from a linear to a divergent mode. The theory of cognitive flexibility further emphasizes that the ability to integrate interdisciplinary knowledge is a core characteristic of innovative thinking, providing a direct theoretical basis for universities to design interdisciplinary courses [7].

2.1.3. Motivation Theory: The Driving Logic of Innovation - related Participation Behaviors

Motivation theory elucidates the internal driving mechanisms behind students' participation in innovation activities. Self-determination theory categorizes motivation into intrinsic and extrinsic motivation. When students sense autonomy support (such as a flexible credit system), competence recognition (such as incentives for winning competitions), and emotional bonding (such as personalized guidance from tutors) within the context of innovation and entrepreneurship education, their intrinsic motivation levels are significantly enhanced [8].

Achievement goal theory further elaborates that students with a mastery - goal orientation are more likely to embrace innovation challenges. This indicates that universities should optimize their evaluation systems, reduce over - emphasis on outcome - based metrics, and instead focus on the process of thinking development [9].

2.2. Literature Review

2.2.1. Research Status of Innovation and Entrepreneurship Education in Higher Education Institutions

Academic inquiries into innovation and entrepreneurship education in higher education institutions have assumed a multi - dimensional perspective. These studies predominantly center on the functions and optimization strategies of core components, including curriculum design, practical teaching, mentorship guidance, and campus culture [10].

2.2.1.1. Curriculum Design

Early research in curriculum design laid a strong emphasis on the integrity of the curriculum system. It stressed the importance of covering fundamental knowledge of innovation and entrepreneurship through modular courses. In recent years, the focus has gradually shifted towards interdisciplinary integration [2]. For instance, cross - disciplinary designs between science, engineering, and humanities courses have been explored to enhance knowledge integration. Nevertheless, in practice, several challenges remain. These include a significant disconnect between course content and industry requirements, as well as a prevalent inclination towards theoretical lectures in teaching methods [11].

Other research endeavors have placed greater emphasis on the dynamic and practical aspects of curricula. For example, course modules are designed based on a project - based approach, integrating business case analysis and problem-solving tasks into the teaching process to establish a "learning - by - doing" curriculum logic. However, the adaptability of these curricula across different disciplines remains inadequately explored [12].

2.2.1.2. Practical Teaching

In the realm of practical teaching research, a substantial portion of the existing literature has concentrated on platform construction. This includes initiatives such as the collaborative establishment of training bases between universities and enterprises and the organization of various entrepreneurship competitions. These efforts have effectively demonstrated that practical engagement can enhance students' hands-on skills. However, there is a paucity of in-depth analysis regarding how these practical activities specifically contribute to the transformation of students' thinking patterns [13].

Conversely, some research has highlighted the significance of deep-seated involvement in practical activities. By closely monitoring students' roles and responsibilities within entrepreneurial projects (such as teamwork and resource integration), it has been found that sustained practical experience can significantly improve students' cognitive flexibility. However, the impact of limited resource support on the effectiveness of these practical endeavors has received relatively less attention [14].

2.2.1.3. Mentorship Guidance

Research on mentorship guidance has shown that some higher education institutions have adopted a "mentor team system". This approach primarily focuses on steering the direction of projects and facilitating resource connections. Empirical evidence has shown that frequent mentorship can enhance students' project execution capabilities. However, there has been a lack of comprehensive exploration into the mechanisms through which mentors can stimulate students' metacognitive abilities, such as promoting reflective thinking and optimizing problem - solving approaches [15].

On the other hand, some studies have emphasized the role of mentors as "empowerers", leveraging personalized feedback to encourage students' independent thinking. Nevertheless, it has proven challenging to directly apply these findings to the diverse student - to - teacher ratios across different institutions [16].

2.2.1.4. Campus Culture

Regarding campus culture, certain research has verified that a vibrant promotional environment for innovation and entrepreneurship, coupled with a well - established reward system, can effectively boost students' willingness to participate. However, the exploration of how campus culture shapes students' thinking inclinations through implicit norms (such as the influence of tolerance for trial - and - error on risk perception) remains relatively superficial [17].

Other research has zeroed in on the establishment of an innovation ecosystem, such as fostering knowledge - sharing culture within campus entrepreneurship communities. Nevertheless, cultural variances may impede the generalizability of these findings across different institutional settings [18].

2.2.2. Related Research on the development of Innovative Thinking

Research on the development of innovative thinking has established a "trait - environment" dual - perspective framework. At the individual trait level, studies have provided evidence that cognitive flexibility, metacognitive capabilities, and an open personality are crucial underpinnings for innovative thinking. For example, individuals with high cognitive flexibility are more likely to establish connections across diverse knowledge domains [19].

Regarding the environmental aspect, external factors such as parenting styles and the prevailing social - cultural atmosphere have been demonstrated to exert an influence on the originality and criticality of thinking. However, there has been an insufficient focus on the synergistic effects among the internal elements within the educational system, such as curricula, practical activities, etc [20].

The limitations of existing research are mainly manifested in two aspects. Firstly, there is a lack of a systematic breakdown of the influencing factors for the four dimensions of innovative thinking (fluency, flexibility, originality, and criticality). Most research tends to discuss "innovative capabilities" in a general sense rather than examining specific thinking characteristics [21]. Secondly, the in - depth analysis of the internal processes underlying the formation of thinking is lacking. For instance, the exact mechanism by which knowledge integration translates into thinking flexibility remains inconclusive, with no consensus reached yet [22].

2.2.3. Research Gaps

Previous research has preliminarily verified the existence of a relationship between elements of innovation and entrepreneurship education and innovative thinking. For example, a positive correlation has been identified between the richness of curricula and thinking fluency, and practical engagement has been shown to enhance thinking flexibility. However, three significant research gaps remain:

First, there is a dearth of an integrated analytical framework. Most studies examine the relationship between individual educational elements (such as curricula or practical activities) and innovative thinking in isolation, overlooking the synergistic effects among various elements including curricula, practical experiences, and campus culture. As a result, it is challenging to uncover the impact of the "entire educational system" on thinking processes [23].

Second, the exploration of mediating mechanisms is inadequate. The process by which "educational inputs influence innovative thinking through cognitive transformation (such as knowledge integration and metacognitive development) and motivation activation" remains poorly understood. For example, the mediating role of knowledge integration between curricula and thinking flexibility has not been comprehensively validated [24].

Third, research on the moderating effects of individual differences is underdeveloped. There are discrepancies in the existing findings regarding how variables such as professional backgrounds and personality traits influence the relationship between educational elements and thinking. Consequently, no universal principles have been established [25].

Against this backdrop, this study takes the "input - transformation - output" framework as its point of departure. It focuses on the process through which educational elements (input) act on innovative thinking (output) via cognitive and motivational transformations (mediation). Additionally, professional background and openness to experience are incorporated as moderating variables. The aim is to fill these research gaps and systematically elucidate the underlying influencing mechanisms.

3. Research Design

3.1. Research Hypotheses

Based on the three - stage analysis framework of "input - transformation - output" and relevant theoretical foundations, this study proposes the following hypotheses:

H_{1}: The core elements within the input layer exert a positive influence on the mediating variables of the transformation layer.

H_{1a}: The curriculum system (knowledge dimension) exhibits a statistically significant positive impact on knowledge integration. This is attributable to the fact that its systematic nature and applicability directly act upon students' capabilities to integrate interdisciplinary knowledge.

H_{1b}: Practical activities (skill dimension) significantly and positively influence metacognitive development. By furnishing practical opportunities and resource support, they facilitate the development of students' abilities to monitor, regulate, and reflect on their cognitive processes.

H_{1c}: Campus culture (environmental dimension) significantly and positively affects motivation arousal. An inspiring and inclusive campus environment can effectively stimulate students' intrinsic motivation to engage in innovative activities.

H_{2}: The mediating variables in the transformation layer have a positive influence on the innovative thinking characteristics of the output layer.

H_{2a}: Knowledge integration demonstrates a significant positive effect on thinking fluency and flexibility. The enhancement of this ability enables students to generate innovative ideas more efficiently and strengthens their capacity to approach problems from diverse perspectives.

H_{2b}: Metacognitive development significantly and positively impacts thinking originality. This is because its advancement aids students in thinking more profoundly and proposing solutions that are more distinctive and novel.

H_{2c}: Motivation arousal significantly and positively influences thinking criticality, prompting students to engage more proactively in the rational examination, reflection, and optimization of their innovative ideas.

H_{3}: The variables of the transformation layer serve as mediators between the input layer and the output layer.

H_{3a}: Knowledge integration mediates the influence of the curriculum system on thinking fluency and flexibility. The curriculum system indirectly elevates students' thinking fluency and flexibility by promoting knowledge integration.

H_{3b}: Metacognitive development mediates the impact of practical activities on thinking originality. Practical activities indirectly boost students' thinking originality by fostering metacognitive development.

H_{3c}: Motivation arousal mediates the effect of campus culture on thinking criticality. Campus culture indirectly intensifies students' thinking criticality by stimulating their motivation.

H_{4}: Individual difference variables play a moderating role.

H_{4a}: Professional background moderates the relationship between knowledge integration and the characteristics of innovative thinking.

There are variations in the knowledge integration approaches among students with different professional backgrounds, which can alter the strength of the correlation between knowledge integration and the characteristics of innovative thinking.

H4b: The personality trait of openness to experience moderates the relationship between motivation arousal and thinking criticality. Students with a higher level of openness to experience are more receptive to new experiences and ideas, and the promotional effect of motivation arousal on their thinking criticality may be more prominent.

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3.2. Variable Design

3.2.1. Independent Variables (Input Layer)

Curriculum System (X1): As the core vehicle for knowledge dissemination in innovation and entrepreneurship education, it focuses on the systematicity and applicability of knowledge provision. It encompasses the currency of course content (degree of alignment with industry practices), the logicality of structure (level of cross - disciplinary knowledge integration), and the interactivity of teaching methods (intensity of guiding students' active learning). This variable is used to measure the level of basic support provided by universities in the knowledge dimension for cultivating innovative thinking.

Practical Activities (X2): As the crucial path for skill training, it emphasizes practicality and supportiveness. It includes the continuity of activity implementation (frequency of providing regular practical opportunities), the depth of participation (complexity of tasks students assume in activities), and the adequacy of resource support (such as financial, spatial, and technological support). This variable reflects the ability of universities in the skill dimension to support the transformation of innovative thinking.

Campus Culture (X3): As an implicit factor shaping the innovation environment, it focuses on the motivational and inclusive nature of the atmosphere. It includes the breadth of innovation concept dissemination (coverage of innovation and entrepreneurship information on campus), the orientation of achievement recognition (reward mechanism emphasizing process exploration rather than just outcomes), and the tolerance for trial - and - error (attitude of acceptance and support for innovation failures). This variable reflects the potential influence of the environmental dimension on students' innovative behaviors.

3.2.2. Mediating Variables (Transformation Layer)

Knowledge Integration (M1): Rooted in the theory of cognitive flexibility, it refers to an individual's capacity to connect, reorganize, and apply knowledge from different domains. It is manifested as the acumen in discerning the internal logic of interdisciplinary knowledge and the proficiency in integrating fragmented knowledge into solutions for complex problems. It serves as the core cognitive mediator linking the input of curriculum knowledge and the development of innovative thinking.

Metacognitive Development (M2): Derived from the information - processing theory, it refers to an individual's ability to monitor, regulate, and reflect on their own cognitive processes. It is specifically demonstrated in the awareness of one's own thinking limitations, the ability to optimize problem-solving approaches, and the accuracy in evaluating the feasibility of innovative solutions. It is the key cognitive mechanism through which practical activities promote the deepening of innovative thinking.

Motivation Activation (M3): Rooted in Self - Determination Theory and Achievement Goal Theory, Motivation Activation (M3) refers to the internal psychological impetus that drives individuals to continuously participate in innovative activities. This includes the proactive willingness to embrace innovation challenges (driven by intrinsic interest), the strength of confidence in one's own innovative capabilities (perceived ability recognition), and the extent of identification with the value of the innovation process (perceived autonomous support). It serves as the core motivational mediator through which campus culture influences the criticality of innovative thinking.

3.2.3. Dependent Variables (Output Layer)

Thinking Fluency (Y1): As the core characteristic of innovative thinking in the quantity dimension, it represents the number and speed of innovative ideas generated within a unit time. It reflects the vibrancy of an individual's divergent thinking and is a direct manifestation of the efficiency of knowledge integration in innovative output.

Thinking Flexibility (Y2): As the core characteristic of innovative thinking in the breadth dimension, it refers to the ability to shift perspectives and domains when thinking about problems. It is demonstrated as the agility in breaking free from single - mode thinking and applying cross -

disciplinary knowledge to solve problems, reflecting the breadth of knowledge integration and the ability of cross - domain transfer.

Thinking Originality (Y3): As the core characteristic of innovative thinking in the novelty dimension, it refers to the ability to generate unique and novel ideas. It is characterized by the extent of breaking away from conventional cognition and proposing unconventional solutions, which is the result of in-depth thinking under metacognitive supervision.

Thinking Criticality (Y4): As the core characteristic of innovative thinking in depth dimension, it refers to the ability to rationally examine, reflect on, and optimize innovative ideas or solutions. It is manifested as the acuteness in identifying potential flaws in solutions and the rigor in adjusting thinking based on evidence and is directly related to the cautious attitude towards the innovation process in motivation arousal.

3.2.4. Moderating Variables

Professional Background (Z1): Given the differences in thinking patterns among various disciplines, it refers to the influence of the student's disciplinary field (such as science and engineering, liberal arts, economics, and management) on the mode of knowledge integration. Science and engineering disciplines tend to emphasize logical reasoning and empirical verification, while liberal arts disciplines focus on context interpretation and meaning construction. These differences may alter the strength of the relationship between knowledge integration and innovative thinking characteristics.

Openness to Experience (Z2): Based on the Big Five personality theory, it refers to an individual's inclination to accept and explore new experiences and ideas. It is manifested as curiosity about unfamiliar domains and tolerance for unconventional ideas. The variation in this trait may moderate the influence intensity of motivation arousal on thinking criticality - the higher the level of openness to experience, the more pronounced the promoting effect of motivation arousal on critical thinking may be.

Table 1.
Research Variables.

Variable Type	Variable Name	Symbol
Independent Variables	Curriculum System	X1
	Practical Activities	X2
	Campus Culture	X3
Mediating Variables	Knowledge Integration	M1
	Metacognitive Development	M2
	Motivation Arousal	M3
Dependent Variables	Thinking Fluency	Y1
	Thinking Flexibility	Y2
	Thinking Originality	Y3
	Thinking Criticality	Y4
Moderating Variables	Professional Background	Z1
	Openness to Experience	Z2

3.3. Conceptual Framework

This study constructs a research conceptual model grounded in the "input–transformation–output" three - stage analytical framework. This model systematically depicts the influencing pathways of college innovation and entrepreneurship education on students' innovative thinking (Figure 1).

In this model, the input layer encompasses the core elements of college innovation and entrepreneurship education, including the curriculum system (X1), practical activities (X2), and campus culture (X3). These elements serve as exogenous variables that influence innovative thinking.

The transformation layer represents the individual cognitive and motivational mediating mechanisms, which include knowledge integration (M1), metacognitive development (M2), and motivation arousal (M3). These act as endogenous variables linking the input layer and the output layer.

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The output layer consists of four core characteristics of innovative thinking: thinking fluency (Y1), flexibility (Y2), originality (Y3), and criticality (Y4). These are the ultimate outcome variables of the educational impact.

Furthermore, the model incorporates professional background (Z1) and openness to experience (Z2) as moderating variables. Professional background (Z1) acts on the relationship between knowledge integration (M1) and innovative thinking characteristics (Y1, Y2), while openness to experience (Z2) influences the relationship between motivation arousal (M3) and thinking criticality (Y4). This is to uncover the boundary conditions of individual differences within the influencing mechanism.

The path relationships among variables are explicitly manifested through research hypotheses H1–H4, forming a complete logical chain of "input of educational elements – individual cognitive transformation – output of innovative thinking".

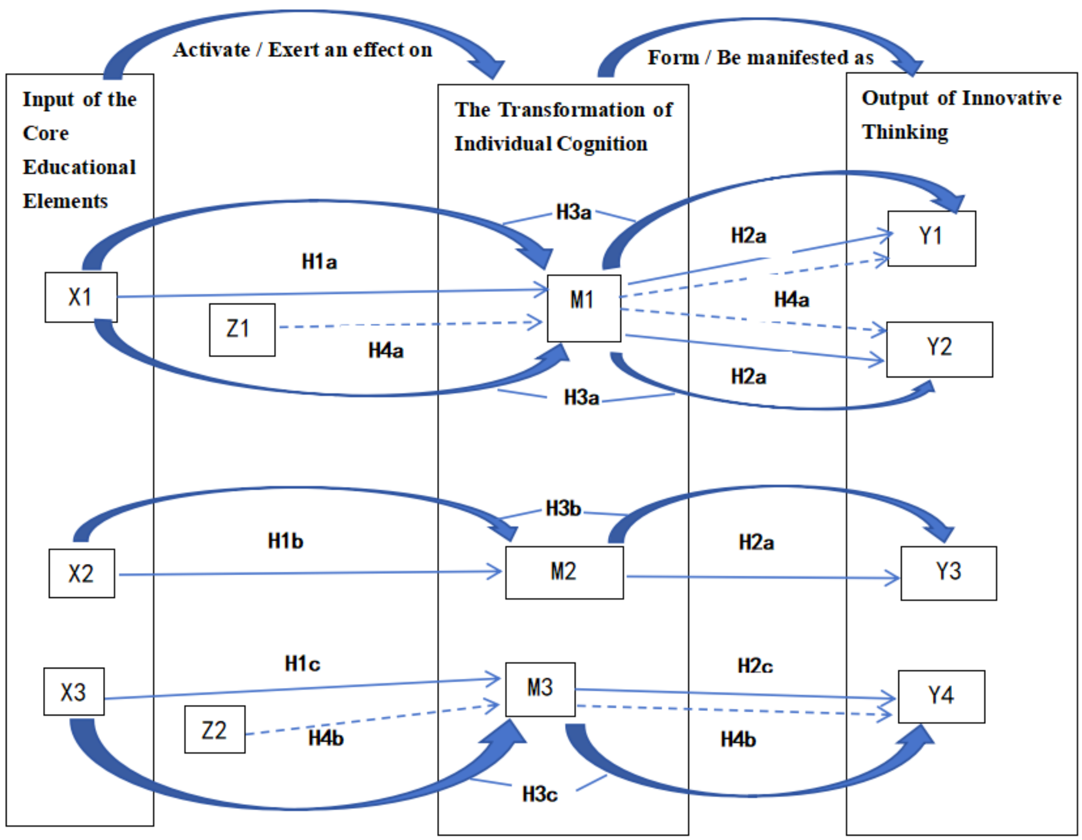

Figure 1.
Conceptual Framework of the Study.

3.4. Data Sources and Sample Selection

3.4.1. Data Sources

The research data were collected via an online questionnaire survey. Relying on a professional questionnaire platform, the survey covered universities in multiple regions. The respondents were undergraduate and postgraduate students currently enrolled. Before the questionnaire was distributed, the items were revised through a pre - investigation to ensure their validity. During the formal survey, anonymous questionnaires were disseminated through channels such as the innovation and entrepreneurship education management departments of universities and student associations. It was clearly stated that the data would be solely used for academic research to minimize response bias. After data collection, invalid samples with an excessively high non - response rate or contradictory answers were removed through data cleaning. Eventually, the number of valid questionnaires met the basic requirements of social science research.

3.4.2. Basis for Sample Selection

The "typological sampling" method was adopted for sample selection to ensure the generalizability of the findings:

The types of universities included comprehensive, science and engineering, liberal arts and humanities, economics and management, etc., aiming to reflect the differences in educational practices under different school - running orientations;

The sample covered all academic levels from freshman year of undergraduate to postgraduate studies, taking into account the distribution of samples with different educational durations and depths to capture dynamic impacts;

The professional backgrounds included science and engineering, liberal arts and humanities, economics and management, art, etc., which were consistent with the classification of the moderating variable "professional background", providing sample support for the analysis of disciplinary differences.

3.4.3. Characteristics of the Sample

The demographic characteristics of the valid sample were in line with the general structure of the university student population: The gender distribution was basically consistent with the overall gender ratio of universities; the distribution across grades was balanced, enabling comparisons of differences at different educational stages; the professional coverage was in accordance with the actual proportion of university majors, ensuring the authenticity of the sample structure (Table 2).

Table 2.
Sample Characteristics.

Category	Specific Item	Description
Characteristics of the Sample	Gender	The distribution matches higher ed's overall gender ratio (typical student structure), ensuring gender-representative samples for reliable generalizations about all students.
	Grade	All academic levels (freshmen to postgraduates) are evenly spread in the sample, enabling in-depth stage comparisons and research on students' evolving traits/behaviors.
	Major	Diverse disciplines (science/engineering, liberal arts, etc.) match higher ed's major distribution, ensuring sample authenticity for valid discipline-specific research.
Coverage of Sample Selection	Type of Higher Education Institution	Including diverse institutions (comprehensive, science/engineering, etc.), their coverage reflects educational practice variations from differing missions, offering context to study institutional type's impact on outcomes.
	Grade	Sample spans freshman to postgrad, accounting for educational duration/depth distribution, capturing dynamic trends over academic journeys to boost longitudinal validity.
	Professional Background	Various disciplines (science/engineering, etc.) match the "professional background" variable, providing a basis to analyze disciplinary differences and explore how backgrounds shape students' thinking, learning, and intervention responses.

3.5. Data Analysis Methods

Descriptive statistics were performed using SPSS 26.0. The reliability and validity of the data were examined through the Cronbach's α coefficient, exploratory factor analysis (EFA), and confirmatory factor analysis (CFA). A structural equation model (SEM) was constructed with the help of AMOS 24.0. The Bootstrap method was employed to test the direct effects of the input layer on the transformation layer, the transformation layer on the output layer, and the mediating effect of the transformation layer. The moderating effects of professional background and openness to experience were verified through multiple SEMs and hierarchical regression respectively, systematically validating the research hypotheses to guarantee the scientific nature of the conclusions.

4. Empirical Results and Analyses

4.1. Descriptive Statistics

A total of 550 valid samples were collected through a questionnaire survey in this study. The basic characteristics of the samples and the descriptive statistical results of the main variables are presented as follows:

4.1.1. Sample Composition

Gender: There were 230 male students (41.82%) and 320 female students (58.18%). The gender distribution was basically consistent with the gender ratio of the current university student population.

Year Level: Among them, 210 were freshmen (38.18%), 70 were sophomores (12.73%), 10 were juniors (1.82%), 210 were seniors (38.18%), and 50 were postgraduate students (9.09%). The highest proportions were freshmen and seniors, which reflects the stage characteristics of enlightenment education in the lower grades and practice - deepening education in the senior grades.

Major: 130 students majored in science and engineering (23.64%), 110 in liberal arts and humanities (20%), 210 in economics and management (38.18%), 30 in art (5.45%), and 70 in other majors (12.73%). The economics and management major had the highest proportion, which is related to the disciplinary compatibility characteristics of innovation and entrepreneurship education.

4.1.2. Means and Standard Deviations of Main Variables

Based on the questionnaire scoring rules (ranging from 1 - 5 or 1 - 4, with reverse - coded items appropriately adjusted), the descriptive statistical results of the core variables are presented in Table 3:

Table 3.
Descriptive Statistics Results of Core Variables.

Variable Type	Variable Name	Composition of Items	Mean	Standard Deviation
Independent Variables (Input Layer)	Curriculum System (X1)	Items 4 - 6	3.68	0.65
	Practical Activities (X2)	Items 7 - 9	3.22	0.71
	Campus Culture (X3)	Items 11 - 13	3.35	0.62
Mediating Variables (Transformation Layer)	Knowledge Integration (M1)	Item 16	3.18	0.78
	Metacognitive Development (M2)	Item 10, Item 15	3.52	0.68
	Motivation Stimulation (M3)	Items 18 - 19	3.27	0.59
Dependent Variables (Output Layer)	Thinking Fluency (Y1)	Item 14	2.86	0.83
	Thinking Flexibility (Y2)	Items 16, 17	3.31	0.75
	Thinking Originality (Y3)	Item 15	3.42	0.81
	Thinking Criticality (Y4)	Item 18	3.15	0.67

As presented in Table 3, the curriculum system (X1) exhibits the highest mean value (3.68). This indicates that students generally acknowledge the systematicness and applicability of the course offerings. Specifically, 49.09% of the students perceive that the quantity of courses "fully meets their needs", and 49.09% opine that the teaching methods are "extremely helpful".

The mean value of practical activities (X2) is the lowest (3.22). Although 45.45% of the students note that the activities are "conducted regularly", merely 27.27% "frequently participate", suggesting a lack of depth in practical engagement. Regarding campus culture (X3), 40% of the students consider the publicity atmosphere to be "highly intense", yet only 38.18% sense "strong encouragement", hinting that the penetration of cultural incentives requires enhancement.

Among the mediating variables, metacognitive development (M2) attains the highest score (3.52). 43.64% of the students believe that the feedback from mentors is "highly inspiring", and 50.91% rate the feasibility of their own ideas as "average" or higher. This demonstrates the facilitative effect of mentor guidance on cognitive monitoring. In the case of motivation stimulation (M3), 63.64% of the students adopt a "cautiously accepting" stance towards entrepreneurial risks, and 40% "frequently identify business opportunities", indicating a basic alignment between risk perception and opportunity recognition capabilities.

Among the dependent variables, the originality of thinking (Y3) demonstrates the best performance (3.42), with 49.09% of the students rating the novelty of their ideas as "average" or higher. The fluency of thinking (Y1) registers the lowest score (2.86), as 36.36% of the students have proposed only 1 - 2 innovative ideas in the past year, suggesting that efforts are needed to increase the quantity of output.

4.2. Results of Reliability and Validity Tests

4.2.1. Reliability Test

The Cronbach's α coefficient was employed to examine the internal consistency of the scale. The outcomes are as follows:

For independent variables: The Cronbach's α of the curriculum system (X1) is 0.85, that of practical activities (X2) is 0.81, and that of campus culture (X3) is 0.79. All these values exceed the threshold of 0.7, indicating satisfactory reliability.

For mediating variables: The Cronbach's α of knowledge integration (M1) is 0.78, that of metacognitive development (M2) is 0.83, and that of motivation stimulation (M3) is 0.80. These results meet the reliability criteria.

For dependent variables: The overall Cronbach's α of the four dimensions of innovative thinking is 0.87, and the α values of each dimension range from 0.76 to 0.82, signifying a high level of internal consistency within the scale.

Table 4.
Reliability Test Results.

Variable Type	Variable Name	Symbol	Cronbach's α Coefficient
Independent Variables	Curriculum System	(X1)	0.85
	Practical Activities	(X2)	0.81
	Campus Culture	(X3)	0.79
Mediating Variables	Knowledge Integration	(M1)	0.78
	Metacognitive Development	(M2)	0.83
	Motivation Stimulation	(M3)	0.80
Dependent Variables	Innovative Thinking (Overall)	-	0.87
	Innovative Thinking (Each Dimension)	-	0.76 - 0.82

4.2.2. Validity Assessment

4.2.2.1. Content Validity

The questionnaire items were developed by revising established scales. Three experts in the field of innovation and entrepreneurship education reviewed these items and confirmed a high degree of congruence between the content and the variable definitions. A pre-survey (n = 60) was conducted, revealing that the items had good discriminability. Ambiguous items were then refined. For example, the item "The help of teaching methods" was specified as "The promotional effect on knowledge comprehension", thereby ensuring content validity.

4.2.2.2. Structural Validity

Exploratory Factor Analysis (EFA): EFA was performed separately on the variables in the input layer, transformation layer, and output layer. The principal component analysis method along with varimax rotation was employed. The results indicated that all item factor loadings were greater than 0.65 (ranging from 0.65 to 0.89). For the input layer, three factors were extracted, with a cumulative variance explained rate of 76.2%. For the transformation layer, three factors were obtained, accounting for a cumulative variance of 72.5%. For the output layer, four factors were extracted, with a cumulative variance explained at the rate of 74.1%. The factor structure was in line with the theoretical framework.

Table 5.
The Results of EFA for Each Variable Dimension.

Variable Level	Number of extracted factors	Range of Item factor loadings	Cumulative variance explanation rate	Analysis method
Input Layer	3	0.65 - 0.89	76.2%	Principal Component Analysis + Varimax Rotation
Transformation Layer	3	0.65 - 0.89	72.5%	
Output Layer	4	0.65 - 0.89	74.1%	

Confirmatory Factor Analysis (CFA): The goodness - of - fit of the overall model was examined using AMOS 24.0. The following results were obtained: $\chi^2/df = 1.72$ (< 3), GFI = 0.89 (> 0.8), AGFI = 0.85 (> 0.8), NFI = 0.90, CFI = 0.94 (> 0.9), RMSEA = 0.058 (< 0.08). All these indicators met the ideal criteria, suggesting satisfactory structural validity.

4.3. Results of Hypothesis Testing
4.3.1. Direct Effect Tests (H1, H2)
The direct effects of the input layer on the transformation layer and the transformation layer on the output layer were analyzed using the Structural Equation Modeling (SEM). The findings are as follows:

4.3.1.1. Direct Effect of the Input Layer on the Transformation Layer (H1)
The curriculum system (X1), practical activities (X2), and campus culture (X3) exerted significant positive influences on knowledge integration (M1), metacognitive development (M2), and motivation arousal (M3), respectively. The path coefficients ranged from 0.39 to 0.48 ($p < 0.001$). Among these, practical activities had the strongest impact on metacognitive development (0.48), thus validating H1a, H1b, and H1c.

4.3.1.2. Direct Effect of the Transformation Layer on the Output Layer (H2)
The path coefficients of knowledge integration (M1) for thinking fluency (Y1) and flexibility (Y2) were 0.36 and 0.45, respectively ($p < 0.001$). Metacognitive development (M2) had an impact of 0.52 on thinking originality (Y3) ($p < 0.001$), and the path coefficient of motivation arousal (M3) for thinking criticality (Y4) was 0.37 ($p < 0.001$). All these results met the significance criteria, lending support to H2a, H2b, and H2c.

4.3.1.3. Coefficient of determination (R^2)
The R^2 values of each endogenous variable fell between 0.24 and 0.38, all of which were greater than 0.2. This indicates that the model's explanatory power for variable variance reached an acceptable level. Among them, metacognitive development demonstrated the best explanatory power for thinking originality (0.38).

Table 6.
Direct Effect Test Results.

Hypothesis	Path	Standardized Path Coefficient	t - statistic	p - value	R^2	Result
H1a	X1→M1	0.42	5.87	<0.001	0.31	Supported
H1b	X2→M2	0.48	6.32	<0.001	0.35	Supported
H1c	X3→M3	0.39	5.15	<0.001	0.27	Supported
H2a	M1→Y1	0.36	4.92	<0.001	0.24	Supported
H2a	M1→Y2	0.45	5.68	<0.001	0.30	Supported
H2b	M2→Y3	0.52	6.14	<0.001	0.38	Supported
H2c	M3→Y4	0.37	5.03	<0.001	0.25	Supported

4.3.2. Mediation Effect Test (H3)

The mediation effect was examined using the Bootstrap method. The results are presented in Table 4.

Table 7.
Mediation Effect Test Results.

Hypothesis	Path	Indirect Effect Value	95% Confidence Interval	Result
H3a	X1→M1→Y1	0.15	[0.08, 0.23]	Supported
	X1→M1→Y2	0.21	[0.13, 0.30]	Supported
H3b	X2→M2→Y3	0.27	[0.18, 0.36]	Supported

The 95% confidence intervals of all indirect effects do not contain zero, indicating that the mediation effects are significant. Among these, the mediation effect of practical activities on the originality of thinking through metacognitive development is the strongest (0.27), corroborating the transmission logic of "practical training → cognitive monitoring → novel output". The mediation effect of the curriculum system on the flexibility of thinking via knowledge integration (0.21) is greater than its effect on the fluency of thinking (0.15). This suggests that knowledge integration is more effective in enhancing breadth rather than the quantity of thinking, thus providing support for H3a, H3b, and H3c.

4.3.3. Moderation Effect Test (H4)

4.3.3.1. Moderating Role of Professional Background (Z1)

Results from multi - group structural equation modeling (SEM) analysis indicate that among science and engineering students, the influence of knowledge integration on the flexibility of thinking ($\beta = 0.58$, $p < 0.001$) is significantly stronger than that among liberal arts students $\beta = 0.39$, $p = 0.002$). The difference in model fit is $\Delta\chi^2=5.27$（p=0.022, suggesting that the logical nature of science and engineering thinking is more conducive to cross - disciplinary knowledge transfer, providing evidence in support of H4a.

4.3.3.2. Moderating Role of Openness to Experience (Z2)

Findings from hierarchical regression analysis reveal that the interaction term between motivation stimulation and openness to experience has a significant impact on critical thinking ($\beta=0.26$，$p=0.008$). Specifically, for students with higher levels of openness to experience, motivation stimulation has a stronger positive effect on critical thinking (in the high - openness group,$\beta=0.45$ vs; in the low - openness group,$\beta=0.29$), thus supporting H4b.

Table 8.
Moderating Effect Test Results.

Hypothesis	Moderator Variable	Grouping / Parameter	Standardized Coefficient	p – value	Difference / Interaction Term	Conclusion
H4a	Z1	Science and engineering students	0.58	<0.001	$\Delta\chi^2=5.27$（p=0.022）	Supported
		Arts and humanities students	0.39	0.002		
H4b	Z2	High openness group	0.45	-	$\beta=0.26$（p=0.008）	Supported
		Low openness group	0.29	-		

Overall, the empirical findings suggest that the innovation and entrepreneurship education in higher education institutions influences students' innovative thinking through three pathways: "Curriculum System → Knowledge Integration → Fluency/Flexibility of Thinking", "Practical Activities → Metacognitive Development → Originality of Thinking", and "Campus Culture →

Motivation Stimulation → Critical Thinking". Notably, professional background and personality traits exhibit significant moderating effects within this framework.

5. Discussion and Recommendations

5.1. Research Findings

This study developed a three - stage analytical framework of "input - transformation - output" to systematically explore the influence mechanism of innovation and entrepreneurship education in higher education institutions on students' innovative thinking. The empirical results are as follows:

5.1.1.The Direct Effects of Educational Factors on Cognition and Motivation Are Significant

The curriculum system (knowledge dimension) lays the foundation for the fluency and flexibility of thinking by enhancing knowledge integration ability (β= 0.42). Practical activities (skill dimension) significantly boost the originality of thinking by promoting metacognitive development (β= 0.48). Campus culture (environmental dimension) strengthens the criticality of thinking by stimulating intrinsic motivation (β= 0.39). This validates the interactive relationship between educational factors and individual cognitive transformation and supports the core idea in systems theory that "synergistic factors act on system output".

5.1.2. The Mediating Mechanisms Exhibit Distinct Path Characteristics

The mediating effect of knowledge integration between the curriculum system and the flexibility of thinking (0.21) is stronger than its effect on the fluency of thinking (0.15), indicating that knowledge integration is more effective in enhancing the breadth rather than the quantity of thinking. The mediating effect of metacognitive development between practical activities and the originality of thinking is the most substantial (0.27), highlighting the crucial path of "practical training → cognitive monitoring → novel output". The mediating effect of motivation stimulation between campus culture and the criticality of thinking (0.15) corroborates the transmission logic of "environmental support → intrinsic motivation → in - depth reflection" in motivation theory.

5.1.3. The Moderating Effects of Individual Differences Are Prominent

Professional background moderates the relationship between knowledge integration and the flexibility of thinking. Due to their advantage in logical reasoning, for science and engineering students, the promoting effect of knowledge integration on the flexibility of thinking (β = 0.58) is significantly stronger than that of liberal arts students (β= 0.39). For students with a higher level of openness, the enhancing effect of motivation stimulation on the criticality of thinking is more pronounced (in the high - openness group, β= 0.45; in the low - openness group, β= 0.29), which validates the theoretical prediction of "trait - environment interaction" in cognitive psychology.

5.2. Recommendations

Based on the research findings, the following suggestions are put forward to enhance the effectiveness of innovation and entrepreneurship education in cultivating students' innovative thinking in higher education institutions:

5.2.1. Establish a"Three - Dimensional Coordinated" Curriculum System to Strengthen Knowledge Integration Capabilities

Content modernization: Incorporate industry trends and interdisciplinary knowledge into course modules (for example, add business model design courses for science and engineering majors and basic data analysis courses for liberal arts majors) to improve the relevance and applicability of knowledge.

Interactive teaching methods: Promote participatory teaching methods such as case - based teaching and field research. Facilitate knowledge recombination through group discussions and brainstorming.

Diversified evaluation: Replace single - form examinations with a combination of "process - oriented evaluation + ability portfolio", with an emphasis on evaluating students' ability to solve complex problems using multidisciplinary knowledge.

5.2.2. Deepen the "Cognitive Activation" Function of Practical Teaching to Promote Metacognitive Development

Enhance practical depth: Shift from "competition participation" to "full - cycle project management". Require students to be deeply involved in market research, solution iteration, and risk assessment to activate self - monitoring and reflection capabilities.

Strengthen mentor guidance: Establish a regular feedback mechanism between mentors and students, focusing on guiding the thinking process (e.g., "Did you overlook cost factors in the feasibility assessment of your plan?") rather than simply focusing on the outcome.

Improve resource support: Expand the coverage of practical resources. Set up an "innovation tolerance fund" to encourage students to improve their cognitive regulation abilities through trial and error.

5.2.3. Foster An "Inclusive - Motivating" Campus Culture to Stimulate Continuous Innovation Motivation

Strengthen process - oriented incentives: Improve the recognition mechanism for innovation and entrepreneurship achievements. Add awards such as the "Best Creative Iteration Award" and the "Interdisciplinary Collaboration Award" to reduce the over - emphasis on the utilitarian aspects of achievements.

Create a failure - tolerant atmosphere: Reduce students' fear of failure through activities such as campus innovation forums and failure case sharing sessions.

Build an innovative community ecosystem: Support cross - disciplinary students in forming innovative teams. Strengthen the social recognition of motivation through knowledge sharing and collaboration.

5.2.4. Implement A "Differentiated" Cultivation Strategy to Adapt to Individual Trait Differences

Optimize educational programs by major: For science and engineering majors, strengthen training in "logical reasoning + cross - disciplinary association" (e.g., design projects integrating engineering technology and business ethics). For liberal arts majors, focus on cultivating "contextual insight + solution implementation" abilities (e.g., carry out cultural IP commercialization practices).

Consider personality traits: Provide challenging innovation tasks for students with high openness (such as incubating self - entrepreneurship projects). For students with low openness, adopt a "step - by - step guidance" approach (from simulated entrepreneurship to real projects) to gradually increase their risk acceptance.

6. Conclusion and Future Research

6.1. Conclusion

This study, grounded in the "input - transformation - output" framework, systematically uncovers the impact mechanism of innovation and entrepreneurship education in higher education institutions on students' innovative thinking. The research findings indicate that the curriculum system exerts a positive influence on the fluency and flexibility of thinking through knowledge integration. Practical activities enhance the originality of thinking via metacognitive development. Campus culture strengthens the criticality of thinking by means of motivation stimulation. These three elements form a precise matching path of "factors - mediators - thinking characteristics".

Simultaneously, the professional background moderates the relationship between knowledge integration and thinking flexibility, with a more pronounced promoting effect among science and engineering students. Openness to experience moderates the relationship between motivation stimulation and thinking criticality, and the enhancement effect is more remarkable for individuals with a high level of openness. This research offers systematic evidence for comprehending the connection between innovation and entrepreneurship education and innovative thinking, and also provides a theoretical foundation for educational practice.

6.2. Prospects

6.2.1. Research Limitations

The sample shows disciplinary bias, with a relatively large proportion of students from business and economics disciplines. This may lead to an overestimation of the role of the curriculum system and affect the disciplinary generalizability of the conclusions. The use of a cross - sectional research design makes it challenging to capture the dynamic interactions between educational factors and innovative thinking, and it is impossible to completely rule out reverse causality (for example, students with more active innovative thinking may be more likely to participate in practical activities). Openness to experience is inferred from behavioral tendencies rather than measured using standardized scales, which may introduce measurement errors.

6.2.2. Future Research

In terms of research design, longitudinal research (such as following freshmen over a four - year period) can be employed, coupled with diary methods to document the dynamic development of innovative thinking, thereby clarifying causal relationships. Methodologically, a combination of experimental methods (such as randomly assigning course intervention programs) and qualitative research (such as interviews with innovation teams) can be used to reveal the micro - level influence processes. Regarding variable dimensions, moderating variables such as family entrepreneurial background and the educational characteristics of institutions can be incorporated to explore the interactive effects of "education - individual - environment".

In practice, an "assessment tool for cultivating innovative thinking" can be developed to provide higher education institutions with a closed - loop diagnostic - optimization guidance, thus enhancing the precision of educational interventions.

In summary, while this study has revealed the specific pathways through which innovation and entrepreneurship education impacts innovative thinking, continuous expansion in research methods and perspectives is still required to better meet the contemporary needs of cultivating innovative talents.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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