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A Study on the Influence of Critical Thinking Ability on Academic Achievement of Chinese College Students----Academic Emotion as a Mediator

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Abstract:
This study conducts an in-depth analysis of the impact of critical thinking skills on academic achievement among Chinese university students through a large-sample survey, using academic emotions as a mediating variable and achievement motivation as a moderating variable. The aim is to explore the correlations among the three variables: critical thinking skills, academic emotions, and academic achievement, as well as the mediating effect of academic emotions between critical thinking skills and academic achievement. The research involved 1,778 participants from regular undergraduate and college institutions across all provinces and autonomous regions in China (excluding Taiwan, Hong Kong, and Macau). Initially, a preliminary analysis was conducted on the participants' critical thinking skills, academic emotions, academic achievement, and achievement motivation. Descriptive statistical analysis, reliability and validity testing, variance analysis, correlation analysis, regression analysis, mediating variable validation analysis, path analysis, and structural equation modeling were performed using SPSS 28.0 and AMOS 28.0 software on the sample data obtained from the questionnaire. Based on the computational results, the study discusses existing issues in the development of critical thinking skills among Chinese university students concerning their academic achievement, the mediating effect of academic emotions, and the moderating effect of achievement motivation. Building on the analysis results, effective strategies to enhance university students' critical thinking skills and improve academic achievement are proposed by clarifying the structural relationships among the traits of critical thinking, academic emotions, and academic achievement. The findings indicate: (1) The comprehensive performance of Chinese university students in critical thinking skills, academic emotions, achievement motivation, and academic achievement is above average. (2) In terms of difference analysis: there are significant gender differences in the overall average scores of critical thinking traits and achievement motivation; however, no significant gender differences are found in the overall average scores of academic achievement and academic emotions. Two dimensions of critical thinking traits—open-mindedness and confidence in critical thinking—show significant differences based on professional categories; significant differences are observed in the overall average scores of critical thinking traits, academic achievement, and academic emotions among different professional categories, while no significant differences are found in the overall average scores of

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achievement motivation across professional categories. Regarding grade differences, no significant differences are observed among university students' critical thinking traits, academic achievement, learning emotions, and achievement motivation across different grade levels. However, significant differences exist in the dimensions of systematic ability, learning ability, and motivation to avoid failure. (3) There are correlations among the three variables of critical thinking skills, academic achievement, and academic emotions, with a moderate positive correlation between critical thinking skills and academic emotions, and a weak positive correlation between academic achievement and academic emotions. (4) Critical thinking skills significantly positively influence academic achievement; critical thinking skills significantly positively influence academic emotions; positive academic emotions significantly positively influence academic achievement, while negative academic emotions also significantly positively influence academic achievement (H3b). Academic emotions play a mediating role between critical thinking skills and academic achievement, exhibiting a certain masking effect. Universities should explore and implement targeted strategies to enhance students' critical thinking skills, improve academic achievement, and reduce negative academic emotions. Improving students' critical thinking skills and critical thinking requires a multi-dimensional integration of strategies. Collaborative efforts across all aspects, from curriculum design and teaching methods to teacher training, can provide a conducive environment for students' cognitive development. This not only aids students' success in academic fields but also lays the foundation for their ability to think independently and make rational decisions in their future careers.

Keywords:
Critical thinking skills; academic achievement; academic emotions; correlation study; mediating effect; masking effect

1. Introduction

1.1 Research Necessity

Under the background of globalization, the competition between countries depends on the comprehensive national strength, and its essence is the competition of talents, especially the confrontation of critical thinking ability. Critical thinking ability is an important part of primary and secondary education in the world in the 21st century, and it is one of the core abilities that students of all disciplines should possess. In recent years, critical thinking ability and its cultivation have been widely concerned by the academic circles, and many excellent research results have emerged at home and abroad. As far as this study is concerned, promoting the development of critical thinking ability at the undergraduate stage from the perspective of multiple intelligences theory is the connotation of educational management, the trend of a new round of scientific and technological revolution, and the requirement of economic and social development for talents, which is of great significance for deepening the reform of higher education.

As a necessary skill in the 21st century, foreign language ability is not only conducive to enhancing international discourse power and influence, but also related to the realization of national strategies such as "The Belt and Road Initiative" and "Chinese culture going out" (Hu Zhuanglin 2015). There are many factors affecting the development of foreign language ability, among which critical thinking is an important factor affecting the development of foreign language ability (Heidari 2020; Liang & Fung 2021).

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In recent years, the cultivation of critical thinking ability has attracted great attention in the field of foreign language education in China. National Standards for Teaching Quality of Foreign Languages and Cultures (GB), College Foreign Language Teaching Guide (2020 Edition) (Guide), The English Curriculum Standards for Senior High Schools (2017 Edition), the New Curriculum Standards for Basic Education, the English Curriculum Standards for Compulsory Education (2022 Edition) and the New Curriculum Standards for Compulsory Education all clearly regard the cultivation of critical thinking ability as an important goal of high-quality foreign language education in the new era of China.

Investment in the cultivation of critical thinking ability is a key element of innovation-driven development strategy. The Eighteenth National Congress of the Communist Party of China clearly put forward the strategy of innovation-driven development, which is an inevitable choice for the Party and the state to cope with environmental changes at home and abroad, enhance international competitiveness and sustainable development ability. To implement innovation-driven development, the core is innovation, the foundation is science and technology, and the key is talent. Whether it is to implement the strategy of innovation-driven development or to promote scientific and technological innovation, the investment in the cultivation of critical thinking ability is the key factor.

Promoting the gradual improvement of critical thinking ability is an important task for the reform and development of higher education. As the most important "transferable ability", critical thinking ability is the most typical feature of a highly educated intellectual. Nowadays, the cultivation of students' critical thinking ability has become the common mission pursued by world-class universities and first-class disciplines. One of the themes of the reform and development of Chinese universities in the future will be to vigorously improve the quality of personnel training, and the cultivation of critical thinking ability will become an important indicator to measure the quality of personnel training in universities, and should become the core goal of all teaching activities in universities. At the same time, it should also become an important task for the reform and development of higher education.

The effective integration of critical thinking training into the skill curriculum has become an important issue in the current teaching reform of English majors. How to effectively integrate speculative training into skills courses is an important issue in the current teaching reform of English majors (Wen Qiufang, Sun Min, 2015). With the development of society, the basic language level of contemporary college students has been greatly improved when they enter college English majors, and the amount of information they occupy has also increased rapidly due to various media in the information society. Therefore, the traditional curriculum, which is designed according to language points and emphasizes language acquisition, gradually fails to meet the needs of the new era. Traditional curriculum knowledge is random, scattered and pedigree is not strong (Feng Yan, 2006: 33-35), while the new era requires English majors to consolidate their language foundation, expand their knowledge, and more importantly, make them learn to think and judge, and lay the foundation for further study and even lifelong learning. Under this consensus, some leading foreign language universities and scholars have begun to try to introduce the cultivation of "critical thinking ability" (also known as "critical thinking ability") into the teaching of professional English, hoping to develop students' thinking ability in addition to language skills. Some researchers have carried out quite solid work on the specific definition of "critical thinking ability" (Wen Qiufang and Wang Jianqing, 2009: 37-43).

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1.2 Research Purpose

This study intends to analyze the influence of college students' critical thinking ability on their academic achievement through large sample statistics, with academic emotions as the mediating variable. The purpose is to explore the relationship between critical thinking ability, academic emotion and academic achievement of college students. The mediating effect of academic emotion between critical thinking ability and academic achievement. Finally, on the basis of empirical conclusions, this paper explores a series of strategies and suggestions to effectively improve the level of college students' critical thinking ability.

1.3 Research Questions

In view of the need to promote the development of students' critical thinking ability in colleges and universities in practice, and to further explore the relationship among critical thinking ability, academic emotion and academic achievement in theory, based on the above research objectives, this study mainly takes college students as the research object, focusing on the following five research questions:

(1)What is the relationship among college students' critical thinking ability, academic emotion and academic achievement?

(2)What is the relationship between critical thinking ability and academic achievement of college students?

(3)What is the relationship between college students' critical thinking ability and academic emotions?

(4)What is the relationship between academic emotion and academic achievement?

(5)How does academic emotion mediate the relationship between critical thinking and academic achievement?

2. Theoretical Background

2.1 Theoretical Basis

1) Information Processing Theory

Cognitive Information Processing Theory (CIP) is an important concept in cognitive psychology. It mainly focuses on how individuals make decisions in their career development and how they use information to solve problems. The theory originated in the 1950s. With the development of computer science, psychologists began to compare the human cognitive process to the information processing mode of computers. This theory was developed by Gary Peterson, James Sampson and Robert Reardon (1991) Career Development and Services: A Cognitive Approach. Especially in the field of career decision-making and career counseling.

2) Rational-emotional Theory

Rational-Emotive Behavior Therapy (Rational Emotive Behavior Therapy, REBT) is a cognitive-behavioral therapy developed by Albert Ellis in the 1950s. It's reasonable the theory emphasizes the relationship between thinking, emotion and behavior, and holds that unreasonable thinking is the main cause of emotional

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distress and behavioral problems. REBT believes that people's emotional problems stem primarily from their irrational beliefs and evaluations of events, not the events themselves. Ellis proposed the ABC model in 1991, which has become the core tool for understanding and applying rational-emotional behavior therapy.

3) Control-value Theory

Pekrun et al. (2002) selected the most frequent academic emotions of college students based on questionnaire and interview data, and divided academic emotions into four types of emotions: positive high arousal, negative high arousal, positive low arousal and negative low arousal from the two dimensions of valence (positive and negative) and pleasure (arousal degree). According to this classification, the Academic Emotion Questionnaire (AEQ) was developed. At the same time, they found that the generation of academic emotions is related to the environmental variables of students' learning, the sense of control and the evaluation of value, so they put forward the Control-Value Theory (CVT) to explain the source of academic emotions. On this basis, Pekrun et al. (2006) expanded the theory from three dimensions of valence, arousal degree and arousal object.

4) Cognitive-motivational Model

In 2002, Pekrun et al. Reanalyzed the Cognitive-Motivational Model (CMM) proposed by Pekrun et al. (1992) based on the measured Academic Emotion Questionnaire (AEQ) data. It further explains how academic emotions affect academic performance through cognitive and motivational mechanisms, and then positive and negative feedback from academic performance to environmental variables, personal cognitive evaluation and academic emotions. The cognitive-motivational model shows that academic emotions will affect learners' academic performance through learning motivation and cognitive resources, and academic performance will in turn affect academic emotions through learning motivation and cognition, which proves that there is a certain correlation between academic emotions and academic performance, and provides theoretical support for this paper to explore the correlation between different characteristics of academic emotions and academic performance.

2.2 Advance research and analysis

1) Critical Thinking Ability

(1) The Concept and Theoretical Framework of Critical Thinking

"Critical thinking skills" are widely used in the West. Many scholars in China translate it as "critical thinking ability". Wen Qiufang (2008) points out that the translation distorts the original meaning. "Critical" comes from two Greek roots: one is "kritikos", meaning "discerning judgment"; The other is "kritrion", meaning "standard", which means "using appropriate evaluation criteria, conscious thinking, and ultimately making informed judgments" (Paul & Elder 2006:20). Wen Qiufang (2008) suggested that "critical thinking skills" should be translated as "high-level thinking skills". Later, when she discussed the translation of the term with researchers at the China Foreign Language Education Research Center, they agreed with her that the translation of "critical thinking ability" was misleading, but they did not agree with the translation of "high-level thinking ability" because it could easily lead to too broad interpretation. They suggested that it be translated as "critical thinking ability".

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(2) Research on Critical Thinking Abroad

In recent years, the study of critical thinking in learning has attracted wide attention in the world. The following are the main ones. Summary of research results: The importance of critical thinking in language learning: Critical thinking is considered to be the key to improving language skills and overall cognitive ability. It helps learners to monitor and evaluate their own learning process and thus acquire the language more effectively (Frontiers). The study shows that integrating critical thinking into language teaching can significantly improve students' communicative competence and cultural understanding (Frontiers). Critical Thinking as a Teaching Approach: Effective critical thinking instruction often includes task-based activities, problem-solving exercises, and opportunities for self-directed learning. These methods encourage students to actively participate in the course content and to think independently (Frontiers). Teachers play a key role in developing students' critical thinking ability. They need to create an environment that encourages inquiry, reflection and creative thinking, not just teaching grammar and vocabulary, but also decision-making and self-evaluation strategies (ERIC). Impact on classroom engagement and academic success: Research has shown a positive relationship between critical thinking and student engagement in the classroom. Students with strong critical thinking skills are more likely to participate actively in classroom activities and perform better academically (Frontiers). It was also found that critical thinking enhances students' self-confidence and helps them see problems from multiple perspectives to come up with innovative solutions (Frontiers).

(3) Research on Critical Thinking Ability in China

In recent years, the research on critical thinking in foreign language learning has gradually increased in China, mainly focusing on the influence of critical thinking on foreign language learning and its related factors. The following is a summary of the main research results: Critical thinking ability and foreign language achievement: a number of studies have shown that critical thinking ability is positively related to foreign language achievement. Students with strong critical thinking ability show higher understanding and application ability in foreign language learning, especially in reading and writing. These studies emphasize the importance of developing students' critical thinking to improve foreign language learning effectiveness. Teaching methods and critical thinking ability: Domestic researchers have also explored the impact of different teaching methods on students' critical thinking ability. The results show that task-based teaching method, project-based learning and discussion method can effectively improve students' critical thinking ability. These methods encourage students' self-inquiry, cooperative learning and critical thinking, and help to develop their comprehensive language ability and critical thinking ability (GitHub). Assessment of critical thinking ability: In terms of assessment, researchers have developed a variety of tools and scales to assess students' critical thinking ability. These tools include not only the traditional written examination and questionnaire, but also dynamic assessment and situational simulation to get a more comprehensive understanding of the students' critical thinking ability level and its performance in actual language use. Research on influencing factors: Domestic studies have also explored a variety of factors that affect students' critical thinking ability, including cognitive style, learning motivation, teacher feedback and classroom interaction. The study found that positive learning motivation and high-quality teacher feedback can significantly improve students' critical thinking ability, while interaction and cooperative learning in the classroom also play an important role (GitHub).

(4) Literature Review

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Based on the research at home and abroad, the importance of critical thinking in foreign language learning cannot be ignored. Foreign research provides rich teaching methods and theoretical support, emphasizing the cultivation of students' critical thinking ability through diversified teaching activities and classroom environment. Domestic research has verified the effectiveness of these methods through empirical research, and developed evaluation tools suitable for local educational environment. Although the research has achieved some results, it is still necessary to further explore how to systematically integrate critical thinking teaching into foreign language courses, develop standardized assessment tools, and conduct in-depth research. Reflect the various factors of critical thinking ability, so as to improve students' foreign language learning effect in an all-round way. The role of critical thinking in foreign language learning has been widely recognized. Future research should continue to deepen the exploration of critical thinking training methods, develop more effective assessment tools, and pay attention to the influence of different factors on the development of critical thinking ability, so as to provide more powerful theoretical and practical support for foreign language teaching. Through these efforts, we can better help students achieve excellent results in foreign language learning, while improving their comprehensive quality and critical thinking ability.

2)Academic Emotion

(1) The Concept of Academic Emotion

Academic emotions refer to various emotional States experienced by students in academic activities, including positive emotions (such as pride and happiness) and negative emotions (such as anxiety and depression). According to the control-value theory proposed by Pekrun (2006), academic emotions come from students' evaluation of their sense of control and value in learning activities. Academic emotions play an important role in learning motivation, learning strategies and academic achievement.

(2) Research on Academic Emotions Abroad

The research on academic emotions abroad mainly focuses on its impact on academic achievement. Through a large number of empirical studies, Pekrun et al. (2011) found that positive academic emotions such as happiness and pride are positively correlated with academic achievement, while negative academic emotions such as anxiety and anger are negatively correlated with academic achievement. In addition, academic emotions were also found to have a significant effect on students' learning strategies and motivation.

(3) Research on Academic Emotions in China

Domestic scholars have also conducted extensive research on academic emotions. Li Hong (2012) found that college students' academic emotions are significantly related to their academic achievements. Positive emotions can promote academic achievements, while negative emotions can inhibit academic performance. Zhang Wei (2016) further explored the mediating effect of academic emotions on learning motivation and learning strategies, and verified the applicability of control-value theory in Chinese context.

(4) Literature Review

To sum up, academic emotions play a key role in academic achievement. Although foreign studies are more systematic and in-depth, domestic studies are gradually enriched and improved. However, the performance of

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academic emotions in different cultural contexts and its specific mechanisms still need to be further explored.

3) Academic achievement

(1) The Concept of Academic Achievement

Academic achievement refers to the level of achievement or achievement of students in the learning process, which is usually measured by test scores, academic performance and other indicators. Academic achievement is not only an important manifestation of educational results, but also a key criterion for evaluating the quality of education.

(2) Research on Academic Achievement Abroad

In terms of academic achievement, foreign studies mainly focus on the influencing factors and their mechanisms. The social psychological model proposed by Gardner (1985) points out that motivation, self-efficacy and learning strategies are important factors affecting academic achievement. In addition, D'Dörnyei (2005) highlighted the impact of learning environment and teacher support on academic achievement.

(3) Research on Academic Achievement in China

Domestic studies have paid more attention to the characteristics of Chinese students' English learning. Liu Yang (2010) found that academic achievement was significantly influenced by learning motivation, learning strategies and family background. Wang Ting (2014) pointed out the mediating role of self-efficacy in English learning achievement through empirical research, which further verified the applicability of foreign related theories in Chinese context.

(4) Literature Review

On the whole, the influencing factors of academic achievement are complex and diverse, and foreign and domestic studies have made important progress in theory and empirical. However, how to further reveal the formation mechanism of their academic achievement according to the specific situation of Chinese students is still an important direction for future research.

4) Achievement Motivation

(1) The Concept of Achievement Motivation

Achievement motivation refers to the internal driving force shown by individuals in the process of pursuing excellence and achieving goals. Achievement motivation is one of the important contents of educational psychology research, which affects individual learning behavior, learning strategies and academic achievement.

(2) Research on Achievement Motivation in Foreign Countries

Achievement motivation has been widely studied by foreign scholars. McClelland (1961) pointed out that individuals with high achievement motivation are more likely to set high standards and pursue success. The research of Eccles and Wigfield (2002) shows that there is a significant positive correlation between achievement motivation and academic achievement, and indirectly affects academic performance by affecting learning strategies and self-efficacy.

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(3) Research on Achievement Motivation in China

Domestic studies also focus on the impact of achievement motivation on academic achievement. Chen Ming (2009) found that achievement motivation significantly predicted the academic achievement of college students and mediated through self-efficacy and learning strategies. Li Li (2015) further explored the multi-dimensional structure of achievement motivation and verified the different effects of different components on academic achievement.

(4) Literature Review

Overall, the important role of achievement motivation in academic achievement is widely recognized. Foreign studies are more systematic in theoretical construction and empirical verification, while domestic studies have gradually followed up and put forward research results with local characteristics. However, the multidimensional structure of achievement motivation and its performance in different cultural contexts still need to be further explored.

5) The Relationship Between the Four Variables

(1) A Study on the Correlation Between Critical Thinking Ability and Academic Achievement

Foreign studies have shown that there is a significant positive correlation between critical thinking ability and academic achievement. Facione (1990) pointed out that students with strong critical thinking ability have more advantages in academic performance. Halpern (2003) The study further shows that critical thinking ability not only directly affects academic achievement, but also indirectly promotes academic achievement by improving students' learning strategies and problem-solving ability. Domestic studies have also verified the positive impact of critical thinking on academic achievement. Zhang Jing (2011) found that the critical thinking ability of college students was positively correlated with their academic performance. Liu Xia (2015) pointed out that critical thinking ability indirectly affects academic achievement by affecting learning motivation and learning strategies. To sum up, the influence of critical thinking ability on academic achievement has been verified both at home and abroad. Foreign studies focus on the construction and validation of theoretical models, while domestic studies pay more attention to the collection and analysis of empirical data. Future research should further explore the specific mechanism of critical thinking ability in academic achievement in the light of different cultural backgrounds.

(2) Research on the Correlation Between Critical Thinking Ability and Academic Emotion

Foreign studies have shown that there is a significant correlation between critical thinking ability and academic emotions. Ennis (1996) found that students with high critical thinking ability are better at managing and regulating their academic emotions. Bailin's (2002) research shows that critical thinking helps students maintain positive emotions and reduce negative emotions in the face of academic challenges. Domestic scholars have also found similar results. Through empirical research, Wang Qiang (2013) found that college students with high critical thinking ability showed more positive emotions and less negative emotions in academic emotions. The research of Chen Lei (2018) further points out that critical thinking can improve students' academic emotions by enhancing their self-efficacy. To sum up, the positive influence of critical thinking ability on academic emotions has been supported in both domestic and foreign studies. Foreign studies

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emphasize the role of critical thinking in emotion regulation, while domestic studies have been empirically verified in the local context. Future research should further explore the specific path and mechanism of critical thinking ability affecting academic emotions.

(3) A Study on the Correlation Between Academic Emotion and Academic Achievement

Foreign studies have shown that academic emotions have a significant impact on academic achievement. Pekrun (2006) pointed out that positive academic emotions such as pride and happiness are positively correlated with academic achievement, while negative emotions such as anxiety and depression are negatively correlated with academic achievement. Since then, further studies have confirmed this point, indicating that academic emotions indirectly affect academic achievement by affecting learning motivation and strategies. Domestic scholars have also explored this relationship. Li Ming's (2011) research shows that positive academic emotions significantly promote the academic achievement of college students, while negative emotions significantly inhibit their academic performance. The research of Zhang Wei (2016) found that academic emotions indirectly affect students' academic achievement by affecting their learning strategies and self-efficacy. To sum up, the relationship between academic emotion and academic achievement has been fully verified in domestic and foreign studies. Although the research has made breakthroughs in both theoretical and empirical aspects, it is still necessary to further explore the specific manifestations of academic emotions in different cultural backgrounds and their long-term effects on academic achievement.

(4) Academic Emotion as a Mediator between Critical Thinking and Academic Achievement

Previous studies have shown that academic emotions play a mediating role between critical thinking and academic achievement. Foreign studies such as Bong (2004) point out that critical thinking ability further promotes academic achievement through positive academic emotions. Similar results have been found in domestic studies. Zhang Wei (2016) verified the mediating effect of academic emotions between critical thinking ability and academic achievement. Future studies should further explore the specific pathways and mechanisms of this mediating role, especially. It is the applicability in different cultural backgrounds.

(5) Achievement Motivation Plays a Moderating Role between Academic Emotion and Academic Achievement

Achievement motivation is considered to be an important factor in regulating the relationship between academic emotions and academic achievement. Schunk (2001) found in foreign studies that students with high achievement motivation were less affected by academic emotional fluctuations. Domestic studies such as Li Li (2015) have also confirmed the moderating role of achievement motivation, pointing out that high achievement motivation can alleviate the negative impact of negative academic emotions on academic achievement. Future research should continue to explore the specific regulatory mechanisms of achievement motivation and their applicability in different cultural contexts.

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3. Research Method

3.1 Research Model and Hypothesis

1) Research Model

In this study, critical thinking ability was the independent variable, academic achievement was the dependent variable, and academic emotion was the mediating variable. The study model is shown in Figure 1.

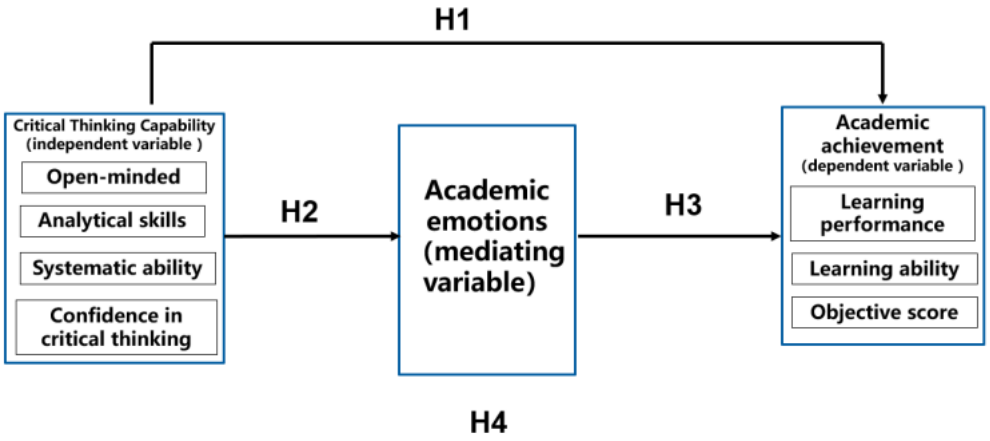


Figure 1 Study model

2) Research Hypothesis

The research hypothesis of this study aims to investigate the relationship among college students' critical thinking ability, academic emotions, academic achievement, and achievement motivation. Based on the previous research on this topic, the following 11 hypotheses are put forward:

H1: College students' critical thinking ability has a significant positive impact on academic achievement

H1a: Open mind has a significant positive impact on academic achievement

H1b: Analytical ability has a significant positive impact on academic achievement

H1c: Systematic ability has a significant positive impact on academic achievement

H1d: Critical thinking confidence has a significant positive effect on academic achievement.

H2: College students' critical thinking ability has a significant positive impact on academic emotions.

H2a: Open mind has a significant positive effect on academic emotions

H2b: Analytical ability has a significant positive effect on academic emotions

H2c: Systematic ability has a significant positive effect on academic emotions

H2d: Critical thinking self-confidence has a significant positive effect on academic emotions

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H3: Academic emotion has a significant positive effect on academic achievement

H3a: Positive academic emotion has a significant positive effect on academic achievement

H3b: Negative academic emotion has a significant negative effect on academic achievement

H4: Academic emotion plays a mediating role between college students' critical thinking ability and academic achievement

3.2 Research Participants

The formal research participants of this study are undergraduates and junior college students in China, and the random sampling method is used. From July 2024 to August 2024, questionnaires were sent out in the form of online questionnaires, and 1785 questionnaires were finally collected. After the obvious tendency to answer and more than 20% of the missing answers were excluded as invalid questionnaires, 1778 valid questionnaires were collected, and the effective recovery rate was 99.607%. The sample sources of the respondents are extensive, covering all provinces and autonomous regions except Taiwan, Hong Kong and Macao, as shown in Figure 2.



Figure 2 Analysis of Sample Sources of Research Participants

3.3 Research Tools

This study used four scales in the empirical investigation: Critical Thinking Trait Scale, Academic Emotion Scale, Academic Achievement Scale and Achievement Motivation Scale, all of which adopted the mature scale with high reliability and validity, and at the same time made localized adjustment and transformation. In this study, the reliability, exploratory factor analysis, convergent validity and discriminant validity of the four scales were tested. The data of empirical investigation were input and processed by SPSS 28.0 and AMOS 28.0.

1) Critical Thinking Ability Scale

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In this study, the Chinese version of the California Critical Thinking Inventory (CTDI-CV) developed by Pan Wei and Pan Shengxiang (2002) was used to measure and assess the critical thinking traits of college students. They translated and culturally adapted the original version of the scale to apply it to the assessment of Chinese students' critical thinking traits and critical thinking tendencies. According to the characteristics of the subjects, the researcher adjusted the dimensions of the scale and the items of each dimension in order to make the scale more suitable for measuring the characteristics of critical thinking ability and critical thinking tendency of the subjects. As shown in Table 1, there are 20 items in the scale, including 5 items of open-mindedness and 5 items of analytical ability. There are five dimensions of systematic ability and five dimensions of self-confidence in critical thinking. Five-point Likert was used to score each item.

Critical Thinking Trait Overall Scale Cronbach alpha coefficient is 0.815, which means the reliability is good. Cronbach α = 0.854 for the dimension of open-mindedness, Cronbach α = 0.853 for the dimension of analytical ability, Cronbach α = 0.850 for the dimension of systematic ability, and Cronbach α = 0.816 for the dimension of self-confidence in critical thinking. The results of exploratory factor analysis showed that KMO = 0.799, higher than 0.7; Bartlett's sphericity test chi-square = 6061.185, its significance level is less than 0.001 ($p < 0.001$), which means that the critical thinking ability is suitable for factor analysis. After rotating by the maximum variance method, four factors are extracted, and the cumulative variance explanation rate is 73.603%. It means that the construct validity of the critical thinking trait scale is good.

Table 1 Research Dimensions and Items distribution of Critical Thinking Ability Scale

Scale Dimensions	**Number of items**	**Corresponding item**
Open-mindedness Dimension	5	S1，S4，S5，S3，S2
Analyticity Dimension	5	S6，S7，S8，S9，S10
Systematicity Dimension	5	S11，S15，S13，S12，S14
The Self-Confidence Dimension of Critical Thinking	5	S16，S20，S19，S17，S18
Total	**20**	------

(1) Reliability Test

In this study, the internal consistency reliability of the formal survey data was tested. Internal consistency reliability refers to the degree of consistency among all items in the scale, and Cronbach's alpha coefficient is used to express internal consistency reliability. The results of Cronbach reliability analysis of College Students' Professional Identity Scale are shown in Table 2.

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Table 2 Cronbach Reliability Analysis of Critical Thinking Ability Scale

Scale Dimensions	Dimensions Cronbach α	Overall scale Cronbach α
Open-mindedness Dimension	0.854	0.815
Analyticity Dimension	0.853	
Systematicity Dimension	0.850	
The Self-Confidence Dimension of Critical Thinking	0.816	

It can be seen from Table 2 that the Cronbach's alpha coefficient of the overall scale of critical thinking traits is 0.815, and the Cronbach's alpha coefficient of each dimension of self-confidence in open thinking, analytical ability, systematic ability and critical thinking is between 0.816 and 0.854. It shows that the internal consistency of the critical thinking ability quality scale is very high, which enhances the reliability of the measurement tool.

(2) Confirmatory Factor Analysis

In this study, confirmatory factor analysis (confirmative factor analysis, CFA) was conducted on the formal survey data of College Students' Critical Thinking Scale, and the structure of the measurement tool was evaluated by testing the fitting model validity, see Table 3 and Figure 3.

Table 3 Model Fitting Degree of Critical Thinking Ability Scale

Common indicators	χ2	df	χ2/df (Chi-square Degrees of Freedom)	GFI	RMSEA	RMR
Criteria for judgment	-	-	<3	>0.9	<0.10	<0.05
This model value	2772.917	164	2.692	0.936	0.095	0.080
Other indicators	TLI	AGFI	PGFI	PNFI	PCFI	SRMR
Criteria for judgment	>0.9	>0.9	>0.9	>0.8	>0.9	<0.1
This model value	0.920	0.990	0.953	0.822	0.929	0.079

The model fitting indexes of each dimension in the critical thinking ability quality table are shown in Table 3. The χ^2/DF ratio is 2.692, which is within the acceptable range due to the large number of samples. The values of TLI, AGFI, PGFI, PCFI, were greater than. 9, the values of SRMR were less than. 1, and the values of PNFI were close to. 9. According to the fitting degree index, the fitting degree of the critical thinking abil-

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ity special quality table is good. Each index reached or exceeded the generally accepted criteria of fit, which proved that the fit between the model and the actual data was good, and the scale of critical thinking ability had good validity in measuring different dimensions of professional identity. Therefore, the confirmatory analysis model of the critical thinking ability trait scale adopted in this study is reasonable and can be used for further analysis and research.

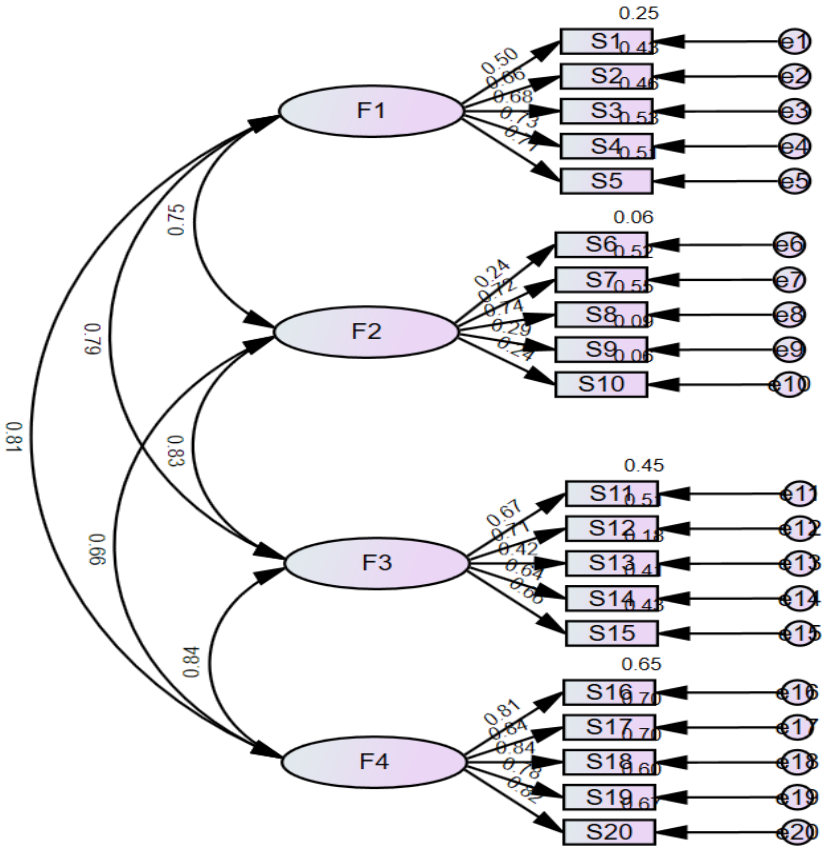


Figure 3 Confirmatory Factor Analysis Model of Critical Thinking Ability Scale

(3) Convergent Validity and Discriminant Validity

Convergent validity is used to assess the relationship between each item in the measurement tool and its corresponding latent factor. If the convergent validity is high, it indicates that the item better represents the latent factor, thus increasing the validity of the measurement tool. Discriminant validity was used to assess the correlation between different latent factors. If the discriminant validity is high, it indicates that the factors in the measurement instrument are conceptually independent rather than confused. See Table 4 and Table 5 for the convergent validity and discriminant validity of college students' critical thinking trait scale in this study.

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Table 4 Convergent Validity of Critical Thinking Ability Scale

Latent variable	Measurement item	Standard error	C.R.	p	Standard load factor	AVE	C.R.
Open-mindedness Dimension	S1	-	-	-	0.501	0.538	0.793
	S2	0.069	18.686	0.000	0.658		
	S3	0.068	18.998	0.000	0.680		
	S4	0.072	19.656	0.000	0.730		
	S5	0.068	19.441	0.000	0.713		
Analyticity Dimension	S6	-	-	-	0.540	0.555	0.774
	S7	0.277	9.017	0.000	0.723		
	S8	0.278	9.034	0.000	0.740		
	S9	0.159	7.243	0.000	0.593		
	S10	0.142	6.664	0.000	0.545		
Systematicity Dimension	S11	-	-	-	0.669	0.595	0.761
	S12	0.039	-	-	0.713		
	S13	0.043	16.161	0.000	0.523		
	S14	0.039	23.526	0.000	0.637		
	S15	0.039	24.195	0.000	0.658		
The Self-Confidence Dimension of Critical Thinking	S16	-	-	-	0.808	0.667	0.909
	S17	0.025	40.747	0.000	0.839		
	S18	0.025	40.640	0.000	0.838		
	S19	0.025	36.685	0.000	0.777		
	S20	0.025	39.548	0.000	0.821		

Note: The bar '-'indicates that the item is a reference item.

It can be seen from Table 4 that the factor load of each item in the special quality table of college students' critical thinking ability is greater than.5, indicating that the items corresponding to each latent variable are highly representative. In addition, the Average Variance Extracted (AVE) of confidence potential variables of open mind, analytical ability, systematic ability and critical thinking were greater than. 5, and the Composite

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Reliability (CR). All of them were greater than 0.7, indicating that the convergent validity of the scale was good.

Table 5 Discriminative Validity of Critical Thinking Scale: Pearson Correlation and AVE Square

	Open-mindedness Dimension	Analyticity Dimension	Systematicity Dimension	The Self-Confidence Dimension of Critical Thinking
Open-mindedness Dimension	**0.662**			
Analyticity Dimension	0.386	**0.505**		
Systematicity Dimension	0.606	0.520	**0.628**	
The Self-Confidence Dimension of Critical Thinking	0.680	0.309	0.689	**0.817**

Note: Diagonal blue numbers are AVE square root values

It can be seen from Table 5 that the characteristic scale of college students' critical thinking ability shows significant discriminant validity in the self-confidence dimensions of thinking, analytical ability, systematic ability, and critical thinking. The square root of AVE of each dimension exceeded the absolute value of the largest inter-factor correlation coefficient, which indicated that the scale could accurately measure the characteristics of college students' professional identity in different dimensions, and provided a solid foundation for further research and application.

2) Academic Achievement Scale

In this study, the measurement tool used to measure and evaluate the academic achievement of college students is the College Student Academic Achievement Scale, which is revised by Wang Yanfei, Li Yunjian and Huang Yuexin (2011) based on the employee organizational performance scale and combined with the characteristics of college students. The researcher of this subject directly quoted this scale. As shown in table 13, There are 10 items in the scale, including 2 items of learning performance, 3 items of learning ability and 5 items of objective achievement. A five-point Likert scale was used for each rating, ranging from 1 (complete nonconformance) to 5 (complete conformance). The Cronbach's alpha coefficient of the overall academic achievement scale is 0.926, which means that the reliability is good. The learning performance dimension subscale Cronbach $\alpha = 0.922$, the learning ability dimension subscale Cronbach $\alpha = 0.923$, and the objective achievement dimension subscale Cronbach $\alpha = 0.936$. The results of exploratory factor analysis showed that KMO was 0.826, higher than 0.7; The chi-square of Bartlett's sphericity test is 779.158, and its significance level is less than 0.001 ($p < 0.001$), which means that the achievement motivation is suitable for factor analysis. After rotating by the maximum variance method, three factors are extracted, and the cumulative variance explanation rate is 76.573%. It means that the construct validity of the Achievement Motivation Scale is good.

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Table 6 Distribution of Research Dimensions and Questions of Academic Achievement Scale

Scale Dimensions	Number of items	Corresponding item
Learning performance dimension	2	C1，C2
Learning ability dimension	3	C15，C16，C17
Objective achievement dimension	5	C12，C11，C14，C13，C8
Total	**10**	------

(1) Reliability Test

In this study, the internal consistency reliability of the formal survey data was tested. Internal consistency reliability refers to the degree of consistency among all items in the scale, and Cronbach's alpha coefficient is used to express internal consistency reliability. The results of Cronbach reliability analysis of College Students' Professional Identity Scale are shown in Table 7.

Table 7 Cronbach Reliability Analysis of Academic Achievement Scale

Scale Dimensions	Dimensions Cronbach α	Overall scale Cronbach α
Learning performance dimension	0.922	**0.926**
Learning ability dimension	0.923	
Objective achievement dimension	0.936	

It can be seen from Table 7 that the Cronbach's alpha coefficient of the overall academic achievement scale is 0.926, and the Cronbach's alpha coefficient of each dimension of learning performance, learning ability and objective achievement is between 0.922 and 0.9364, indicating that the critical thinking ability feature scale has high internal consistency. This enhances the reliability of the measurement tool.

(2) Confirmatory Factor Analysis

In this study, confirmatory factor analysis (confirmative factor analysis, CFA) was conducted on the formal survey data of the Academic Achievement Scale, and the construct validity of the measurement tool was evaluated by testing the fitting model, as shown in Table 8 and Figure 4.

Table 8 Model Fit of Academic Achievement Scale

Common indicators	**χ2**	**df**	**χ2/df (Chi-square Degrees of Freedom)**	**GFI**	**RMSEA**	**RMR**
Criteria for judgment	-	-	<3	>0.9	<0.10	<0.05
This model value	512.858	32	2.488	0.943	0.092	0.041
Other indicators	TLI	AGFI	PGFI	PNFI	PCFI	SRMR
Criteria for judgment	>0.9	>0.9	>0.9	>0.9	>0.6	<0.1
This model value	0.952	0.902	0.949	0.985	0.687	0.048

The model fitting indicators of each dimension of the academic achievement scale are shown in Table 8. As shown in Table 8, the χ^2/DF ratio is 2.488, which is within the acceptable range due to the large number

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of samples. The values of TLI, AGFI, PGFI, PNFI, were greater than. 9, the value of SRMR was less than. 1, and the value of PCFI was close to. 6. According to the fit index, the fit of the academic achievement scale is good. Each index reached or exceeded the commonly accepted criteria of fitness, which proved that the fit between the model and the actual data was good, and the academic achievement scale had good validity in measuring different dimensions of professional identity. Therefore, the confirmatory analysis model of the academic achievement scale adopted in this study is reasonable and can be used for further analysis and research.

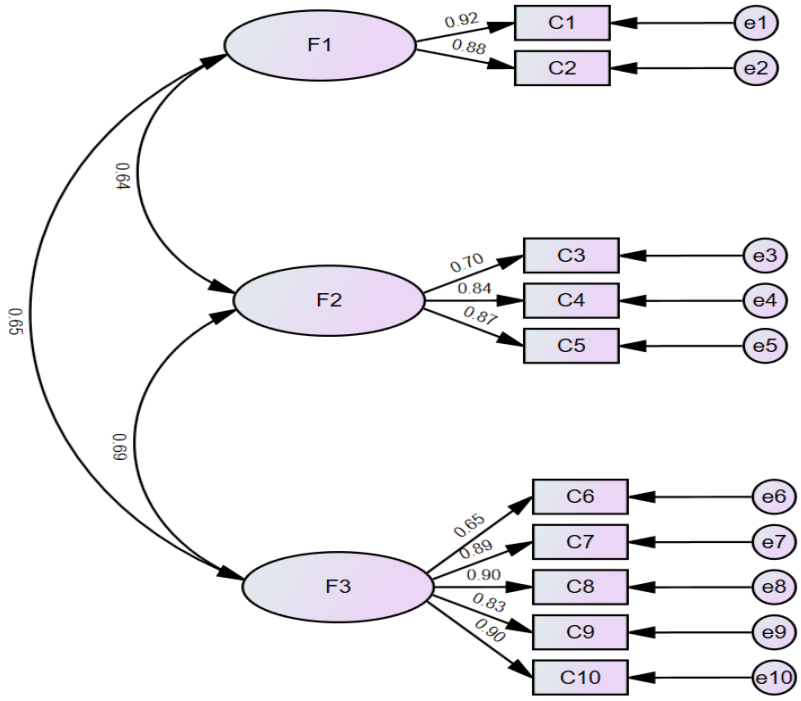


Figure 4 Confirmatory Factor Analysis Model of Academic Achievement Scale

(3) Convergent Validity and Discriminant Validity

In order to evaluate the correlation and difference between each item of the academic achievement scale and its corresponding potential factors, this study tested the convergent validity and discriminant validity of the academic achievement scale, as shown in Table 9 and Table 10.

Table 9 Convergent Validity of the Academic Achievement Scale

Latent variable	Measurement item	Standard error	C.R.	p	Standard load factor	AVE	C.R.
Learning Performance	C1	-	-	-	0.917	0.806	0.893
	C2	0.023	42.178	0.000	0.879		
Learning Ability	C3	-	-	-	0.701	0.660	0.885
	C4	0.040	31.757	0.000	0.813		
	C5	0.040	33.582	0.000	0.866		
	C6	0.037	33.363	0.000	0.859		

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Objective Achievement	C7	-	-	-	0.896	0.779	0.934
	C8	0.017	57.075	0.000	0.899		
	C9	0.020	48.294	0.000	0.831		
	C10	0.018	57.426	0.000	0.902		

Note: The bar '- 'indicates that the item is a reference item.

It can be seen from Table 10 that the factor load of each item in the academic achievement scale is greater than.5, indicating that the items corresponding to each latent variable are highly representative. In addition, the Average Variance Extracted (AVE) of the latent variables of the three dimensions of learning performance, learning ability and objective achievement were greater than. 5, and the combined reliability (CR) was greater than. 7, indicating that the convergent validity of the scale was good.

Table 10 Discriminant Validity of the Academic Achievement Scale: Pearson Correlation and AVE

	Open Mind	Analytical Ability	Systematic Ability
Learning Performance	**0.898**		
Learning Ability	0.628	**0.813**	
Objective Achievement	0.573	0.638	**0.883**

3) Academic Emotion Scale

In this study, the academic emotion scale (AEQ) (The Academic Emotion Questionnaire) developed by Pekrun et al. (2002) was used to measure and evaluate the academic emotions of college students. According to the characteristics of the subjects, the researcher adjusted the dimensions of the scale and the items of each dimension in order to make the scale more suitable for measuring the academic emotions of the subjects. As shown in Table 11, the total number of scale items is 24 among them, there were 7 positive emotions (happiness, hope) and 17 negative emotions (anxiety, anger, depression). A five-point Likert scale was used for each rating, ranging from 1 (complete nonconformance) to 5 (complete conformance). The Cronbach's alpha coefficient of the overall scale of academic emotions is 0.865, which means that the reliability is good. Exploratory factor analysis showed that KMO was 0.813, higher than 0.7; The chi-square of Bartlett's sphericity test is 9647.260, and its significance level is less than 0.001 ($p < 0.001$), which means that achievement motivation is suitable for factor analysis. After rotating by the maximum variance method, two factors are extracted, and the cumulative variance explanation rate is 77.265%, so the structural validity of achievement motivation is good.

Table 11 Distribution of Research Dimensions and Problems of Academic Emotion Scale

Scale Dimensions	**Number of items**	**Corresponding item**
Positive emotions (happiness, hope)	7	Q4，Q1，Q2，Q3，Q5，Q6，Q8
Negative emotions (anxiety, anger, depression)	17	Q17, Q16, Q14, Q15, Q19, Q18 Q29, Q27, Q26, Q25, Q30, Q28, Q24, Q20, Q 23, Q21, Q22
Total	**24**	------

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(1) Reliability Test

In this study, the internal consistency reliability of the formal survey data was tested. Internal consistency reliability refers to the degree of consistency among all items in the scale, and Cronbach's alpha coefficient is used to express internal consistency reliability. The results of Cronbach reliability analysis of College Students' Professional Identity Scale are shown in Table 12.

Table 12 Cronbach Reliability Analysis of Academic Emotion Scale

Scale Dimensions	Dimensions Cronbach α	Overall scale Cronbach α
Positive emotions (happiness, hope)	0.863	**0.865**
Negative emotions (anxiety, anger, depression)	0.872	

It can be seen from Table 12 that the Cronbach's alpha coefficient of the overall academic emotion scale is 0.865, and the Cronbach's alpha coefficient of each dimension of learning performance, learning ability and objective achievement is between 0.863 and 0.872, indicating that the critical thinking ability feature scale has high internal consistency. This enhances the reliability of the measurement tool.

(2) Confirmatory Factor Analysis

In this study, confirmatory factor analysis (confirmative factor analysis, CFA) was conducted on the formal survey data of the Academic Emotions Scale, and the construct validity of the measurement tool was evaluated by testing the fitting model, as shown in Table 13 and Figure 5.

Table 13 Model Fitting Degree of Academic Emotion Scale

Common indicators	**χ2**	**df**	**χ2/df (Chi-square Degrees of Freedom)**	**GFI**	**RMSEA**	**RMR**
Criteria for judgment	-	-	<3	>0.9	<0.10	<0.05
This model value	7331.544	251	2.687	0.611	0.126	0.121
Other indicators	TLI	AGFI	PGFI	PNFI	PCFI	SRMR
Criteria for judgment	>0.9	>0.9	>0.5	>0.5	>0.5	<0.1
This model value	0.764	0.935	0.511	0.709	0.714	0.109

The model fitting indicators of each dimension of the Academic Emotion Scale are shown in Table 13. As shown in Table 13, the χ^2/DF ratio is 2.687, which is within the acceptable range due to the large number of samples. The values of TLI and AGFI were more than.9, the values of PGFI, PNFI and PCFI were more than.5, and the value of SRMR was less than.1. According to the fit index, the fit of the academic emotion scale is good. Each index reached or exceeded the commonly accepted criteria of fit, which proved that the fit between the model and the actual data was good, and the Academic Emotion Scale had good validity in measuring different dimensions of professional identity. Therefore, the confirmatory analysis model of the Academic Emotion Scale adopted in this study is reasonable and can be used for further analysis and research.

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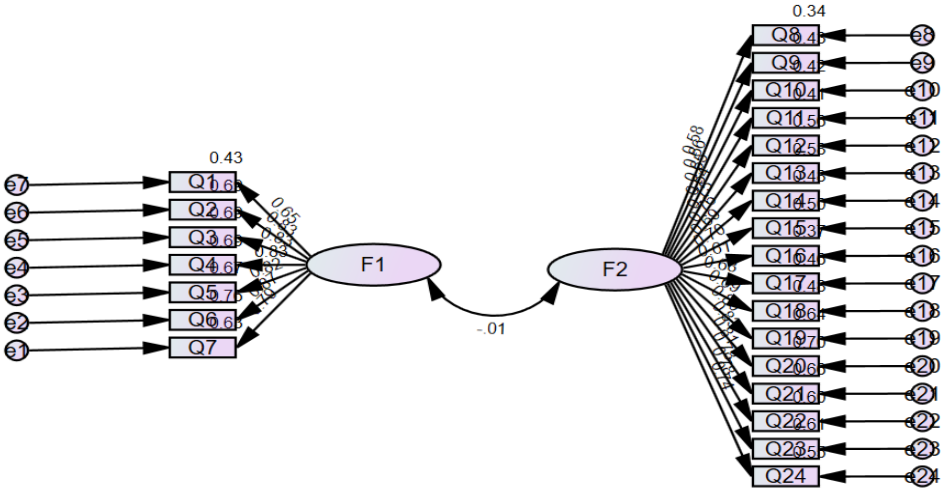


Figure 5 Confirmatory Factor Analysis Model of Academic Emotion Scale

(3) Convergent Validity and Discriminant Validity

In order to evaluate the correlation and difference between each item of the Academic Emotion Scale for College Students and its corresponding latent factors, this study tested the convergent validity and discriminant validity of the scale, as shown in Table 14 and Table 15.

Table 14 Convergent Validity of the Academic Emotions Scale

Latent variable	Measurement item	Standard error	C.R.	p	Standard load factor	AVE	C.R.
Positive emotions	Q1	-	-	-	0.653	0.650	0.928
	Q2	0.040	30.259	0.000	0.831		
	Q3	0.040	30.239	0.000	0.831		
	Q4	0.042	30.226	0.000	0.830		
	Q5	0.042	29.869	0.000	0.818		
	Q6	0.041	31.381	0.000	0.872		
	Q7	0.042	29.083	0.000	0.791		
Negative emotions	Q8	-	-	-	0.580	0.517	0.947
	Q17	0.047	23.241	0.000	0.681		
	Q18	0.048	23.454	0.000	0.691		
	Q19	0.051	25.783	0.000	0.799		
	Q20	0.052	26.464	0.000	0.835		
	Q21	0.048	26.089	0.000	0.815		
	Q22	0.050	25.350	0.000	0.778		
	Q23	0.047	25.421	0.000	0.781		
	Q24	0.048	24.650	0.000	0.744		
	Q9	0.047	22.642	0.000	0.656		
	Q10	0.046	22.385	0.000	0.646		
	Q11	0.048	22.197	0.000	0.638		
	Q12	0.049	24.747	0.000	0.749		
	Q13	0.048	24.969	0.000	0.759		
	Q14	0.046	23.463	0.000	0.691		
	Q15	0.047	23.761	0.000	0.704		
	Q16	0.044	21.474	0.000	0.610		

Note: The bar '-' indicates that the item is a reference item

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It can be seen from Table 14that the factor load of each item in the Academic Emotion Scale for College Students is greater than.5, indicating that the items corresponding to each latent variable are highly representative. In addition, the Average Variance Extracted (AVE) of the latent variables of the two dimensions of positive and negative emotions was greater than. 5, and the combined reliability (CR) was greater than. 7, indicating that the convergent validity of the scale was good.

Table 15 Discriminant Validity of the Academic Emotions Scale: Pearson Correlation and AVE

	Positive emotions	Negative emotions
Positive emotions	0.806	
Negative emotions	0.003	0.719

Note: Diagonal blue numbers are AVE square root values

It can be seen from Table 15 that the AVE square root values of positive and negative emotions are much higher than the maximum value of the absolute value of the correlation coefficient between factors, which indicates that they have good discriminant validity in the learning emotion scale, meaning that the two potential variables are relatively independent and unique in measuring positive and negative emotions, which verifies the validity of the scale in different dimensions.

Table 16 Analysis Summary of Reliability and Validity of the Scale

Scale	Cronbach's alpha	KMO value	Bartlett's test for sphericity		
			Approximate chi-square	df	Sig
Critical Thinking Ability Scale	0.815	0.799	6061.185	190	.000
Academic Achievement	0.926	0.826	779.158	45	.000
Academic Emotion Scale	0.865	0.813	9647.260	276	.000

3.4 Data analysis

This study mainly used rating scale data analysis to investigate the impact of critical thinking ability on academic achievement of college students, and academic emotions as a mediator variable. Using SPSS 28.0 and AMOS28.0 software, the sample data obtained from the questionnaire survey were analyzed by descriptive statistics, reliability and validity test, variance analysis, correlation analysis, regression analysis, confirmatory analysis of mediating variables, path analysis and structural equation model construction and evaluation. Then, based on the results of the calculation, the paper discusses the problems existing in the development of Chinese college students' critical thinking ability and their academic achievement, the mediating effect of academic emotions, and the moderating effect of achievement motivation. Based on the analysis of the results, by clarifying the structural relationship among critical thinking traits, academic emotions, academic achievement and achievement motivation, this paper puts forward relevant strategies to effectively improve college students' critical thinking ability and academic achievement.

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4. Research Results

4.1 Descriptive Statistics

Through the analysis of 1778 valid questionnaires, the results show that the reliability coefficients of the four scales of critical thinking trait, academic emotion, academic achievement and achievement motivation are high as a whole, and the Cronbach's alpha coefficients are 0.815,0.926,0.865 and 0913, respectively. The Cronbach's alpha coefficients of each dimension of the four scales were maintained between 0.815-0.943, indicating that the four scales officially released had good reliability. At the same time, the KMO values were 0.799, 0.826, 0.813 and 0.876 respectively, which indicated that the four scales of critical thinking trait, academic emotion, academic achievement and achievement motivation had high internal consistency and good construct validity.

Table 17 Descriptive Statistical Analysis of Measurement Scale Data (N = 1778)

	Min	Max	M	SD	SEM	Ske	Kur
Critical Thinking ability	1.00	5.00	3.4547	.55546	.01317	.392	1.860
Open mind	1.00	5.00	3.5134	.68397	.01622	.180	.587
Analytical ability	1.00	5.00	3.1861	.66224	.01571	.506	1.304
Systematic ability	1.00	5.00	3.5277	.64679	.01534	.222	.718
Critical thinking Self-confidence	1.00	5.00	3.5918	.76184	.01807	.167	-.120
Academic Emotion	1.00	5.00	3.6345	.72354	.01716	.120	-.098
Positive emotion	1.00	5.00	3.9328	.87827	.02083	-.371	-.503
Negative emotion	1.00	5.00	3.4872	.81589	.01935	.254	-.208
Achievement motivation	1.00	5.00	3.6327	.82788	.01963	.113	-.392
Pursuing success motivation	1.00	5.00	3.0970	.62358	.01479	.624	1.428
Avoiding failure motivation	1.00	5.00	3.8299	.74510	.01767	-.131	-.391
Academic achievement	1.00	5.00	2.8033	.83022	.01969	.113	.425

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Learning performance	1.00	5.00	3.1946	.55365	.01313	.434	3.499
Learning ability	1.00	5.00	3.2259	.68800	.01632	.377	1.277
Objective score	1.00	5.00	3.1575	.76133	.01806	-.103	1.214

4.2 Difference Analysis

In order to test whether there are differences in the four variables and dimensions of college students' critical thinking traits, academic achievement, learning emotions and achievement motivation in the choice of gender, age, grade and professional type, this study uses independent sample t-test (two groups) and analysis of variance (three or more groups) to analyze the differences between the four variables and each dimension.

1) Analysis of Gender Differences

This study uses independent sample t-test to test the gender differences of college students' critical thinking traits, academic achievement, learning emotions and achievement motivation. The analysis results are shown in Table 18.

Table 18 Independent sample t-test analysis for gender (N = 1778)

Dimension	**Sex (mean ± SD)**		**F**	**p**
	① Boys (n=517)	**② Girls (n=1261)**		
The trait of critical thinking	3.5597±0.64628	3.4117±0.50766	26.285	.000
Open mind	3.6356±0.76047	3.4633±0.64352	19.881	.000
Analytical ability	3.2356±0.75707	3.1657±0.61837	19.771	.043
Systematic ability	3.6259±0.73623	3.4874±0.60201	28.622	.000
Confidence in critical thinking	3.7416±0.81397	3.5304±0.73091	8.527	.000
Academic achievement	3.6733±0.81824	3.6186±0.68063	31.376	.148
Learning performance	3.8694±0.91915	3.9588±0.85998	7.365	.051
Ability to learn	3.6151±0.89454	3.4348±0.77566	21.233	.000
Objective results	3.6335±0.90345	3.6324±0.79520	16.451	.981
Academic mood	3.1203±0.71322	3.0875±0.58290	15.712	.314
Positive emotions	3.8317±0.82002	3.8292±0.71245	11.233	.948
Negative emotions	2.8291±0.93313	2.7927±0.78430	12.568	.401

p<0.05 ** p<0.01

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It can be seen from Table 3 that in terms of gender, the subjects' critical thinking traits (p = 0.000) and achievement motivation (P = 0.002) There was a significant gender difference in the overall mean scores of both variables (p <.05); there was no significant gender difference in the overall mean scores of academic achievements (p = 0.148) and academic emotion (p = 0.314) (p >.05).

2) Analysis on the Difference of Majors

This study uses independent sample t-test to test the differences between the three variables of college students' critical thinking traits, academic achievement, learning emotions and achievement motivation and each dimension in the professional categories. The analysis results are shown in Table19.

Table 19 Independent sample t-test for specialty categories (N = 1778)

Dimension	Professional category (mean ± SD)		F	p
	① Humanities majors （n=861）	② Science and engineering majors （n=917）		
The trait of critical thinking	3.3966±.51893	3.5093±.58271	13.056	.000
Open mind	3.4046±.65803	3.6155±.69243	6.230	.000
Analytical ability	3.1842±.62990	3.1878±.69158	5.484	.909
Systematic ability	3.5050±.61556	3.5490±.67443	8.318	.152
Confidence in critical thinking	3.4925±.73491	3.6851±.77516	8.293	.000
Academic achievement	3.5354±.68435	3.7276±.74698	14.715	.000
Learning performance	3.8577±.89431	4.0033±.85747	3.350	.000
Ability to learn	3.3342±.76792	3.6309±.83370	19.808	.000
Objective results	3.5755±.80340	3.6865±.84714	7.443	.004
Academic mood	3.1358±.59003	3.0606±.65174	2.187	.011
Positive emotions	3.7896±.72886	3.8677±.75847	2.083	.027
Negative emotions	2.8773±.77064	2.7337±.87726	15.092	.000

* p<0.05 ** p<0.01

It can be seen from Table 19 that in terms of professional categories, there are significant differences (p <.05) in the overall average scores of the three variables of critical thinking traits (p = 0.000), academic achievement (p = 0.000), and academic emotions (p = 0.011).

3) Difference analysis of Grades

In this study, ANOVA was used to test the differences of the four variables and dimensions of college students' critical thinking traits, academic achievement, learning emotions and achievement motivation in different grades. The analysis results are shown in Table 20.

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Table 20 ANOVA for grades (N = 1778)

Dimension	Grade (mean ± SD)				F	p	Snow fee (Post Inspection)
	① Freshman（n=767）	② Sophomore（n=637）	③ Junior（n=264）	④ Senior year（n=110）			
Critical thinking ability	3.4344±.56009	3.4849±.56578	3.4455±.52924	3.4436±.52274	1.009	.388	
Open mind	3.5189±.68413	3.5447±.70082	3.4477±64342	3.4509±.67263	1.581	.192	
Analytical ability	3.1640±.63967	3.1840±.68326	±.653223.2402	3.2218±.65433	.979	.402	
Systematic ability	3.4772±.63804	3.5705±.65522	3.5553±.65928	3.5655±.61113	2.782	.040*	②>①
Critical thinking Self-confidence	3.5776±.76593	3.6405±.77585	3.5386±.72250	3.5364±.73643	1.581	.192	
Academic achievement	3.6317±.73087	3.6678±.72934	3.5621±.70046	3.6355±.68838	1.336	.261	
Learning performance	3.9342±.88240	3.9670±.85258	3.8655±.93002	3.8864±.86909	.942	.420	
Ability to learn	3.5261±.82033	3.5188±.81181	3.3352±.80151	3.3977±.80444	4.419	.004**	①>②>③
Objective results	3.5860±.82190	3.6672±.84181	3.6373±.81621	3.7477±.80530	1.894	.129	
Academic mood	3.0837±.62200	3.0958±.63457	3.1544±.59048	3.0595±.64731	.994	.395	
Positive emotions	3.8018±.75976	3.8767±.75131	3.7835±.70063	3.8662±.70100	1.628	.181	
Negative emotions	2.7945±.82639	2.7818±.84214	2.9089±.77686	2.7352±89920	1.843	.137	

* p<0.05 ** p<0.01

It can be seen from Table 19 that there is no significant difference in the four variables of critical thinking traits, academic achievement, learning emotion and achievement motivation among college students of different grades (p >.05). However, there were significant differences (p < 0.05) in the dimensions of systematic ability (p = 0.040) and learning ability (p = 0.004).

4.3 Correlation Analysis

In order to explore the correlation among the three variables of college students' critical thinking traits, academic achievement and academic emotion, this study uses Pearson correlation analysis to analyze the correlation between the three variables of college students' critical thinking traits, academic achievement and academic emotion and each dimension. The analysis results are shown in Table 21.

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Table 21 Pearson Correlation Analysis among the Four Variables

Variable name	The trait of critical thinking	Academic achievement	Academic emotion
The trait of critical thinking	1		
Academic achievement	.653**	1	
Academic mood	.420**	.239**	1

* *. Correlation is significant at the 0.01 level (two-tailed).

*. At the 0.05 level (two-tailed), the correlation is significant.

As can be seen from Table 21, all correlation coefficients are reported as follows: The correlation coefficient between the critical thinking trait and academic achievement is = 0.653 and is significant at the 0.01 level (two-tailed). The correlation coefficient between critical thinking trait and academic emotion is = 0.420, and it is significant at the 0.01 level (two-tailed). The correlation coefficient between the trait of critical thinking ability and achievement motivation is 0.567, which is significant at the 0.01 level (two-tailed). Academic Achievement and Learning. The correlation coefficient between professional sentiment is = 0.239, and it is significant at the 0.01 level (two-tailed). The correlation coefficient between academic achievement and achievement motivation is 0.420, which is significant at the 0.01 level (two-tailed). The correlation coefficient between academic emotion and achievement motivation is 0.676, which is significant at the 0.01 level (two-tailed).

4.4 Hypothesis Testing

1) Regression Analysis

In this study, SPSS 28.0 software was used to conduct regression analysis on the data. The major identity, learning self-efficacy and resilience of college students were used as independent variables, and learning burnout was used as dependent variable for multiple linear regression analysis. The results are shown in Table 22, Figure 6 and Figure 7.

Table 22 Multiple Regression Analysis of College Students' Critical Thinking Trait, Academic Emotion, Academic Achievement and Achievement Motivation

Model	Unnormalized coefficient		**Normalization factor**	**P**	**VIF** (Variance expansion Bulge factor)	**D-W** (Durbin Watson) Statistics)	After adjustment **R 2**	**F**
	B	Standard Error	**Beta**					
(Constant)	.659	.090		.000	1.479	1.990	.437	460.785
Critical thinking ability	.804	.028	.617	.000	1.849			
Academic emotion	-.145	.028	-.125	.000	2.246			

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Dependent variable: academic achievement

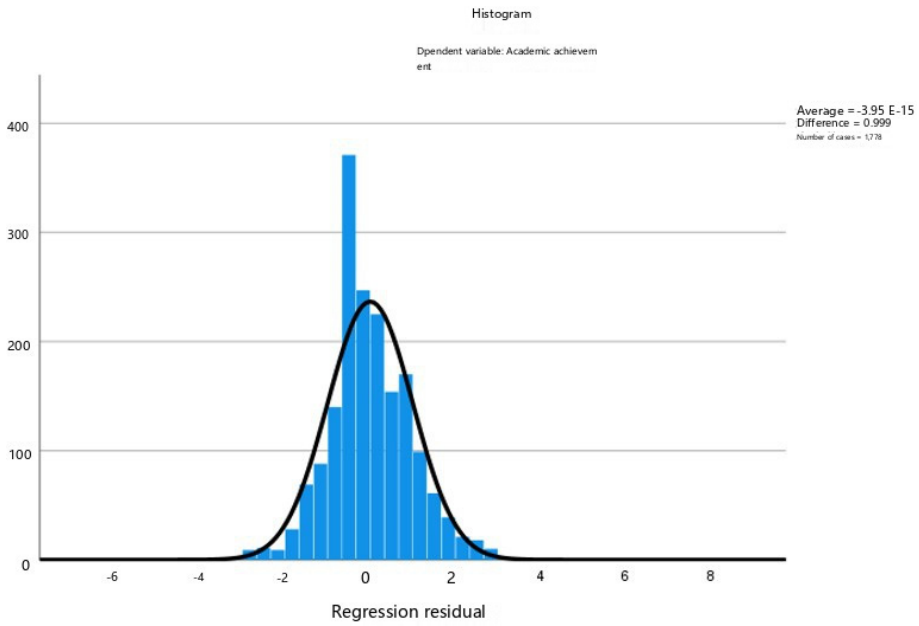


Figure 6 Histogram of Normalized Residuals of Regression

A Histogram Graph of Regression Normalized Residuals

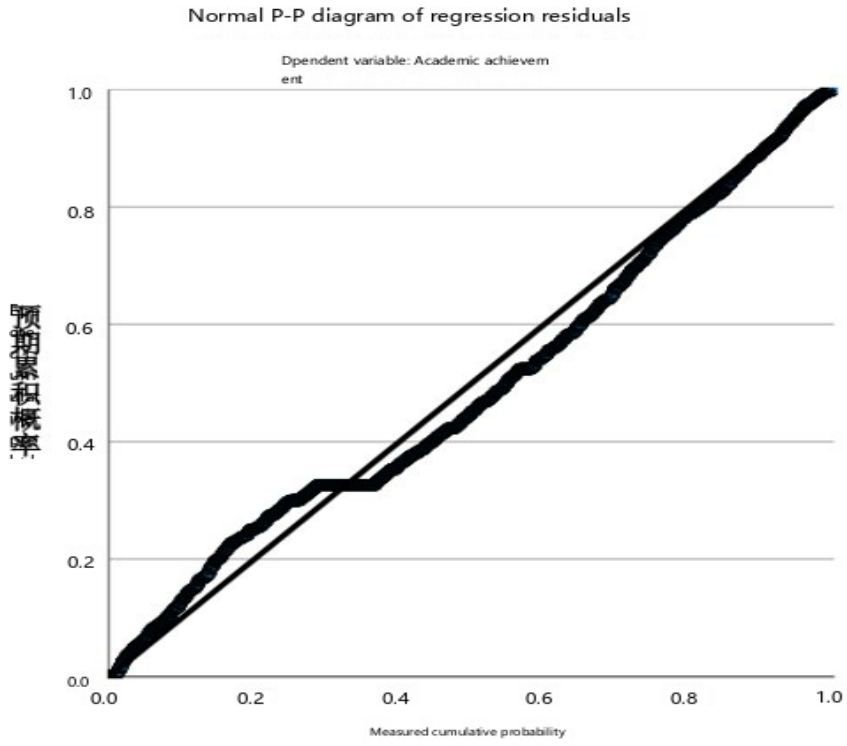


Figure 7 Normal Plot of Normalized Residuals for Regression

A Normal Graph of Regression Normalized Residuals

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It can be seen from Table 21, Figure 6 and Figure 7 that the adjusted R 2 = 0.437, and the trait of critical thinking ability, academic emotion and achievement motivation can explain 43.7% of the change in learning achievement. This was a moderately strong relationship, indicating that the independent variables (critical thinking traits, academic emotions) together explained a significant portion of the variation in academic achievement. The F test in the model has F = 460.785, p <.0001, VIF (Variance Inflation Factor) < 5, and 1 < VIF < 5 is acceptable multicollinearity, that is, there is no serious multicollinearity between the predictor variables, that is, there is no strong linear relationship between the independent variables. The D-W (Dubin-Watson statistic) value = 1.990 is near the number 2, i.e., D-W ≈ 2, indicating no significant autocorrelation between the residuals. It can be seen that the three indicators in the independent variables do not have the problem of collinearity and at least one of them will have an impact on the learning achievement of college students, and the regression model fits well.

2) Test of Mediating Effect

SPSS28.0 and Amos28.0 were used to test the mediating effect in the research model, and the test results are shown in Table 23 and Table 24.

Table 23 Testing of Mediating Effects in the Study Model

Item	Symbol	Meaning	Effect Value	95% CI		Standard error	Z-value/ t-value	p-value	Conclusion
				Lower limit	Upper limit				
Critical Thinking Trait = > Academic Emotion = > Academic Achievement	a*b	Indirect effects	0.023	0.038	0.003	0.010	-2.254	0.024	
Critical Thinking Trait = > Academic mood	a	X=>M	0.471	0.424	0.518	0.024	19.482	0.000	
Academic Emotions = > Academic achievement	b	M=>Y	0.049	0.094	0.004	0.023	-2.133	0.033	**Masking effect**
Critical Thinking Trait = > Academic achievement	c'	Indirect effects	0.873	0.823	0.924	0.026	33.869	0.000	
Critical Thinking Trait = > Academic achievement	c	总效应	0.850	0.804	0.896	0.023	36.290	0.000	

Proportion of effects in masking effect refers to the proportion of mediating effect/direct effect.

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Table 24 Summary of Mediating Effect Size Results

Item	Inspection conclusion	c	a*b	c'	Calculation formula of effect proportion	Proportion of effect
		Total effect	Mediating effect	Direct Effect		
Characteristics of critical thinking ability = > academic situation Sentiment = > Academic Achievement	Masking effect	0.850	-0.023	0.873	| a * b / c' |	2.643%

Indirect effect: The effect value of the mediating path (critical thinking trait-> academic emotion-> academic achievement) is 0.023, indicating that academic emotion plays a partial mediating role between critical thinking trait and academic achievement. The mediating effect was significant (p = 0.024). Direct effect: The trait of critical thinking ability has a direct effect on academic achievement, and the effect value is 0.873, which is significant (p = 0.000). Total effect: The total effect is 0.850, which indicates the total effect of critical thinking trait on academic achievement through direct and indirect paths. Proportion of effect: The mediating effect accounted for 2.643% of the direct effect, indicating that most of the effect came from the direct effect, while the mediating effect was small, but still significant.

It is worth noting that in the above analysis, the direct effect (C ') is positive (0.873). The indirect effect (a * B) is negative (-0.023). The total effect (C) is positive but becomes smaller in absolute terms (0.850). Since the signs of the direct and indirect effects are opposite and the absolute value of the total effect is smaller than that of the direct effect, it can be determined that there is a masking effect. Suppression effect is a special case in the analysis of mediation effect. In this case, instead of explaining the relationship between the independent variable and the dependent variable, the mediating variable enhances the relationship, making the signs of the direct and indirect effects opposite, resulting in a smaller total effect. Specifically, the masking effect occurs when the direct effect (C ') and the indirect effect (a * B) have opposite signs: this means that the direct effect of the independent variable on the dependent variable and the indirect effect through the mediating variable are in opposite directions. The total effect (C) becomes smaller: the total effect is the sum of the direct and indirect effects, but since the direct and indirect effects have opposite signs, the absolute value of the total effect will be smaller than the absolute value of the direct effect. The existence of the masking effect indicates that the mediating variable acts as an inhibitor between the independent variable and the dependent variable, weakening the total influence of the independent variable on the dependent variable. Understanding this effect is important for accurately interpreting relationships between variables, as it reveals complex mechanisms underlying apparent relationships. The masking effect is a complex but important phenomenon that reveals the details and mechanisms of the relationships between variables. Identifying and understanding the masking effect helps to interpret the findings more fully when conducting the mediating effect analysis.

Overall, the trait of critical thinking ability has a significant direct impact on academic achievement. The produces a partial mediating effect (masking effect). Although the proportion of mediation effect is relatively

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small, it is still a significant path.

4.5 Research Hypothesis Validation Results

The research hypothesis of this study aims to investigate the relationship among college students' critical thinking ability, academic emotions, academic achievement, and achievement motivation. A total of 11 hypotheses have been proposed based on the relevant previous studies of this topic, and the research hypotheses are verified according to the research results, as shown in Table 25.

Table 25 Research Hypothesis Testing

Research hypothesis	Inspection results
H1: The critical thinking ability of college students has a significant impact on their academic achievements.	
H1a: Open mindedness has a significant positive effect on academic achievement	**Accepted**
H1b: Analytical ability has a significant positive effect on academic achievement.	**Accepted**
H1c: Systematic ability has a significant positive impact on academic achievement.	**Accepted**
H1d: Critical thinking confidence has a significant positive effect on academic achievement.	**Accepted**
H2: College students' critical thinking ability has a significant effect on academic emotions.	
H2a: Open mind has a significant positive effect on academic emotions.	**Accepted**
H2b: Analytical ability has a significant positive effect on academic emotions.	**Accepted**
H2c: Systematic ability has a significant positive impact on academic emotions.	**Accepted**
H2d: Critical thinking self-confidence has a significant positive impact on academic emotions.	**Accepted**
H3: Academic emotion has a significant positive effect on academic achievement.	
H3a: Positive academic emotions have a significant positive impact on academic achievement.	**Accepted**
H3b: Negative academic emotions have a significant reverse effect on academic achievement.	**Accepted**
H4: Academic emotion plays a mediating role (Masking role) between critical thinking ability and academic achievement of college students.	**Accepted**

5. Conclusion

The final results show that the comprehensive performance of critical thinking ability, academic emotion and academic achievement of Chinese college students is above the middle level. In the aspect of difference analysis: in the aspect of gender, there are significant gender differences in the overall average scores of the two variables of critical thinking traits and achievement motivation; there are no significant gender differences in the overall average scores of the two variables of academic achievement and academic emotion. The two dimensions of critical thinking trait, open thinking and critical thinking, have significant differences in

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professional categories. In terms of major categories, there are significant differences in the overall average scores of the three variables of critical thinking traits, academic achievement, and academic emotions. In terms of grade differences, there are no significant differences in the three variables of critical thinking traits, academic achievements and learning emotions of college students in different grades. However, there are significant differences in the dimensions of systematic ability, learning ability and motivation to avoid failure. The three dimensions of systematic ability, learning ability and motivation to avoid failure were compared by post multiple test. (Xue Fei) found that in the dimension of systematic ability, freshmen and sophomores had significant differences.

There was a significant difference, and the mean value of sophomores was higher than that of freshmen. In the dimension of learning ability, there are significant differences among freshmen, sophomores and juniors, and the average of freshmen is higher than that of sophomores and that of juniors. In the dimension of motivation to escape failure, there are significant differences among freshmen, sophomores and juniors, and the mean of juniors is higher than that of sophomores and that of freshmen.

In the aspect of correlation analysis, this study uses Pearson correlation analysis to analyze the correlation between the four variables of college students' critical thinking ability, academic achievement, academic emotion and achievement motivation and each dimension. There is a correlation between all the variables involved. There is a moderate positive correlation between critical thinking trait and academic emotion. There is a weak positive correlation between academic achievement and academic emotion.

College students' critical thinking ability has a significant positive impact on academic achievement (H1a, H1b, H1c, H1d), and college students' critical thinking ability has a significant positive impact on academic emotions (H2a, H2b, H2c, H2d). Positive academic emotion has a significant positive effect on academic achievement (H3a), while negative academic emotion has a significant positive effect on academic achievement (H3b). Academic emotion plays a mediating role between critical thinking ability and academic achievement, and there is a certain masking effect (H4). After testing, the above twelve assumptions are all valid.

Finally, based on the results of the study, this paper makes a profound and comprehensive reflection, and puts forward effective strategies to improve college students' critical thinking ability and level, strategies and methods to improve college students' academic achievements, and effective strategies to reduce college students' negative academic emotions. It provides theoretical support and practical scientific basis for maintaining and promoting the development and improvement of Chinese college students' critical thinking ability.

VI. Prospects for Future Research

In the field of "the relationship and influence among college students' critical thinking ability, academic emotion and academic achievement", future research can focus on the following five potential issues to explore the complex relationship and influence mechanism among these variables.

Firstly, the measurement and influence of multi-dimensional critical thinking ability is an important research direction. At present, most studies have a single understanding of critical thinking ability. In the future, we can explore how different dimensions of critical thinking ability, such as logical reasoning, critical think-

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ing and creative thinking, affect academic emotions and academic achievement respectively. In addition, the development and validation of multi-dimensional measurement tools for critical thinking is also an important task for future research, which will help to understand the impact of critical thinking on academic performance more comprehensively.

Secondly, the dynamic changes and regulation of academic emotions are worthy of further study. Although some studies have explored the influence of academic emotions, there is still insufficient attention to its dynamic changes in the learning process and its interaction with critical thinking ability and achievement motivation. Future research could use a longitudinal study design to examine how academic emotions change over time and analyze their moderating effects in different learning situations. In addition, exploring the interaction between academic emotions and other psychological factors (such as self-efficacy, anxiety level, etc.) Will provide a deeper perspective for understanding students' emotional experience.

Thirdly, the mediating role of achievement motivation between critical thinking and academic emotions is a potential research topic Question. The existing literature has shown the importance of achievement motivation to academic achievement, but the specific mechanism between critical thinking ability and academic emotion has not been fully explored. Future research can use structural equation modeling and other methods to systematically test the mediating effect of achievement motivation on the influence of critical thinking ability on academic emotions, so as to enrich the theoretical model.

Fourthly, the influence of cultural and social background on college students' critical thinking ability, academic emotion and achievement motivation should also be an important research direction. College students in different cultural backgrounds may show different critical thinking ability and emotional state. Therefore, cross-cultural comparative study can reveal the role of cultural factors in this series of relationships. Especially in the context of globalization, how to understand the learning experience and performance of students in different cultural backgrounds will have an important impact on educational practice and policy formulation.

Fifthly, empirical research on educational interventions is also an important area for future research. The intervention strategies on how to effectively improve college students' critical thinking ability, regulate academic emotions and promote academic achievement still need to be empirically verified. By designing and implementing specific educational programs and evaluating their impact on students' critical thinking ability, academic mood and academic achievement, practical guidance will be provided for educational practice.

To sum up, in the future research on the relationship and influence among college students' critical thinking ability, academic emotion, academic achievement and achievement motivation, we need to pay attention to multi-dimensional measurement, dynamic change, cross-cultural comparison and educational intervention, in order to provide more rich perspectives and insights for the theoretical development and practical application in this field.

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