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THE INFLUENCE OF META COGNITION AND LEARNING ENGAGEMENT ON CRITICAL THINKING ABILITY OF COLLEGE STUDENTS IN PRIVATE UNIVERSITIES OF YUNNAN, CHINA

Yanqi Yang[1,2] and Yuancheng Zhang[2]*

[1] College of Arts and Sciences · Kunming, Kunming, Yunnan, China

[2] Dhurakij Pundit University, Bangkok, Thailand

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ABSTRACT

This study aims to explore the influence and mechanism of metacognition and learning engagement on critical thinking ability of college students in private universities of Yunnan. A questionnaire survey was conducted among 426 students from 3 private universities in Yunnan. Descriptive statistics, correlation analysis and multiple regression analysis were used for data processing. The results show that: (1) The overall levels of metacognition, learning engagement and critical thinking of the subjects are at a medium-to-high level; (2) Metacognition and learning engagement are significantly positively correlated with critical thinking ability ($p<0.01$); (3) Metacognition and learning engagement can jointly explain 38.2% of the variance in critical thinking ability, and both have significant positive predictive effects. It is suggested that private universities should carryout metacognition training,optimize classroom teaching design, and improve learning engagement, so as to effectively promote the development of students' critical thinking.

KEYWORDS: Metacognition; Learning Engagement; Critical Thinking; Private Universities; Yunnan.

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1.0 INTRODUCTION

In the context of high-quality development of higher education, critical thinking has become one of the core competencies for college students to adapt to social development and achieve sustainable growth. Metacognition refers to individuals ‘cognitive knowledge and regulatory ability of their own thinking processes, which is the basis for the formation of critical thinking. Learning engagement reflects the degree of students' psychological and behavioral investment in learning activities, and is an important situational factor affecting the development of thinking ability.

Compared with public universities, private universities generally have problems such as uneven student foundation, weak autonomous learning awareness, and insufficient high-level thinking training. At present, there is a lack of targeted empirical research on the mechanism of metacognition and learning engagement affecting critical thinking in private universities in Yunnan. This study takes college students in private universities of Yunnan as the research object, constructs a structural relationship model of metacognition-learning engagement-critical thinking, and provides empirical support and practical strategies for improving the quality of applied talents training in private universities.

Against this backdrop, exploring how to enhance college students' critical thinking through the synergy of metacognition and learning engagement has become an urgent practical need for private universities in Yunnan to improve their educational quality and cultivate application-oriented talents. Specifically, clarifying the intricate relationships between metacognition, learning engagement, and critical thinking not only helps to reveal the internal psychological mechanisms underlying the development of critical thinking among private university students but also provides targeted educational interventions for educators. For instance, understanding the specific dimensions of metacognition that most strongly predict critical thinking, or identifying the types of learning engagement that serve as key intermediaries in this process, can inform the design of more effective teaching strategies and learning support systems. Furthermore, given the unique student demographics and educational contexts of private universities in Yunnan, such as potential differences in learning motivations and academic backgrounds compared to students in public institutions, this research holds the potential to fill a significant gap in the existing literature. By focusing on this specific population, the findings can offer more nuanced and applicable insights, contributing to the development of contextually appropriate educational practices that foster critical thinking, thereby ultimately enhancing the competitiveness and employability of graduates from Yunnan's private universities in the increasingly complex and demanding modern society.

2.0 METHODOLOGY

2.1 *Participants*

A stratified random sampling method was adopted to select 450 students from 3 private undergraduate universities in Yunnan. A total of 426 valid questionnaires were recovered, with an effective rate of 94.7%. The sample included 198 males (46.5%) and 228 females (53.5%); 106 freshmen (24.9%), 112 sophomores (26.3%), 104 juniors (24.4%), and 104 seniors (24.4%); 236 students majoring in liberal arts (55.4%) and 190 students majoring in science and engineering (44.6%).

In terms of age distribution, the participants ranged from 18 to 24 years old, with a mean age of 20.5 years (SD = 1.2). The age groups were as follows: 18-year-olds accounted for 12.2% (52 students), 19-year-olds 23.5% (100 students), 20-year-olds 28.4% (121 students), 21-year-olds 21.1% (90 students), 22-year-olds 10.8% (46 students), and 23–24-year-olds 4.0% (17 students). Regarding household registration, 287 participants (67.4%) were from rural areas, and 139 (32.6%) were from urban areas. In terms of monthly living expenses, 153 students (35.9%) reported expenses between 1000–1500 yuan, 138 (32.4%) between 1501–2000 yuan, 85 (19.9%) between

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2001–2500 yuan, 36 (8.5%) above 2500 yuan, and 14 (3.3%) below 1000 yuan. Additionally, 294 students (69.0%) lived in school dormitories, 88 (20.7%) rented off-campus housing, and 44 (10.3%) lived with family or relatives. Academic performance was self-reported as excellent by 56 students (13.1%), good by 215 (50.5%), average by 132 (31.0%), and poor by 23 (5.4%).

2.2 Research Tools

In the process of academic research on college students' learning and psychological development, the selection and standardization of measurement tools are crucial to ensuring the scientificity, reliability and validity of research results. The measurement tools adopted in this study, including the Metacognition Scale, Learning Engagement Scale, Critical Thinking Ability Scale and Academic Achievement Test, are carefully selected, revised or self-designed on the basis of fully considering the characteristics of Chinese college students' group and the research objectives. Each tool has a clear theoretical basis, reasonable structure and good psychometric indicators, which can effectively measure the corresponding psychological characteristics and academic level of college students. The following is a detailed description of each measurement tool, including its source, structural dimensions, item design, scoring standards, reliability and validity testing, so as to provide a clear basis for the scientificity of the research.

Metacognition, as an important higher-order cognitive ability, refers to individuals' awareness, monitoring and regulation of their own cognitive activities, which plays a key role in college students' independent learning, problem-solving and academic development. In order to accurately measure the metacognition level of college students in the Chinese cultural context, this study adopted the college student metacognition scale compiled by domestic scholars, which is based on the classic metacognition theory and combined with the actual learning situation of Chinese college students, and has been verified and revised in many studies, with good applicability and operability. The compilation of this college student metacognition scale is mainly based on Flavell's metacognition theory. Flavell pointed out that metacognition includes two core components: cognitive knowledge and cognitive regulation. Cognitive knowledge refers to individuals' knowledge and understanding of their own cognitive processes, cognitive abilities, cognitive strategies and the relationship between cognitive tasks and cognitive methods; cognitive regulation refers to the process in which individuals monitor, adjust and control their own cognitive activities in the process of completing cognitive tasks, so as to ensure the smooth progress of cognitive activities and the realization of cognitive goals. On the basis of this theory, domestic scholars combined with the learning characteristics of Chinese college students (such as the emphasis on knowledge memory, the dependence on teachers' guidance and the gradual formation of independent learning ability), optimized and adjusted the content of the scale, making the scale more in line with the cognitive characteristics and learning context of Chinese college students, avoiding the cultural differences caused by directly using foreign scales, and improving the ecological validity of the measurement.

The scale consists of two first-level dimensions: cognitive knowledge and cognitive regulation, with a total of 18 items, of which 8 items belong to the cognitive knowledge dimension and 10 items belong to the cognitive regulation dimension. The item design fully reflects the core connotation of each dimension, and the language expression is concise, clear and in line with the

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cognitive level of college students, avoiding ambiguous or difficult-to-understand expressions, so as to ensure that the subjects can accurately understand the meaning of each item and make true and effective responses.

The cognitive knowledge dimension mainly measures college students' understanding and mastery of their own cognitive abilities, cognitive strategies and cognitive tasks. For example, the items include "I know which learning methods are more suitable for me", "I can clearly realize my own advantages and disadvantages in learning", "I understand the difficulty of different learning tasks and the corresponding cognitive requirements", etc. These items are designed to investigate whether college students can objectively perceive their own cognitive level, master the appropriate learning strategies, and have a clear understanding of the characteristics of learning tasks, which is the basis for the formation and development of metacognition.

The cognitive regulation dimension mainly measures the ability of college students to monitor, adjust and control their own cognitive activities in the learning process, including the planning before learning, the monitoring during learning and the evaluation after learning. For example, the items include "Before learning new knowledge, I will make a detailed learning plan", "During learning, I will timely check whether I have mastered the key points", "If I find that my learning method is not effective, I will adjust it in time", "After completing the learning task, I will summarize my learning effect and find out the existing problems", etc. These items comprehensively cover the whole process of cognitive regulation and can effectively reflect the initiative and flexibility of college students in regulating their own learning activities.

The scale adopts a 5-point Likert scoring method, in which 1 represents "completely inconsistent", 2 represents "basically inconsistent", 3 represents "neutral", 4 represents "basically consistent", and 5 represents "completely consistent". The subjects need to combine their own actual learning situation and make a true choice for each item. The total score of the scale is the sum of the scores of all 18 items, and the higher the total score, the higher the metacognition level of the college students. In addition, the scores of each dimension can be calculated separately (the sum of the scores of the items included in each dimension), so as to analyze the level of each component of metacognition of the subjects separately.

Reliability refers to the stability and consistency of the measurement results of the scale, which is an important indicator to measure the quality of the scale. This study used Cronbach's α coefficient to test the internal consistency reliability of the scale. The Cronbach's α coefficient of the whole scale is 0.872, which is higher than the standard of 0.8, indicating that the internal consistency of the scale is good, and the items in the scale have a high degree of correlation, which can stably measure the metacognition level of college students.

In addition, in the process of compiling the scale by domestic scholars, the content validity and construct validity of the scale were also tested. The content validity was evaluated by experts in the field of educational psychology and cognitive psychology. The experts reviewed the items of the scale one by one and put forward revision suggestions on the expression of the items and the coverage of the dimensions. After repeated revision, the content of the scale can fully reflect the

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core connotation of metacognition, and the content validity is good. The construct validity was tested by factor analysis, and the results showed that the two-factor structure (cognitive knowledge and cognitive regulation) of the scale was consistent with the theoretical assumption, and the factor load of each item was greater than 0.6, indicating that the scale had good construct validity and could effectively measure the two core components of metacognition.

Learning engagement is an important indicator to measure the quality of college students' learning, which refers to the positive psychological state and behavioral performance of college students in the learning process, including investment in behavior, cognition and emotion. A high level of learning engagement is conducive to improving college students' learning efficiency, promoting knowledge mastery and ability development. In order to adapt to the research needs, this study adopted the revised learning engagement scale, which is based on the international classic learning engagement scale, combined with the learning characteristics and educational background of Chinese college students, and revised to ensure that the scale is more in line with the actual situation of Chinese college students' learning engagement.

The original learning engagement scale is based on the learning engagement theory proposed by Fredricks et al., who pointed out that learning engagement is a multi-dimensional construct, including three core dimensions: behavioral engagement, cognitive engagement and emotional engagement. Behavioral engagement refers to the positive behaviors of students in the learning process, such as active participation in learning activities, adherence to learning tasks and compliance with learning rules; cognitive engagement refers to the deep processing of knowledge by students in the learning process, such as active thinking, independent exploration and the use of effective learning strategies; emotional engagement refers to the positive emotional experience of students in the learning process, such as interest in learning, sense of belonging to the learning group and satisfaction with learning.

On the basis of this theory, the revised learning engagement scale in this study mainly made the following revisions according to the characteristics of Chinese college students: first, adjusted the expression of some items to make it more in line with the language habits and learning context of Chinese college students, such as changing the "school" in the original scale to "university" to adapt to the college student group; second, deleted the items that are not in line with the actual learning situation of Chinese college students, such as the items related to after-school tutoring, which are not universal in Chinese universities; third, added items that reflect the characteristics of Chinese college students' learning engagement, such as items related to online learning engagement, which are in line with the current situation of college students' online learning. After revision, the scale is more suitable for measuring the learning engagement level of Chinese college students, and the ecological validity and applicability of the scale are greatly improved.

The revised learning engagement scale consists of three first-level dimensions: behavioral engagement, cognitive engagement and emotional engagement, with a total of 15 items. Among them, the behavioral engagement dimension includes 5 items, the cognitive engagement dimension includes 5 items, and the emotional engagement dimension includes 5 items. The item design is

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closely around the core connotation of each dimension, and the content is specific and operable, which can effectively reflect the actual learning engagement state of college students.

The behavioral engagement dimension mainly measures the positive behaviors of college students in the learning process, focusing on the external performance of learning engagement. For example, the items include "I will actively participate in classroom discussions and group learning activities", "I can insist on completing learning tasks on time without being absent or late", "I will take the initiative to use after-class time to review and consolidate the knowledge learned in class", etc. These items can directly reflect the initiative and persistence of college students in learning behavior.

The cognitive engagement dimension mainly measures the deep participation of college students in the cognitive process of learning, focusing on the internal cognitive state of learning engagement. For example, the items include "When learning new knowledge, I will actively think about the connection between it and the existing knowledge", "I will try to use different learning strategies to solve difficult learning problems", "I will take the initiative to explore the deep meaning of knowledge instead of just memorizing the surface content", etc. These items can reflect the depth and initiative of college students in cognitive activities.

The emotional engagement dimension mainly measures the emotional experience of college students in the learning process, focusing on the emotional state of learning engagement. For example, the items include "I am very interested in the professional courses I learn", "I feel a sense of accomplishment when I complete a difficult learning task", "I am willing to communicate and learn with teachers and classmates", "I have a sense of belonging to the learning group of my major", etc. These items can reflect the positive emotional attitude of college students towards learning and the learning environment.

Similar to the Metacognition Scale, this scale also adopts a 5-point Likert scoring method, with 1 representing "completely inconsistent", 2 representing "basically inconsistent", 3 representing "neutral", 4 representing "basically consistent", and 5 representing "completely consistent". The subjects need to combine their own actual learning behavior and emotional experience to make a true response to each item. The total score of the scale is the sum of the scores of all 15 items, and the higher the total score, the higher the learning engagement level of the college students. At the same time, the scores of each dimension can be calculated separately, so as to analyze the advantages and disadvantages of college students in different dimensions of learning engagement, and provide targeted suggestions for improving college students' learning engagement.

The reliability test of the revised learning engagement scale mainly adopts the Cronbach's α coefficient to test the internal consistency. The test results show that the Cronbach's α coefficient of the whole scale is 0.856, which is higher than the standard of 0.8, indicating that the internal consistency of the scale is good, and the items in each dimension have a high degree of correlation, which can stably measure the learning engagement level of college students.

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In terms of validity, the content validity of the scale was evaluated by three experts in the field of educational psychology and higher education. The experts reviewed the revised items and confirmed that the items of the scale can fully cover the three dimensions of learning engagement, the expression of the items is accurate and concise, and the content is in line with the actual learning situation of Chinese college students, so the content validity is good. The construct validity was tested by confirmatory factor analysis, and the results showed that the three-factor structure (behavioral engagement, cognitive engagement and emotional engagement) of the scale was consistent with the theoretical assumption, the fit index of the model was good (such as RMSEA < 0.08, CFI > 0.9), and the factor load of each item was greater than 0.55, indicating that the scale had good construct validity and could effectively measure the three core dimensions of college students' learning engagement.

Critical thinking ability is an important higher-order thinking ability necessary for college students to adapt to the development of the times and achieve personal growth, which refers to the ability of individuals to objectively analyze, evaluate, reason and judge information, and make rational decisions on the basis of independent thinking. In order to accurately measure the critical thinking ability of Chinese college students, this study adopted the critical thinking disposition scale suitable for Chinese college students, which is compiled on the basis of combining foreign critical thinking theories and the cultural background and educational characteristics of Chinese college students, and has been widely used in domestic research on college students' critical thinking.

The compilation of this critical thinking disposition scale is mainly based on the critical thinking theory proposed by Ennis and Facione. Ennis pointed out that critical thinking is a reasonable and reflective thinking that focuses on deciding what to believe or do; Facione further put forward that critical thinking includes seven core dispositions: truth-seeking, open-mindedness, systematicity, self-confidence, inquisitiveness, cognitive maturity and analytical ability. On the basis of these theories, domestic scholars combined with the cultural characteristics of Chinese society (such as emphasizing modesty, prudence and collective consciousness) and the training objectives of Chinese higher education (such as cultivating students' independent thinking ability and innovative ability), optimized the dimensions of the scale, and finally determined four core dimensions: truth-seeking, open-mindedness, systematicity and self-confidence. These four dimensions can fully reflect the key characteristics of Chinese college students' critical thinking disposition, and avoid the inadaptability caused by directly applying foreign scales.

The scale consists of four first-level dimensions: truth-seeking, open-mindedness, systematicity and self-confidence, with a total of 20 items, of which each dimension includes 5 items. The item design is closely around the core connotation of each dimension, and the language expression is in line with the cognitive level and language habits of Chinese college students, which can effectively measure the critical thinking disposition of college students.

The truth-seeking dimension mainly measures the attitude of college students towards the truth, that is, whether they can adhere to the principle of seeking truth from facts, actively pursue the truth, and not be influenced by subjective prejudices or external pressures. For example, the items include "I will actively verify the authenticity of the information I receive", "When facing different

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viewpoints, I will try to find evidence to support or refute them", "I will not easily believe the conclusions put forward by others without verification", etc. These items reflect the core requirement of critical thinking for seeking truth and pragmatism.

The open-mindedness dimension mainly measures the attitude of college students towards different viewpoints and ideas, that is, whether they can respect the differences of others, objectively listen to different opinions, and not be limited by their own inherent thinking patterns. For example, the items include "I am willing to listen to the opinions of others with different backgrounds", "I can accept the viewpoints that are different from my own if there is sufficient evidence", "I will not reject new ideas because they are inconsistent with my existing cognition", etc. These items reflect the inclusiveness and openness of critical thinking.

The systematicity dimension mainly measures the ability of college students to think systematically and comprehensively, that is, whether they can sort out the logical relationship between things, analyze problems from multiple angles and levels, and avoid one-sidedness and superficiality. For example, the items include "When analyzing a problem, I will consider all possible influencing factors", "I will sort out the logical relationship between different information to form a complete thinking framework", "I will avoid making hasty conclusions before fully understanding the problem", etc. These items reflect the systematicity and comprehensiveness of critical thinking.

The self-confidence dimension mainly measures the confidence of college students in their own critical thinking ability, that is, whether they believe in their own ability to analyze, evaluate and judge problems, and dare to put forward their own views and opinions. For example, the items include "I am confident in my ability to analyze and solve complex problems", "I dare to put forward my own different views in group discussions", "I believe that I can accurately judge the rationality of various viewpoints", etc. These items reflect the subjective confidence of individuals in their own critical thinking ability, which is an important guarantee for the exertion of critical thinking ability.

The scale adopts a 5-point Likert scoring method, with 1 representing "completely inconsistent", 2 representing "basically inconsistent", 3 representing "neutral", 4 representing "basically consistent", and 5 representing "completely consistent". The subjects need to combine their own thinking habits and attitude towards problems to make a true response to each item. The total score of the scale is the sum of the scores of all 20 items, and the higher the total score, the stronger the critical thinking disposition of the college students. In addition, the scores of each dimension can be calculated separately, so as to analyze the advantages and disadvantages of college students in different dimensions of critical thinking, and provide targeted training suggestions.

The reliability test of the scale uses Cronbach's α coefficient to test the internal consistency. The test results show that the Cronbach's α coefficient of the whole scale is 0.863, which is higher than the standard of 0.8, indicating that the internal consistency of the scale is good, and the items in each dimension have a high degree of correlation, which can stably measure the critical thinking disposition of college students.

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In terms of validity, the content validity of the scale was evaluated by experts in the field of psychology and education. The experts reviewed the items of the scale and confirmed that the items can fully reflect the four dimensions of critical thinking disposition, the expression of the items is accurate and in line with the actual situation of Chinese college students, so the content validity is good. The construct validity was tested by exploratory factor analysis and confirmatory factor analysis. The results of exploratory factor analysis showed that four common factors were extracted, which were consistent with the four dimensions of the scale, and the cumulative variance contribution rate was more than 60%; the results of confirmatory factor analysis showed that the four-factor structure of the scale was consistent with the theoretical assumption, the fit index was good, and the factor load of each item was greater than 0.6, indicating that the scale had good construct validity and could effectively measure the critical thinking disposition of Chinese college students.

Academic achievement is an important indicator to measure the learning effect of college students, which directly reflects the mastery of professional knowledge and the development of comprehensive ability of college students. In order to ensure the pertinence and validity of the measurement of academic achievement, this study adopted a self-designed academic achievement test, which is developed on the basis of the core knowledge points of the major courses of the participating students, and has been strictly reviewed and pre-tested to ensure that the test has good content validity, difficulty and discriminative power.

The design of the self-designed academic achievement test follows three core principles: pertinence, scientificity and operability. First, pertinence: the test content is closely around the core knowledge points, key theories and practical application abilities of the major courses of the participating students, so as to ensure that the test can truly reflect the learning effect of the students in their major courses, and avoid the test content being too broad or irrelevant to the major. Second, scientificity: the test design follows the principles of educational measurement, the difficulty and discriminative power of the test are reasonable, the question types are diverse, and the scoring standards are objective and accurate, so as to ensure the reliability and validity of the test results. Third, operability: the test time is reasonable, the question types are easy to understand, and the scoring process is simple and feasible, so as to ensure the smooth progress of the test and the efficiency of scoring.

The academic achievement test is developed based on the core knowledge points of the major courses of the participating students. Before the test design, the researchers first sorted out the syllabus of the major courses of the participating students, identified the core knowledge points, key concepts, important theories and practical application skills, and then designed the test content according to the proportion of each knowledge point in the course. The test covers three aspects: key concepts, theoretical applications and problem-solving skills, which can comprehensively measure the academic level of college students.

The total score of the test is 100 points, and the question types include multiple-choice questions, fill-in-the-blank questions, short-answer questions and comprehensive application questions, with reasonable score distribution. Specifically, multiple-choice questions account for 30 points (15

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questions, 2 points each), mainly testing the mastery of key concepts and basic theories of students; fill-in-the-blank questions account for 20 points (10 questions, 2 points each), mainly testing the accuracy of students' memory of key concepts and important conclusions; short-answer questions account for 30 points (5 questions, 6 points each), mainly testing the ability of students to explain theoretical knowledge and clarify the logical relationship between concepts; comprehensive application questions account for 20 points (1 question, 20 points), mainly testing the ability of students to apply the learned theoretical knowledge to solve practical problems, which can reflect the comprehensive application ability and innovative thinking ability of students.

The design of the test questions fully considers the difficulty gradient, from easy to difficult, so as to distinguish the academic level of students with different learning levels. The easy questions account for 30% (mainly testing basic knowledge), the medium-difficulty questions account for 50% (mainly testing the application of knowledge), and the difficult questions account for 20% (mainly testing comprehensive application ability), so as to ensure that the test has good discriminative power.

In order to ensure the content validity of the academic achievement test, the test was reviewed by three senior professors in the related field of the participating students' majors. The three professors have rich teaching experience and profound academic attainments in the field, and are familiar with the syllabus and teaching key points of the major courses. The review content mainly includes: whether the test content covers the core knowledge points of the major courses, whether the proportion of each knowledge point is reasonable, whether the question types are appropriate, whether the expression of the questions is accurate and clear, whether the difficulty of the questions is in line with the learning level of the students, and whether the scoring standards are objective and reasonable.

According to the review opinions of the professors, the researchers revised and improved the test questions. For example, some questions with ambiguous expressions were modified to make the meaning more clear; some questions that did not cover the core knowledge points were deleted; the proportion of some knowledge points was adjusted to make it more in line with the teaching focus; the scoring standards were further refined to ensure the objectivity and accuracy of scoring. After repeated revisions and reviews, the three professors confirmed that the test has good content validity, and the test content can fully reflect the learning effect of students in their major courses, which can effectively measure the academic achievement of students.

In order to ensure that the test has reasonable difficulty and good discriminative power, a pre-test was carried out before the formal test. The pre-test objects were 50 college students outside the formal sample, who were in the same grade and major as the formal sample, and had the same learning background and learning level, so as to ensure the representativeness of the pre-test sample.

After the pre-test, the researchers sorted out and analyzed the test results, mainly calculating the difficulty coefficient and discriminative power of the test. The difficulty coefficient (P) of the test is calculated by the formula: P = average score of the test / full score of the test. The difficulty

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coefficient ranges from 0 to 1, and the ideal difficulty coefficient is between 0.5 and 0.7. If the difficulty coefficient is too high (close to 1), it means that the test is too easy, and it is difficult to distinguish the academic level of students; if the difficulty coefficient is too low (close to 0), it means that the test is too difficult, and most students cannot get a good score, which also affects the discriminative power.

The pre-test results showed that the initial difficulty coefficient of the test was 0.58, which was slightly lower than the ideal range. In order to adjust the difficulty coefficient to the ideal level, the researchers revised the test questions: slightly reduced the difficulty of some difficult questions (such as simplifying the conditions of comprehensive application questions), and appropriately increased the number of medium-difficulty questions, so as to improve the average score of the test. After revision, the test was pre-tested again with another 30 students outside the sample, and the difficulty coefficient was adjusted to 0.65, which was within the ideal range (0.5–0.7), indicating that the difficulty of the test was reasonable.

At the same time, the discriminative power of the test was also tested. The discriminative power (D) is calculated by the formula: D = average score of the top 27% of the test takers − average score of the bottom 27% of the test takers. The higher the discriminative power, the stronger the ability of the test to distinguish the academic level of students. The test results showed that the discriminative power of the test was 0.28, which was higher than the standard of 0.2, indicating that the test had good discriminative power and could effectively distinguish students with high academic levels from those with low academic levels.

The four measurement tools adopted in this study (Metacognition Scale, Learning Engagement Scale, Critical Thinking Ability Scale and Academic Achievement Test) are all designed or selected on the basis of combining theoretical foundations and practical needs, and have good reliability and validity. The Metacognition Scale can effectively measure the metacognition level of college students from two dimensions of cognitive knowledge and cognitive regulation; the revised Learning Engagement Scale can comprehensively reflect the learning engagement state of college students from three dimensions of behavioral engagement, cognitive engagement and emotional engagement; the Critical Thinking Ability Scale suitable for Chinese college students can accurately measure the critical thinking disposition of college students from four dimensions of truth-seeking, open-mindedness, systematicity and self-confidence; the self-designed Academic Achievement Test has good content validity, reasonable difficulty and strong discriminative power, which can effectively measure the academic level of college students.

The application of these measurement tools provides a scientific and reliable basis for the research on college students' learning and psychological development, and can ensure the authenticity, accuracy and validity of the research results. In the formal research process, the researchers will strictly follow the operation specifications of each measurement tool, guide the subjects to make true and effective responses, and standardize the scoring process, so as to maximize the role of the measurement tools and provide strong support for the smooth progress of the research.

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2.3 Data Analysis

SPSS 26.0 statistical software was used to process the data, including descriptive statistics, Pearson correlation analysis and multiple linear regression analysis.

First, descriptive statistical analysis was conducted to calculate the mean, standard deviation, minimum value, and maximum value of the main variables, so as to understand the overall distribution characteristics and central tendency of the data. Then, Pearson correlation analysis was performed to explore the strength and direction of the linear relationship between the independent variables and the dependent variable, as well as among the independent variables, which laid a foundation for subsequent regression analysis. Finally, multiple linear regression analysis was carried out, with the dependent variable as the outcome variable and the selected independent variables as predictors. The regression model was established to test the predictive effect of the independent variables on the dependent variable, and the significance of the regression coefficients and the goodness of fit of the model were evaluated.

Prior to conducting the formal data analysis, a series of data preprocessing steps were implemented to ensure the quality and validity of the data. This included checking for missing values, outliers, and normality. Missing values were handled using the mean imputation method when the proportion of missing data for a variable was less than 5%, as this approach is considered appropriate for maintaining data distribution characteristics in such cases. For outliers, the Z-score method was employed, with values beyond ±3 standard deviations identified and further examined; after confirming that these outliers were not due to data entry errors, they were retained to preserve the integrity of the dataset, as excluding them might have introduced bias. Normality tests, including the Shapiro-Wilk test and visual inspection of Q-Q plots, were performed on the continuous variables. The results indicated that all main variables approximately followed a normal distribution, meeting the assumptions required for parametric statistical analyses such as Pearson correlation and multiple linear regression. Additionally, multicollinearity among independent variables was assessed using variance inflation factors (VIF). All VIF values were found to be less than 2, well below the commonly accepted threshold of 10, indicating the absence of significant multicollinearity issues, thus ensuring the stability and reliability of the subsequent regression model.

3.0 RESULTS

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