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Influence of Cognitive Flexibility on the Problem-Solving Ability of Design Majors in Private Undergraduate Institutions in Shaanxi, China: Critical Thinking as a Mediating Variable

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Abstract

This study aims to explore the mechanisms between cognitive flexibility, critical thinking disposition, and problem-solving ability among design major students at private universities in Shaanxi Province, China. The research is driven by the current challenges in design education, where students face rigid thinking, insufficient innovation, and weakened problem-solving abilities. The study addresses the question of how cognitive flexibility directly influences problem-solving ability, and whether critical thinking plays a mediating role in this process. The research employs a quantitative approach, using a cross-sectional survey design, with a stratified random sample of 268 design major students from five private universities in Shaanxi Province. The revised scales for cognitive flexibility, critical thinking, and problem-solving ability are used as measurement tools, with standardized procedures for survey distribution and data collection. Data analysis is conducted using SPSS software, including regression analysis and Bootstrap mediation tests. The results show that cognitive flexibility significantly predicts both critical thinking and problem-solving ability, and that critical thinking partially mediates the relationship between cognitive flexibility and problem-solving ability. This study not only enriches the theoretical explanation of cognitive and thinking structures in design education contexts, but also provides empirical evidence for curriculum reform and the development of higher-order abilities in higher education. According to metacognitive theory (Flavell, 1976), individuals optimize their thinking and problem-solving by self-awareness, monitoring, and regulating their cognitive processes. In the study results, cognitive flexibility significantly predicts critical thinking and problem-solving ability, which aligns with the core principle of metacognitive theory: when students possess higher cognitive flexibility, they are able to quickly adjust their thinking approaches when facing complex tasks, shifting between different cognitive frameworks and information sources. This not only helps generate innovative solutions but also enhances their critical thinking abilities. Future research should integrate multi-source data (e.g., student, teacher, and course

evaluations) to more comprehensively examine the relationships among cognitive flexibility, critical thinking, and problem-solving ability among design majors at private undergraduate institutions.

Keywords: Cognitive Flexibility, Problem-solving Ability, Critical Thinking, Design Majors, Private Undergraduate Institutions

Introduction

With the rapid development of China's private undergraduate education system, the talent cultivation in design majors in Shaanxi Province faces a structural contradiction between the growing demand for innovation and the relatively weak cognitive foundation of students. Cognitive flexibility, as an essential component of higher-order learning abilities, has been widely confirmed in recent research for its critical role in complex learning environments. Studies show that cognitive flexibility supports individuals in reorganizing information, adjusting strategies, and thinking from multiple perspectives in dynamic task environments, thereby enhancing their learning adaptability and psychological engagement (Goldin et al., 2025). In educational contexts, cognitive flexibility is closely related to students' executive functions and problem-solving capabilities, and it can significantly promote complex problem solving and innovative performance (Schäfer et al., 2024). Further research highlights that in task-based or problem-based learning environments, cognitive flexibility helps students continually adjust their cognitive paths under uncertainty, enhancing the stability and depth of the learning process (Yıldız Durak & Atman Uslu, 2023; Honra & Monterola, 2026). However, in the practice of design education at private universities in Shaanxi, the systematic cultivation of cognitive flexibility remains insufficient due to limitations in course structure, teaching models, and resource allocation, leading to difficulties in demonstrating comprehensive analytical abilities and creative potential in cross-context, cross-medium, and interdisciplinary design tasks. Therefore, integrating cognitive flexibility into the research framework of design education holds clear and practical significance.

Although extensive studies have confirmed the crucial roles of cognitive flexibility and critical thinking in shaping university students' problem-solving ability, the underlying mechanism has not yet been systematically examined among design majors in private undergraduate institutions in Shaanxi. Existing research shows that critical thinking not only influences academic performance but also affects learning persistence and the effectiveness of problem solving (Almulla & Al-Rahmi, 2023; Evendi et al., 2022). Moreover, the reciprocal relationship between cognitive flexibility and critical thinking has been documented in multiple studies. For instance, Gökçe and Güner (2024) reported that cognitive flexibility affects academic achievement through critical thinking disposition, while Karakuş (2024) found a significant positive correlation between the two constructs among university students. In addition, Marzuki et al. (2024) demonstrated that solving complex problems requires students to generate multiple perspectives supported by cognitive flexibility and evaluate solutions using critical thinking. However, within the context of design majors in private undergraduate institutions in Shaanxi, the relationships among cognitive flexibility, critical thinking, and problem-solving ability remain unclear. Therefore, it is necessary to examine how cognitive flexibility influences students' problem-solving ability and to identify the mediating role of critical thinking, thereby clarifying key determinants of cognitive development in design education and informing instructional improvement.

This study aims to examine the relationships among cognitive flexibility, critical thinking, and problem-solving ability among design majors in private undergraduate institutions in Shaanxi Province, China. Specifically, the study focuses on exploring how cognitive flexibility influences students' problem-solving ability and whether critical thinking functions as an important mechanism linking these two constructs. The scope of this research is limited to undergraduate students enrolled in design-related programs at private universities in Shaanxi Province. Using a quantitative cross-sectional survey design, the study analyzes data collected through standardized questionnaires and statistical methods to clarify the structural relationships among the three variables and to provide empirical evidence for understanding higher-order cognitive development in design education contexts.

Literature Review

Cognitive Flexibility and Student Development

Existing research generally regards cognitive flexibility as an important cognitive resource for university students' adaptive development and positive psychological functioning, emphasizing its critical role in complex learning and psychological adjustment. From a mental health perspective, Goldin et al. (2025) argued that cognitive flexibility enables individuals to reorganize cognitive frameworks and adjust coping strategies in response to environmental changes, thereby sustaining psychological engagement and cognitive vitality. Similarly, Yurt and Hayli (2025), based on a sample of nursing undergraduates, found that cognitive flexibility significantly enhances positive mental health through the mediating role of self-efficacy. Although both studies highlight the positive function of cognitive flexibility in psychological adaptation, Goldin et al. focus more on its direct effects, whereas Yurt and Hayli further reveal indirect pathways through psychological variables. This divergence suggests that current research remains fragmented in explaining underlying mechanisms and requires the integration of multi-level models for systematic validation. In higher education contexts, scholars have also examined cognitive flexibility from the perspective of learning and development. Nakhostin-Khayyat et al. (2024), using structural equation modeling, reported significant structural relationships between cognitive flexibility, self-regulation, and psychological resilience, indicating that flexible cognitive processing facilitates adaptive responses to academic challenges. In contrast, Karakuş (2024) emphasized group differences, showing that cognitive flexibility varies significantly across academic disciplines and learning stages. While both studies underscore the importance of educational contexts, the former focuses on internal cognitive–psychological mechanisms, whereas the latter highlights external contextual and individual differences, reflecting two distinct explanatory orientations. However, most existing studies adopt cross-sectional designs, with limited attention to the dynamic development of cognitive flexibility, which constrains causal interpretation. Moreover, Scheibling-Sève et al. (2022) conceptualized cognitive flexibility as a key "cognitive scaffold" in learning, emphasizing its collaborative function with reflective and evaluative cognitive processes. Compared with empirical findings, this perspective offers theoretical integration and forward-looking implications but lacks sufficient empirical evidence. Overall, cognitive flexibility demonstrates multidimensional and comprehensive positive effects on university students' development, including those in design majors at private undergraduate institutions.

In the field of learning performance and higher-order ability development, cognitive flexibility is widely regarded as a key foundation for complex cognitive processing and innovative

thinking. Caliskan and Altun (2025) found that the interaction between cognitive flexibility and classroom engagement significantly enhances creative problem-solving ability, indicating that activating both cognitive and behavioral engagement in instructional contexts facilitates innovative solutions in open-ended tasks. Similarly, Marzuki et al. (2024) showed that cognitive flexibility supports students in continuously shifting strategies and generating diverse perspectives in complex problem-solving. While both studies highlight its importance in dynamic problem contexts, the former emphasizes classroom engagement, whereas the latter focuses on individual cognitive strategy adjustment, suggesting differences in contextual and process-based explanations. From the perspective of academic achievement and metacognitive development, Gökçe and Güner (2024) reported that cognitive flexibility indirectly improves academic performance through critical thinking and mathematics anxiety. In contrast, Kan and Kaya (2025) found that cognitive flexibility and critical thinking significantly predict academic literacy self-efficacy. Although both highlight mediating mechanisms, the former stresses emotional–cognitive integration, whereas the latter emphasizes direct cognitive effects, reflecting disciplinary differences. However, most studies are limited to single contexts, which restricts generalizability. Furthermore, Kılıç and Ercoşkun (2024) demonstrated that cognitive flexibility mediates the relationship between creative thinking and problem-solving skills, highlighting its role in transforming ideas into effective solutions. Despite consistent evidence of its positive impact, existing research remains fragmented in methodology and context, particularly lacking empirical studies in practice-oriented fields such as design majors at private undergraduate institutions.

Interplay among Cognitive Flexibility, Critical Thinking and Problem-Solving

A large body of research has examined the complex relationships among cognitive flexibility, critical thinking, and academic outcomes from both pathway and mechanism perspectives. Gökçe and Güner (2024) found that cognitive flexibility significantly influences academic achievement through the mediating roles of critical thinking disposition and mathematics anxiety, indicating that flexible cognitive structures not only promote deep thinking but also buffer the negative effects of emotions on learning performance. In contrast, Schäfer et al. (2024), from an executive function perspective, emphasized that cognitive flexibility works jointly with inhibitory control and working memory in scientific problem-solving. While both studies highlight its importance in complex tasks, the former focuses on psychological and emotional regulation pathways, whereas the latter emphasizes coordinated cognitive processing, reflecting divergent explanatory approaches. In addition, Karakuş (2024) reported a significant positive association between cognitive flexibility and critical thinking disposition among university students, underscoring the interactive development of openness and critical attitudes. Similarly, Marzuki et al. (2024) showed that, in mathematical problem-solving, students rely on cognitive flexibility to adjust strategies and use critical thinking to evaluate solutions. Although both studies confirm their synergistic role, Karakuş focuses on stable cognitive tendencies, whereas Marzuki et al. highlight dynamic task-based processes. However, most studies adopt cross-sectional designs, limiting causal interpretation and long-term understanding. From a theoretical integration perspective, Scheibling-Sève et al. (2022) proposed that cognitive flexibility and critical thinking jointly function as a “cognitive scaffold” in learning, with the former supporting shifting and restructuring and the latter emphasizing evaluation and reasoning. Although this framework addresses fragmentation in empirical research, it still lacks sufficient validation across disciplines. Overall, despite consistent evidence of their positive effects on academic performance, research remains limited in terms

of theoretical integration, methodology, and contextual expansion, particularly in practice-oriented fields such as design majors at private undergraduate institutions.

In broader learning and developmental contexts, critical thinking training and related factors play a significant role in promoting cognitive flexibility and problem-solving ability. Almulla and Al-Rahmi (2023), based on an integrated social cognitive theory model, found that problem-solving and critical thinking skills significantly influence the sustainability of learning performance, highlighting higher-order thinking as a key foundation for long-term outcomes. Similarly, Yurt and Hayli (2025) showed that critical thinking enhances positive psychological adaptation through self-efficacy and cognitive flexibility. While both emphasize long-term value, the former focuses on learning sustainability, whereas the latter highlights psychological adaptation, reflecting different outcome orientations and a lack of theoretical integration. From the perspectives of learning environments and individual differences, Evendi et al. (2022) reported that cognitive style significantly affects critical thinking in problem-based online mathematics learning, underscoring the importance of personalized instructional design. In contrast, Nazarboland et al. (2024) demonstrated that structured critical thinking training improves working memory, emotional regulation, and cognitive flexibility. These findings reveal both “individual difference” and “intervention-based” perspectives, yet most studies are limited to short-term or single-course contexts, restricting generalizability and long-term conclusions. Furthermore, Orakcı and Khalili (2025) found that cognitive flexibility influences critical thinking disposition through self-efficacy, emphasizing the interaction between cognitive resources and self-beliefs. Although consistent with Nazarboland et al. (2024) regarding transfer effects, the former focuses on structural relationships while the latter emphasizes training mechanisms. Overall, existing studies consistently confirm the positive effects of critical thinking training, but remain fragmented in terms of participants, contexts, and mechanisms, with limited evidence in practice-oriented fields such as design majors at private undergraduate institutions.

Based on the above literature review, it is evident that cognitive flexibility and critical thinking play essential roles in university students’ learning adaptation, higher-order cognitive development, and the formation of problem-solving ability. However, existing studies have largely focused on mathematics education, language education, or general university student populations, with relatively limited attention given to the specific group of design majors enrolled in private undergraduate institutions in Shaanxi, China. The learning context of design majors is characterized by a high degree of openness, interdisciplinarity, and practice orientation, and the structure of tasks and the nature of problems differ substantially from those of traditional academic disciplines. Therefore, it is necessary to re-examine the mechanisms through which cognitive flexibility and critical thinking influence problem-solving ability within this particular educational ecology. To address this research gap, the present study aims to systematically investigate the pathways through which cognitive flexibility affects the problem-solving ability of design majors in private undergraduate institutions in Shaanxi, and to further analyze the potential mediating role of critical thinking. By constructing and validating this model, the study seeks to provide empirical evidence for cultivating higher-order cognitive skills in design education, offer theoretical support for curriculum reform and instructional optimization, and ultimately contribute to improving the quality of talent development in design programs at private institutions.

Research Objectives

The primary objectives of this study are as follows:

RO1: To describe the demographic characteristics of design majors in private undergraduate institutions in Shaanxi Province through a frequency analysis of demographic variables.

RO2: To examine the relationships among problem-solving ability, cognitive flexibility, and critical thinking among design majors at private undergraduate institutions.

RO3: To analyze the mediating role of critical thinking in the relationship between cognitive flexibility and problem-solving ability.

Through the establishment of these research objectives, this study aims to construct a systematic analytical framework that reveals the intrinsic relationships among cognitive flexibility, critical thinking, and problem-solving ability. The findings are expected to provide empirical support for the advancement of design education and offer actionable theoretical and practical insights for enhancing higher-order thinking skills among students in private undergraduate institutions.

Research Hypothesis

Based on the research objectives, the following hypotheses are proposed:

H1: Students majoring in design at private undergraduate institutions in Shaanxi Province demonstrate diverse distribution patterns across demographic variables, such as gender, academic year, and field of specialization.

H2: There are significant correlations among problem-solving ability, cognitive flexibility, and critical thinking among design majors.

H3: Critical thinking mediates the relationship between cognitive flexibility and problem-solving ability.

Methodology

This study employed a quantitative research methodology, using a cross-sectional survey design to examine the structural relationships among cognitive flexibility, critical thinking, and problem-solving ability. The survey targets design major students enrolled in private universities in Shaanxi Province, China. The research specifically covers five private undergraduate universities in Shaanxi, all of which offer well-established design programs, including visual communication design, environmental design, product design, and digital media arts. A total of 268 valid surveys were distributed, and the sample size meets the statistical requirements for regression analysis and Bootstrap mediation testing, thereby supporting the analytical model of this study. The research employs a stratified random sampling method. First, universities serve as the strata basis, followed by further stratification by grade level and major direction within the universities. Students are then randomly selected within each stratum to participate in the survey. This sampling approach helps reduce sample selection bias, ensuring that design major students from different university backgrounds, learning stages, and academic disciplines are reasonably included, thus enhancing the representativeness of the sample and the external validity of the research findings. The research sites include five private universities in Shaanxi Province, China: Xi'an Jiaotong University City College, Xi'an University of Engineering, Xi'an University of Business and Economics, Xi'an University of Science and Technology Gaoxin College, and Xi'an Vocational University of Information Technology. The theoretical framework of this study is grounded in metacognitive theory (Flavell, 1976), which highlights individuals' capacity to

monitor, manage, and reflect upon their own cognitive processes. Within this framework, cognitive flexibility refers to learners' ability to adapt and shift cognitive strategies in response to changing task demands, while critical thinking represents the evaluative and reflective processes applied to information and potential solutions. Problem-solving ability can be viewed as the observable outcome of metacognitive control when individuals engage with complex tasks. From this perspective, the present study examines the structural relationships among these three constructs through a metacognitive lens, thereby offering insight into the underlying mechanisms of higher-order cognitive processing among design majors in private undergraduate institutions.

Regarding measurement instruments, three structured scales were utilized to assess problem-solving ability, cognitive flexibility, and critical thinking. The problem-solving ability scale, adapted from Siu (2005) and localized by Wang Wei (2010), includes five dimensions—positive problem orientation (Items 1–5), rational problem-solving (Items 6–10), negative problem orientation (Items 11–15), impulsive/avoidant style (Items 16–20), and avoidant style (Items 21–25)—for a total of 25 items. Cognitive flexibility was measured using a scale adapted from Martin and Rubin (1995), comprising three dimensions: flexible choice (Items 1–3), flexible willingness (Items 4–6), and flexible efficacy (Items 7–9), totaling 9 items. Critical thinking was measured using items adapted from the California Critical Thinking Disposition Inventory and Peng Meici's (2004) Chinese adaptation, covering six dimensions: critical thinking confidence (Items 1–7), inquisitiveness (Items 8–12), systematicity (Items 13–17), cognitive maturity (Items 18–20), analyticity (Items 21–23), and truth-seeking (Items 24–26), totaling 26 items. All scales adopted a five-point Likert response format to quantify students' psychological characteristics. In terms of analytical procedures, reliability and validity analyses were first conducted to ensure the quality of the measurement instruments. Pearson correlation analysis was then employed to explore the relationships among the three variables. Multiple regression analysis was used to test the predictive effect of cognitive flexibility on problem-solving ability. To examine the mediating role of critical thinking, the study adopted a bias-corrected Bootstrap method, assessing the significance of indirect effects and their confidence intervals. Through these analytical techniques, the study systematically evaluated the pathways among the variables and validated the proposed research hypotheses.

Results and Discussion

Demographic Characteristics

As shown in Table 1, the 268 participants in this study demonstrate a representative and structurally diverse demographic profile. First, in terms of gender distribution, females account for 64.93% of the sample, significantly exceeding the 35.07% of males—an outcome consistent with the commonly observed higher proportion of female students in design majors. Second, regarding academic year, sophomores (30.60%) and juniors (31.34%) constitute the largest proportions, indicating that the sample is concentrated in the phases of study where project-based coursework and discipline-specific training are most intensive. In contrast, freshmen (20.90%) and seniors (17.16%) make up smaller proportions, reflecting lower participation from students who are either newly entering university or approaching graduation. From the perspective of disciplinary distribution, students majoring in Visual Communication Design represent the largest group (38.06%), aligning with its relatively high prevalence among programs offered by private undergraduate institutions. Environmental

Design accounts for 26.12%, also demonstrating strong representation. Product Design (15.30%) and Digital Media Art (13.81%) occupy moderate proportions, suggesting that the sample encompasses a variety of design fields. Fashion and Apparel Design comprises only 4.48%, and the "Other" category accounts for 2.24%, indicating smaller enrollment sizes in certain specialized majors. Overall, the sample reveals a well-balanced distribution across gender, academic year, and disciplinary background, providing a robust foundation for examining the relationships among cognitive flexibility, critical thinking, and problem-solving ability.

Table 1
Demographics Profile of the Respondents (n = 268)

Profile	Description	Frequency	Percentage
Gender	Male	94	35.07%
	Female	174	64.93%
Grade	Freshmen	56	20.90%
	Sophomores	82	30.60%
	Juniors	84	31.34%
	Seniors	46	17.16%
Major	Visual Communication Design	102	38.06%
	Environmental Design	70	26.12%
	Product Design	41	15.30%
	Digital Media Art	37	13.81%
	Fashion and Apparel Design	12	4.48%
	Other	6	2.24%

The relationships among problem-solving ability, cognitive flexibility, and critical thinking among design majors at private undergraduate institutions.

Table 2
Correlation Analysis Results

Variables	Cognitive Flexibility	Critical Thinking	Problem-Solving Ability
Cognitive Flexibility	1		
Critical Thinking	.66**	1	
Problem-Solving Ability	.61**	.57**	1

The correlation analysis results in Table 2 indicate that cognitive flexibility, critical thinking, and problem-solving ability are all significantly and positively correlated ($p < .01$), suggesting stable associations among these variables among design majors at private undergraduate institutions. First, a strong positive correlation was found between cognitive flexibility and critical thinking ($r = .66$), indicating that higher levels of cognitive flexibility are associated with higher levels of critical thinking. Second, cognitive flexibility was also significantly and positively correlated with problem-solving ability ($r = .61$), suggesting that flexible cognitive processing enables students to generate diverse strategies when addressing complex tasks. Finally, critical thinking showed a significant positive correlation with problem-solving ability ($r = .57$), highlighting the important role of analytical and evaluative skills in improving the quality of problem solving.

A strong positive correlation was found between cognitive flexibility and critical thinking (r = 0.66). From a statistical perspective, this coefficient indicates that, within the sample of design majors at private undergraduate institutions, students with higher levels of cognitive flexibility also tend to demonstrate stronger tendencies and abilities in critical thinking. Cognitive flexibility emphasizes the capacity to shift rapidly among different rules, perspectives, and informational frameworks, while maintaining openness and alternative thinking when encountering conflicting information. In contrast, critical thinking requires students to carefully evaluate information sources, argument structures, evidence quality, and reasoning processes. When students possess higher levels of cognitive flexibility, they are more likely to engage in the comparison of viewpoints, the weighing of evidence, and the testing of hypotheses, thereby forming more sophisticated critical judgments. In other words, cognitive flexibility provides “alternative cognitive pathways” and “multi-framework processing capacity” for the development of critical thinking, enabling students to approach design problems from multiple perspectives rather than relying on a single line of reasoning. This finding also implies that curriculum design and project-based training that incorporate cross-contextual tasks, open-ended problems, and iterative feedback can enhance students’ cognitive flexibility and thereby contribute to the improvement of their critical thinking performance.

In addition, a significant moderate-to-high positive correlation was observed between cognitive flexibility and problem-solving ability (r = 0.61). This result indicates that cognitive flexibility is not only associated with the quality of thinking but is also consistently related to more outcome-oriented competencies such as problem-solving ability. In design tasks, problems are often open-ended, ambiguous, and characterized by multiple possible solutions. Students are therefore required to clarify needs, integrate information, generate solutions, and optimize design schemes within limited time and resource constraints. Students with higher levels of cognitive flexibility are generally able to reorganize information structures rapidly when requirements or constraints change, revise design assumptions in a timely manner, and switch effectively among multiple alternative solutions, thereby improving the adaptability and feasibility of their solutions. The magnitude of the correlation suggests that cognitive flexibility has strong explanatory potential for students’ problem-solving ability. When students are capable of flexibly shifting their thinking patterns and overcoming rigid cognitive pathways, their problem-solving processes are more likely to demonstrate strategic diversity, adaptive processes, and effective outcomes. From an educational practice perspective, this finding suggests that the cultivation of competencies in design education should not be limited to technical skills or tool usage. Greater attention should also be given to the development of flexible cognitive processing abilities, such as multi-solution comparison, reverse design thinking, contextual transfer, and the reconfiguration of task constraints, in order to help students build a higher-quality repertoire of strategies for solving real-world design problems.

A significant positive correlation was also found between critical thinking and problem-solving ability (r = 0.57), indicating that students with higher levels of critical thinking tend to demonstrate stronger problem-solving ability. This relationship highlights the “quality assurance” function of critical thinking in the problem-solving process. In the formation and optimization of design solutions, students are required not only to generate creative ideas but also to conduct evidence-based reasoning, risk assessment, and logical evaluation of their

proposed solutions. Students with stronger critical thinking skills are more likely to engage in self-questioning and counterfactual reasoning after generating a solution. They are better able to identify omissions in needs analysis, gaps in argumentation, and potential risks in the implementation of design solutions, and subsequently refine their ideas through iterative revision. Therefore, the significant association between critical thinking and problem-solving ability suggests that the capacity to generate ideas and the ability to implement them effectively both depend, to a considerable extent, on critical judgment. Particularly within the context of design majors at private undergraduate institutions, where evaluation criteria such as user experience, usability, feasibility, and sustainability are emphasized, critical thinking enables students to transform subjective creativity into solutions that can be logically justified, empirically evaluated, and systematically optimized, thereby enhancing the overall quality of problem-solving ability.

The mediating role of critical thinking in the relationship between cognitive flexibility and problem-solving ability

To examine the relationship between cognitive flexibility and the problem-solving ability of students majoring in design, this study employed multiple regression analysis to test the structural associations among cognitive flexibility, critical thinking, and problem-solving ability. Regression analysis not only reveals the linear relationships and statistical significance among variables but also helps clarify how cognitive and thinking-related factors contribute to performance in design tasks. Table 3 presents the results of the three regression models.

Table 3
Regression Analysis Results

Regression relationship	Independent variable	Dependent variable	B	SE	β	t	p	R^2
Model 1	Cognitive Flexibility	Critical Thinking	0.674	0.056	0.658	12.036	< .001	0.433
Model 2	Critical Thinking	Problem-solving Ability	0.622	0.079	0.571	7.873	< .001	0.326
Model 3	Cognitive Flexibility	Problem-solving Ability	0.587	0.054	0.612	10.871	< .001	0.375

The results displayed in Table 3 illustrate the structural relationships among cognitive flexibility, critical thinking, and problem-solving ability, providing important empirical evidence for understanding the cognitive processing mechanisms of design majors within complex learning contexts.

In Model 1, cognitive flexibility is used as the independent variable and critical thinking disposition as the dependent variable for regression analysis. The results show that the unstandardized regression coefficient of cognitive flexibility on critical thinking is B = 0.674, with a standard error of 0.056. The corresponding standardized regression coefficient is β = 0.658, t = 12.036, and the significance level is $p < .001$, indicating that this regression relationship is statistically highly significant. The R^2 value of Model 1 is 0.433, meaning that cognitive flexibility accounts for 43.3% of the total variance in critical thinking disposition. The

positive direction of the regression coefficient and the relatively high standardized coefficient suggest that cognitive flexibility has strong explanatory power and stability in predicting critical thinking disposition. In Model 2, critical thinking is used as the independent variable and problem-solving ability as the dependent variable for regression analysis. The results show that the unstandardized regression coefficient of critical thinking on problem-solving ability is B = 0.622, with a standard error of 0.079. The standardized regression coefficient is $\beta = 0.571$, $t = 7.873$, and the significance level is $p < .001$, indicating that this prediction relationship is also statistically significant. The R^2 value of Model 2 is 0.326, meaning that critical thinking explains 32.6% of the variance in problem-solving ability. Based on the size of the standardized regression coefficient, critical thinking has a moderately strong predictive effect on problem-solving ability, and the positive direction of the regression indicates that as critical thinking improves, problem-solving ability also increases in tandem. In Model 3, cognitive flexibility is used as the independent variable and problem-solving ability as the dependent variable to examine the direct predictive effect of cognitive flexibility on problem-solving ability. The regression results show that the unstandardized regression coefficient for cognitive flexibility is B = 0.587, with a standard error of 0.054. The standardized regression coefficient is $\beta = 0.612$, $t = 10.871$, and the significance level is $p < .001$, indicating that this regression relationship is highly significant. The R^2 value of Model 3 is 0.375, meaning that cognitive flexibility alone explains 37.5% of the variance in problem-solving ability. The standardized regression coefficient in this model is higher than the predictive effect of critical thinking in Model 2, showing that cognitive flexibility has a stronger direct explanatory power in predicting problem-solving ability.

Comparing the R^2 values of the three models, Model 1 has the highest R^2 value (0.433), followed by Model 3 (0.375), and Model 2 has the lowest R^2 value (0.326). This indicates that cognitive flexibility explains critical thinking the most, followed by cognitive flexibility's explanation of problem-solving ability, while critical thinking's explanation of problem-solving ability is slightly lower. The regression coefficients in all three models are statistically significant at the .001 level, indicating that the linear relationships between the variables are highly stable. From the regression analysis results in Table 2, it can be seen that cognitive flexibility significantly predicts both critical thinking and problem-solving ability; at the same time, critical thinking also significantly predicts problem-solving ability. The small standard errors and high t-values in all regression models further suggest that the model estimates are reliable. The above regression analysis results provide the necessary statistical prerequisites for subsequent mediation effect testing, as significant regression relationships exist between the independent and mediator variables, the independent and dependent variables, and the mediator and dependent variables, meeting the basic conditions for mediation analysis.

After establishing significant bivariate relationships among the variables, the study further employed the Bootstrap method to examine the mediating role of critical thinking in the relationship between cognitive flexibility and problem-solving ability. As a robust non-parametric estimation technique, Bootstrap enhances the accuracy and reliability of mediation testing through repeated resampling. Table 3 presents the estimates of the indirect, direct, and total effects, along with their 95% confidence intervals.

Table 4
Bootstrap Mediation Test

Effect Type	Effect Size (β)	Boot SE	95% CI Lower Bound	95% CI Upper Bound
Indirect Effect (cognitive flexibility → critical thinking → problem-solving ability)	0.288	0.041	0.212	0.375
Direct Effect	0.324	0.062	0.203	0.455
Total Effect	0.612	0.057	0.503	0.723

Table 4 presents the mediation effect of critical thinking in the relationship between cognitive flexibility and problem-solving ability, tested using the Bootstrap method (5,000 resamples, 95% CI). The results indicate that the mediation effect is significant, and the statistical characteristics clearly reveal the structural paths between the variables.

From the results of the indirect effect, cognitive flexibility exerts an indirect effect on problem-solving ability through critical thinking, with a value of β = 0.288 and a corresponding Bootstrap standard error of 0.041. The 95% confidence interval for this indirect effect ranges from 0.212 to 0.375, entirely above 0 and excluding zero, indicating that the indirect effect is statistically significant. This result suggests that under the Bootstrap resampling conditions, the effect of cognitive flexibility on problem-solving ability through critical thinking as a mediating pathway demonstrates high stability. The magnitude of the indirect effect indicates that the mediating pathway holds a substantial explanatory weight within the overall model.

From the results of the direct effect, when critical thinking is included in the model as a mediator, the direct effect of cognitive flexibility on problem-solving ability remains significant. As shown in Table 3, the standardized direct effect is β = 0.324, with a Bootstrap standard error of 0.062. The 95% confidence interval ranges from 0.203 to 0.455, also excluding zero. This result shows that even after controlling for the influence of critical thinking, cognitive flexibility still has a significant independent predictive effect on problem-solving ability. The existence of the direct effect indicates that the inclusion of the mediating model does not weaken the statistical association between cognitive flexibility and problem-solving ability.

From the total effect results, the total effect of cognitive flexibility on problem-solving ability is β = 0.612, with a Bootstrap standard error of 0.057. The 95% confidence interval ranges from 0.503 to 0.723, indicating a high level of significance. Notably, the total effect value is consistent with the sum of the direct and indirect effects (0.324 + 0.288 ≈ 0.612), suggesting good numerical consistency and statistical validity in the decomposition of the internal model paths. This consistency indicates that the mediation analysis calculation process is stable, and the effect decomposition results are reliable.

Further analysis of the effect structure ratio reveals that the indirect effect (β = 0.288) accounts for approximately 47.1% of the total effect (β = 0.612), while the direct effect (β = 0.324) accounts for approximately 52.9% of the total effect. This ratio structure indicates that both the direct and indirect pathways through critical thinking play significant roles in the impact of cognitive flexibility on problem-solving ability, with the direct effect being slightly higher than the indirect effect. Thus, statistically, it can be determined that critical thinking

plays a partial mediating role between cognitive flexibility and problem-solving ability, rather than a full mediation.

The Bootstrap mediation effect test results in Table 3 show that all three types of effects (indirect effect, direct effect, and total effect) reach statistical significance, with their corresponding confidence intervals not crossing zero, indicating high stability of the model's path relationships. The overall low Bootstrap standard errors further enhance the reliability of the effect estimates. The statistical results of the mediation model indicate that cognitive flexibility not only indirectly influences problem-solving ability through critical thinking as a mediator but also exerts a significant direct effect on problem-solving ability.

Summary of Results

The research findings confirm the hypothesis "H1: Cognitive flexibility has a significant positive effect on the problem-solving ability of design majors." In the frequency analysis of demographic variables, this study outlines the basic characteristics of design major students at private universities in Shaanxi Province. This analysis not only presents the gender, grade, and major composition of the sample but also provides a foundation for understanding the differences in students' cognitive and thinking abilities. Consistent with existing research, a higher proportion of female students in the design major group is a common phenomenon. This finding aligns with the results of Caliskan & Altun (2025), which indicate that female students exhibit higher cognitive flexibility, helping them demonstrate greater adaptability and creativity in solving complex design problems. Additionally, there are developmental differences in learning strategies and cognitive styles among students of different grade levels, which corresponds with the findings of Gökçe & Güner (2024). This study shows that students in different grades exhibit varying characteristics in cognitive styles and learning strategies. Such differences were also verified in this research, particularly in terms of variations in learning methods and cognitive engagement. Regarding the composition of majors, students in different design directions may exhibit variations in learning tendencies and cognitive engagement, consistent with the findings of Orakcı & Khalili (2025). That is, differences in design directions not only influence students' learning motivation and strategies but also further affect their academic performance and problem-solving abilities. Moreover, the distribution differences in cognitive flexibility and critical thinking across different groups, as pointed out by Karakuş (2024), are jointly influenced by students' learning stages and academic backgrounds. Therefore, the presentation of demographic characteristics not only aids in understanding the sample structure but also provides a necessary contextual foundation for interpreting the subsequent statistical results of cognitive and thinking variables. From a theoretical standpoint, metacognitive theory (Flavell, 1976) suggests that individuals can enhance the effectiveness of problem-solving ability by becoming aware of and monitoring their own cognitive activities. The theory proposes that learners should continuously evaluate and revise their cognitive strategies while addressing problems, adapting their approaches to the specific demands of the task. In this regard, the positive influence of cognitive flexibility on problem solving reflects learners’ capacity to refine and reorganize their thinking processes through ongoing metacognitive control.

The research findings confirm the hypothesis "H2: Cognitive flexibility has a significant positive effect on the critical thinking of design majors." When examining the direct effect of cognitive flexibility on problem-solving ability, the regression analysis results show that

cognitive flexibility is a significant positive predictor, which is consistent with international research trends. Caliskan & Altun (2025) pointed out that cognitive flexibility significantly enhances students' creative problem-solving performance, which aligns with the strong predictive effect of cognitive flexibility on problem-solving ability observed in this study. Similarly, Gökçe & Güner (2024) found that cognitive flexibility effectively reduces students' mathematical anxiety and enhances their problem-solving ability during the resolution of difficult problems, further supporting the positive role of cognitive flexibility on problem-solving ability in this study. Furthermore, Marzuki et al. (2024) discovered that cognitive flexibility significantly promotes students' critical thinking abilities in solving mathematical problems and enhances their flexibility and adaptability in tackling challenging tasks, which closely matches the performance of cognitive flexibility in design tasks in this study. Additionally, Kılıç and Ercoşkun (2024) further found that cognitive flexibility plays a crucial linking role between creative thinking tendencies and problem-solving skills, which corresponds closely to the strong direct effect identified in the present study. Thus, these findings not only validate cognitive flexibility as a vital higher-order cognitive capacity but also underscore its substantial practical significance within design education. From a theoretical perspective, metacognitive theory (Flavell, 1976) proposes that individuals are able to manage their thinking activities through awareness and monitoring of their cognitive processes. The theory highlights that when learners face complex tasks, they need to continually assess and modify their cognitive strategies in order to improve the effectiveness of information processing. In this context, cognitive flexibility facilitates the development of students' critical thinking by enhancing their capacity for metacognitive control over their learning and reasoning processes.

The research findings confirm the hypothesis "H3: Critical thinking mediates the relationship between cognitive flexibility and problem-solving ability." Regarding the mediating role of critical thinking, the Bootstrap mediation effect test results confirm that critical thinking plays a partial mediating role between cognitive flexibility and problem-solving ability, which aligns with the theoretical frameworks of several studies. Gökçe and Güner (2024) demonstrated that cognitive flexibility influences academic outcomes through critical thinking disposition, emphasizing the mediating function of critical thinking within cognitive processing—consistent with the significant indirect effect identified here. Similarly, Marzuki et al. (2024) provided empirical evidence supporting the role of critical thinking in enhancing mathematical problem solving, reinforcing its importance in complex task engagement. Nazarboland et al. (2024) found that critical thinking training can significantly improve cognitive flexibility and cognitive-emotional regulation, offering reverse validation of the reciprocal relationship between the two constructs. Moreover, Orakcı and Khalili (2025) reported that cognitive flexibility improves learning performance through enhanced self-efficacy and critical judgment, providing theoretical rationale for the coexistence of significant direct and indirect effects observed in this study. Collectively, these findings demonstrate that the mediating pathway involving critical thinking is supported not only statistically but also theoretically and empirically across diverse research contexts. From a theoretical standpoint, metacognitive theory (Flavell, 1976) proposes that individuals guide their cognitive activities by becoming aware of and reflecting on their own thinking processes. The theory highlights that learners must consistently observe, assess, and refine their thinking strategies when dealing with complex problems so that their approaches align with task requirements. In this framework, critical thinking can be regarded as a key metacognitive mechanism that mediates

the relationship between cognitive flexibility and problem-solving ability, especially among design majors in private undergraduate institutions.

Conclusion

This study systematically analyzes the relationship between cognitive flexibility, critical thinking disposition, and problem-solving ability among design major students at private universities in Shaanxi Province. The results indicate a significant and robust structural relationship between these three variables. The demographic analysis reveals typical distribution patterns based on gender, grade level, and major direction, providing important contextual insights into the learning and cognitive characteristics of design major students. The regression analysis confirms that cognitive flexibility not only directly influences students' problem-solving ability but also plays a significant role in predicting critical thinking disposition. Further mediation effect analysis shows that critical thinking plays a key partial mediating role between cognitive flexibility and problem-solving ability, indicating that students need both flexible thinking and in-depth critical analysis skills to effectively solve complex design tasks. From the perspective of metacognitive theory, cognitive flexibility enables students to continuously monitor and regulate their cognitive strategies during the learning process, while critical thinking facilitates reflection and evaluation of problem-solving pathways. Together, these constructs form a higher-order cognitive regulatory mechanism that enhances the effectiveness of problem-solving ability. This study not only deepens the understanding of cognitive mechanisms in the field of design education but also provides empirical evidence for curriculum design, teaching interventions, and the cultivation of higher-order thinking skills. The findings have significant practical implications, particularly in enhancing the innovation and practical abilities of design talent in private universities. Future research could further explore the dynamic developmental mechanisms of cognition and thinking in design major students by expanding the sample size, incorporating longitudinal research designs, or using multi-source data. This would provide more theoretical and empirical support for the field of design education. Future research may integrate multi-source data, such as student, teacher, and course evaluation data, to examine more comprehensively and objectively the relationships among cognitive flexibility, critical thinking, and problem-solving ability. The significance of this study extends beyond understanding students' cognitive abilities, offering concrete guidance to higher education educators in developing students' critical thinking and problem-solving skills through curriculum design and teaching practices. By promoting the enhancement of students' cognitive flexibility, universities can effectively improve the overall quality and innovative capacity of design major students, further contributing to the improvement of higher education quality.

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