Journal of Psychology in Africa, 2026
Vol. 36, No. 4, 691–699, http://doi.org/10.32604/jpa.2026.079470

Learning cognition, attitude, and academic performance: The mediation role of executive ability

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Received: 21 January 2026; Accepted: 19 May 2026; Published: 31 August 2026

Abstract: This study investigated how learning cognition influences college students' academic performance, focusing on the mediating role of learning attitude and the sequential mediating role of executive ability and learning attitude. Data were from the Tsinghua University's "Chinese College Students Learning and Development Tracking Study" project (N = 766; 41.37% female; mean age = 20 years, SD = 1.2 years). Results from panel data analysis showed that learning cognition was associated with higher academic performance. Learning attitude positively mediated this relationship. Moreover, learning attitude and executive ability served as positive sequential mediators linking learning cognition to academic performance. These findings add to self-regulation theory by demonstrating that executive ability serves as a key behavioral mechanism translating cognition and attitude into academic outcomes. Based on these findings, student development support services should promote initiatives for integrated development of cognition, attitude, and willpower in the learning process.

Keywords: Learning cognition factors; learning attitude; executive ability; academic performance

Introduction

How students learn remains an important research endeavor in the context of rapidly evolving knowledge-based economies (Baker & Mayernik, 2020; Lane et al., 2021). The pursuit of connotative development in higher education has thus become an imperative aligned with contemporary demands (Qiu & Li, 2022; Wang & Zhou, 2023; Zhao, 2024). Learning is driven by thinking abilities and attitudes, which translate into academic achievement. Current literature predominantly examines dimensions such as emotional perception, environmental sensitivity, learning motivation, learning strategies, and self-efficacy. However, executive function as a learning mediator is less well studied alongside learning cognition and attitude for academic performance; hence this study.

Learning cognition, attitude, and academic achievement. Cognition, involving information processing, memory, imagination, and reasoning, has been widely recognized as a core predictor of academic achievement (Sun et al., 2012). However, cognitive factors by themselves do not fully account for differences in academic performance, highlighting the need to also consider non-cognitive constructs such as self-regulation (Broadbent & Fuller-Tyszkiewicz, 2025).

Attitude is commonly conceptualized as a relatively stable psychological orientation comprising cognitive, affective, and behavioral components (Rosenberg & Hovland, 1960), and exhibits high internal consistency under normal conditions, with the affective dimension playing a more dominant role under conditions of cognitive dissonance. From the perspective of positive psychology, psychological capital—characterized by confidence, hope, optimism, and resilience—has also been identified as a crucial factor in individual development (Luthans et al., 2004). When applied to educational contexts, this construct demonstrates significant correlations with academic outcomes across four validated dimensions (Luthans et al., 2026). Moreover, psychological variables—including learning motivation, emotional valence, and self-esteem—have been shown to influence academic achievement through both cognitive and attitudinal mechanisms (Acosta-Gonzaga & Ramirez-Arellano, 2021). Proactive agency underpins learning motivation, as it reflects a learner's consciously constructed identity and desire for change (Dobryakova & Yurchenko, 2023). Building on this motivational foundation, goal attainment further requires not only cognitive readiness and a positive learning attitude but also executive capacity—the behavioral ability to translate intentions into sustained self-regulated action (Nicolau et al., 2023).

Learning attitude determines whether learners persist when facing academic challenges. Empirical research has consistently identified learning attitude as a significant predictor of academic outcomes across diverse educational contexts. Studies have shown that students with positive learning attitudes exhibit higher levels of engagement, persistence, and achievement (Chestnut & Johnson, 2025; Chung & Bing, 2025).

Executive ability mediation

Executive ability refers to the behavioral capacity to convert learning intentions into outcomes. Empirical studies have consistently demonstrated that executive function skills significantly predict academic achievement across educational levels. A study (Soltani Nezhad & Delroba, 2024) examining university students found that executive function performance significantly correlated with academic achievement ($p < 0.05$), suggesting that students with stronger inhibitory control and cognitive flexibility achieve better academic outcomes. Similarly,

Budwig et al. (2025) investigated the relationship between executive function, student engagement, and academic success among U.S. college students, finding that executive function not only directly influenced grades but also exerted indirect effects through the mediating mechanism of behavioral engagement. Their mediation analysis confirmed that student engagement partially mediated the executive function-academic performance relationship. These findings indicate that executive ability serves as a behavioral bridge between cognitive intentions and achievement outcomes.

Although existing studies have extensively examined college students' academic performance and the roles of cognitive, motivational, behavioral, and family background factors, several limitations remain. First, prior research often tests learning cognition, learning attitude, or self-regulation variables separately, while their combined and conditional mechanisms receive less systematic examination. In practice, course cognitive demands and students' learning attitudes co-occur, yet the way they jointly relate to GPA trajectories is not consistently tested within a unified model (Richardson et al., 2012; Zimmerman, 2000). Moreover, many studies rely on cross-sectional indicators or single-time-point outcomes, which limits inference about changes across learning stages. Longitudinal evidence linking time-varying learning-related factors to multi-stage GPA outcomes remains comparatively limited (Liu et al., 2024; Zimmerman, 2000).

Theoretical basis

Bloom's Taxonomy classifies learning into six hierarchical levels—remembering, understanding, applying, analyzing, evaluating and creating—where higher-order processing leads to better knowledge transfer and long-term retention (Krathwohl, 2002). Studies show that students who engage more deeply in analytical and synthesis-based learning develop more effective learning strategies and demonstrate superior performance across academic stages (Anderson & Krathwohl, 2001). Course cognitive objectives therefore directly shape students' perceived task difficulty and engagement depth, which theoretically explains why clearer cognitive structuring improves GPA progression.

Expectancy–value theory posits that individuals' behavioral persistence and effort intensity are primarily driven by their perceived task value and success expectations. Learning attitude represents students' motivational orientation toward academic tasks and significantly determines their learning engagement and academic persistence. According to self-regulation theory, executive ability serves as a central mechanism that transforms cognitive intent and motivational orientation into concrete learning behaviors. Students with stronger executive control are better at time management, task execution, and goal persistence. Therefore:

Integrating the above frameworks, this study proposes a sequential mediation model: cognition determines learning clarity, which in turn shapes attitude and motivational strength; positive attitude then enhances the capacity for self-regulation, strengthening executive ability; finally, executive ability converts these psychological resources into academic outcomes. Thus, learning attitude is expected to mediate the relationship between learning cognition and academic performance, while executive ability and learning attitude sequentially mediate this relationship. This theoretical path forms the basis for the hypotheses proposed in the subsequent section.

The China context

In the Chinese context, recent empirical studies confirmed that learning attitude significantly predicted academic performance, exerting both direct and indirect effects through mechanisms such as student engagement (Zhang, 2024). China's 14th Five-Year Plan and the Long-Range Objectives Through 2035 explicitly prioritize the establishment of high-quality undergraduate education and the enhancement of postgraduate teaching standards as core goals for the higher education sector (Kuang & Duan, 2025; Chen, 2021; Wang, 2021). However, persistent challenges such as insufficient student motivation and academic burnoutremain widespread across Chinese higher education institutions (Li et al., 2026; Lu & Guo, 2024). This study, therefore, delves into the core factors influencing contemporary university students' academic performance, with particular emphasis on the student perspective. Its primary objective is to identify pathways for improving learning efficiency and quality based on these determinants. In the Chinese context, scholars have predominantly employed quantitative metrics derived from students' stage-specific academic scores, utilizing standardized tests and survey-based approaches to assess academic achievement. Academic performance has often been categorized by learning stages and examined for temporal correlations to identify longitudinal learning trajectories (Liu et al., 2024). Researchers have also used questionnaire surveys to collect self-reported GPA data from students, which are then validated against institutional academic records as key indicators of academic outcomes (Puah et al., 2024).

The present study. To address these gaps, the present study constructs an integrated framework incorporating learning cognition, learning attitude, executive ability, and family background factors, and applies panel regression with interaction and mediation specifications. Specifically, this study examines the direct effect of learning cognition on GPA; tests the mediating role of learning attitude in the cognition-performance relationship; and evaluates the sequential mediation pathway through learning attitude and executive ability. Therefore, the following hypotheses were proposed for testing:

H1: Higher learning cognition is associated with higher college academic performance.

H2: Learning attitude mediates the relationship between learning cognition and academic performance for higher academic performance.

H3: Executive ability and learning attitude sequentially mediate learning cognition and academic performance for higher academic performance.

Methods

Data source and sample

The data for this study were obtained from the "Chinese College Students' Learning and Development Tracking Study" (CCSS) project, led by Tsinghua University. Over 100 higher education institutions across China participate in this project, including a "Double First-Class" university in City N, which has been involved in the survey for 14 waves since 2009.

The analysis sample consists of undergraduates from the Class of 2023 with complete longitudinal records across three academic years (2020–2023). Participants were selected through randomized online sampling. The initial valid sample sizes were 1167 in the freshman year, 1083 in the sophomore year, and 957 in the junior year. After data matching and cleaning, a total of 766 students with continuous responses and complete information over all three years were retained, accounting for 33.33% of the sample each year.

Inclusion and exclusion criteria were defined to ensure a balanced three-wave panel and transparent data processing. Inclusion criteria were: (a) undergraduates who could be matched across the three academic years (2020–2023) with consistent identifiers; and (b) complete records for GPA and the focal learning-related measures at each wave. Exclusion criteria were: (a) cases that could not be reliably matched across waves; and (b) missingness on core variables that prevented construction of the panel models. The final dataset thus consisted of 766 individuals observed over three time points (i.e., 2298 person-year records), which clarifies the unit of analysis for the panel regressions. Because this study is a secondary analysis of an existing institutional dataset, the sample size was constrained by the availability of matched longitudinal records; a sensitivity consideration following conventional regression power logic suggests that $N = 766$ is adequate for detecting small incremental effects under typical settings (Cohen, 1988).

Regarding demographic composition, 58.63% of the sample were male and 41.37% female. By discipline, 28.58% were enrolled in humanities and social sciences, 33.45% in natural sciences, and 37.97% in engineering. In terms of geographical background, 67.12% held urban household registration (hukou), while 32.88% had rural hukou. These distributions align closely with the overall student population at the university.

Procedure

This study was conducted in accordance with the ethical standards of the institutional research committee. Ethical approval was obtained from the Research Ethics Committee of Nanjing University of Posts and Telecommunications (Project Number: 2026B027). All participants were fully informed about the purpose of the study, and written informed consent was obtained prior to participation. Participation was voluntary, and all data were used for research purposes only with strict anonymity and confidentiality ensured.

Measures/Variable operationalization

Academic performance

Academic performance was operationalized using students' cumulative Grade Point Average (GPA), obtained from institutional academic records. GPA was calculated using a credit-weighted method and reflects students' overall academic achievement and long-term learning quality. This indicator has been widely adopted in educational research.

Learning cognition (course cognitive objectives)

Learning cognition was measured using the course cognitive objective module in the CCSS database, capturing students' perceived cognitive engagement and cognitive demands in coursework. Representative item content includes (e.g.,) "the course emphasizes understanding key concepts", "the course requires applying learned knowledge to problems or tasks", and "the course requires analysis/evaluation or integration of ideas". Items were rated on a Likert-type scale (4-point) and scored according to the CCSS protocol, with higher values indicating stronger higher-order cognitive engagement. In the present study, internal consistency reliability was acceptable (Cronbach's $\alpha = 0.87$).

Learning attitude

Learning attitude was assessed using the learning attitude subscale of the CCSS survey, reflecting students' motivational and evaluative orientation toward learning tasks. Representative item content includes (e.g.,) "I find learning meaningful/valuable", "I am willing to persist when study becomes difficult", and "I feel tired of studying" (reverse-coded). Items were rated on a Likert-type scale (4-point) and scored following the CCSS protocol, with higher scores indicating a more positive learning attitude. The Cronbach's α coefficient in this study was 0.89.

Executive ability

Executive ability refers to students' capacity for goal implementation and behavioral self-regulation during learning. Representative item content includes (e.g.,) "I can follow a study plan and complete tasks on schedule", "I manage study time efficiently", and "I monitor my progress and adjust when falling behind". This measure used an ordered 3-category response format and was scored on a 1–3 scale, with higher scores indicating stronger executive control. Internal consistency reliability was satisfactory (Cronbach's $\alpha = 0.85$).

Dependent variable: academic performance (GPA)

Academic performance was operationalized using students' Grade Point Average (GPA) obtained from institutional academic records. To capture students' longitudinal learning outcomes, GPA values from the second, fourth, and sixth semesters were included in the empirical analysis. GPA serves as an objective indicator reflecting students' cumulative academic achievement.

Table 1. Control variables, measurement and coding description

Variable	Measurement/Coding	Meaning
Place of residence	1 = rural area; 2 = township; 3 = small city; 4 = medium city; 5 = large city; 6 = mega-city	Indicates the economic development level of the student's family location
Previous-year household income	Continuous variable (RMB/year)	Total household income in the previous year
Father's highest education level Mother's highest education level	1 = Primary school or below; 2 = Junior high school; 3 = Senior high school; 4 = Vocational college; 5 = Bachelor's degree; 6 = Master's degree; 7 = Doctoral degree; 8–9 = additional CCSS coded categories (see CCSS coding scheme). Same coding as father's education level	Father's highest educational attainment Mother's highest educational attainment

Independent variables

Learning cognition/course cognitive objectives (COC)

Learning cognition, operationalized as course cognitive objectives (COC), reflects the level of cognitive demand perceived by students during the learning process. This construct is grounded in Bloom's cognitive taxonomy, which conceptualizes learning cognition as a hierarchical progression from lower-order processes such as memorization to higher-order tasks including analysis, evaluation, and integration.

Learning attitude (SWL attitude subscale)

Learning attitude was assessed using the pro-learning/anti-learning orientation scale from the CCSS database, which captures students' motivational orientation toward learning tasks, including learning interest, persistence, and value perception. Higher scores represent a more positive learning attitude toward academic activities.

Executive ability

Executive ability was measured using the behavioral self-regulation and execution module of the CCSS survey. This scale reflects students' capacity for time management, goal implementation, and behavioral persistence in learning tasks. Higher scores indicate stronger executive control ability.

Control variables

Several family background variables were included as control variables, including place of residence, previous-year household income, father's highest education level, and mother's highest education level, to reduce potential confounding effects. Table 1 summarizes the measurement and coding of these variables.

Control variables improve model robustness and reduce omitted-variable bias.

Statistical analysis

All analyses were conducted using SPSS 25.0 and Stata 16.0. SPSS 25.0 was used to compute descriptive statistics and Pearson correlations, and to perform the clustering procedures. Specifically, k-means clustering was applied to course cognitive objectives, and Ward's hierarchical clustering was used as a validation check. The three-wave tracking dataset (2020–2023) was organized as a balanced panel (766 individuals observed across three time points). Panel regressions and grouped regressions were estimated in Stata 16.0.

Model selection between fixed effects and random effects was guided by the Hausman test, and random-effects specifications were adopted for estimation. Robust standard errors were used and reported in parentheses. To evaluate the joint effect of learning cognition and learning attitude, both variables were mean-centered and multiplied to construct the interaction term. Regression models were estimated sequentially by adding or removing key variables (course cognitive objectives, learning attitude, their interaction term, and executive ability), and cluster-specific regressions were further conducted based on the grouping results. All tests were two-tailed, and statistical significance was evaluated at the 10%, 5%, and 1% levels.

Results

Descriptive statistics

Table 2 presents the descriptive statistics of the key variables. The dynamic trajectory of academic performance indicates that the average GPA increased progressively from 3.043 in the second semester to 3.454 in the sixth semester, showing an overall upward trend across semesters. Concurrently, variations in the standard deviation of GPA across semesters point to noticeable between-student heterogeneity. The greater dispersion observed in later semesters indicates increased differentiation in academic performance among students.

Cluster analysis results

Cluster analysis groups data based on similarity to compare and reorganize observations into relevant categories. Since course cognitive objectives represent the primary cognitive dimension of learning, this study selected them as the clustering variable.

Using SPSS 25, k-means cluster analysis was performed on the course cognitive objectives of the 766 valid samples. To validate the k-means results, Ward's hierarchical clustering method was also applied. A dendrogram was generated to visualize the clustering structure (Figure 1).

K-means cluster analysis categorized students' course cognitive objectives into three levels—high, medium, and

Table 2. Descriptive statistics of variables

Variables	Sample	Mean	Standard deviation	Minimum	Maximum
Second-semester GPA	766	3.043	0.657	1.33	4.56
Fourth-semester GPA	766	3.249	0.739	0.38	4.59
Sixth-semester GPA	766	3.454	0.630	0.32	4.76
Course-related cognitive objectives	2298	61.138	20.832	0	100
Learning attitude	2298	64.367	14.532	0	100
Interaction term	2298	4059.8	1935.7	0	10,000
Execution ability	2298	1.421	1.248	1	3
Previous-year family income	2298	354,319.5	473,711.7	4000	500,000
Family place of residence	2298	3.675	1.383	1	6
Father's highest education level	766	4.517	1.834	1	9
Mother's highest education level	766	4.081	1.762	1	9

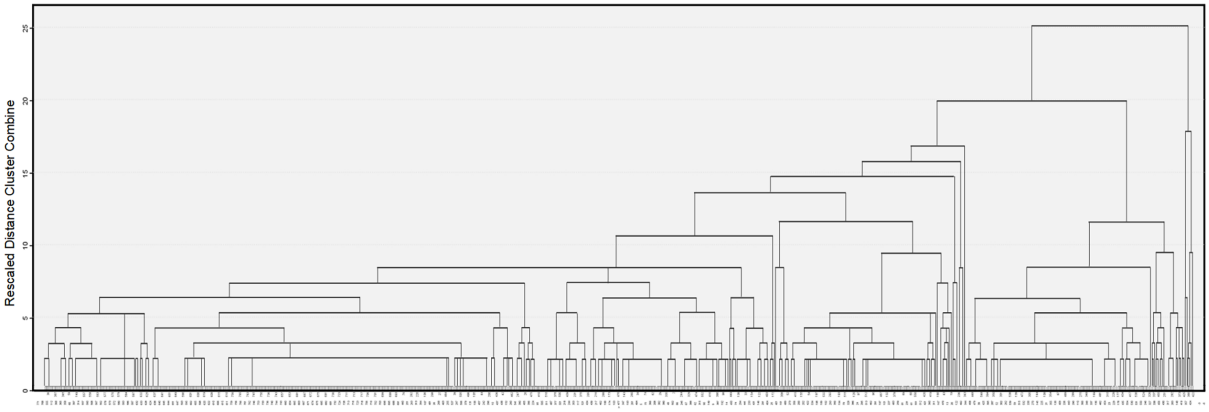

Figure 1. Hierarchical cluster analysis dendrogram

Table 3. Cluster analysis based on course cognitive objectives

Cluster	Cluster 1	Cluster 2	Cluster 3
Number of cases (individuals)	149	485	132
Cluster center (percentage-based)	91.01	60.32	32.61

low—corresponding to Cluster 1, Cluster 2, and Cluster 3 in Table 3, respectively.

Panel regression analysis

This study treats the three-year longitudinal tracking data as panel data and constructs econometric models for analysis. Based on the Hausman test, the random effects model was selected for estimation. The econometric model is specified as:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 (x_1 \times x_2) + \beta_4 x_3 + \varepsilon \quad (1)$$

In Eq. (1), the dependent variable y represents the academic performance (GPA) of students; x_1 denotes course cognitive objectives; x_2 represents learning attitude; x_1x_2 is the interaction term of the two; and x_3 is a set of control variables related to family background, including household income from the previous year, place of residence, father's highest education level, and mother's highest education level. The coefficients β_1, β_2, β_3 and β_4 correspond to the respective explanatory variables. To ensure the robustness and efficiency of the analysis, a total of 13 regression models were estimated by sequentially adding or removing key variables-course cognitive objectives, learning attitude, their interaction term, and executive ability.

Regression results based on the full sample (Table 4) indicate that academic performance is significantly and positively correlated with both course cognitive objectives and learning attitude in Model 1. Models 2 to 4 further examine the effects by including different combinations of key variables. The regression coefficients across Models 1–4 remain consistent in both sign and significance. Specifically, in Model 1, the coefficient for course cognitive objectives was positive and significant ($\beta = 0.00831$, $p < 0.01$). This finding directly tests H1, which proposed that higher learning cognition is associated with higher academic performance. Therefore, H1 is supported.

Grouped regression analysis

Based on the cluster grouping results, further grouped regressions were conducted on course cognitive objectives, learning attitude, their interaction term, and executive

Table 4. Model regression results

Variables	Variable coefficients			
	Model 1	**Model 2**	**Model 3**	**Model 4**
Course cognitive objectives	0.00831***	−0.000991		0.00302***
	(0.00203)	(0.0013)		(0.000614)
Pro-learning/anti-learning	0.0112***		0.00414***	0.00614***
	(0.00224)		(0.00139)	(0.00103)
Place of residence	0.0156	0.0172	0.0166	0.0165
	(0.0113)	(0.0112)	(0.0112)	(0.0113)
Previous year household income	4.62E−08	5.15E−08	5.10E−08	4.84E−08
	(4.24E−08)	(4.14E−08)	(4.15E−08)	(4.19E−08)
Father's highest Education	0.00282	0.00367	0.00344	0.00307
	(0.0132)	(0.0132)	(0.0131)	(0.0132)
Mother's highest Education	0.0193	0.019	0.0196	0.0192
	(0.014)	(0.0139)	(0.0139)	(0.0139)

Note. ① Data sourced from Stata 16; ② ***$p < 0.01$, respectively; robust standard errors are reported in parentheses.

Table 5. Grouped regression results for academic performance

Explanatory variables		Course cognitive objectives		Pro-learning/anti-learning		Interaction term		Execution ability	
	Model 5	0.00414	(0.00214)			0.0000353	(2.18E−05)	0.097**	(0.0435)
Cluster 1	Model 6			0.00147	(0.0025)	3.18e − 05**	(0.000016)	0.0998**	(0.0435)
	Model 7	0.00253**	(0.00111)	0.00362**	(0.00177)			0.101**	(0.0431)
	Model 8	−0.00298	(0.00184)			7.79e−05***	(2.05E−05)	0.0351	(0.0323)
Cluster 2	Model 9			0.00482***	(0.00185)	2.27e−05*	(1.32E−05)	0.0359	(0.0324)
	Model 10	0.00184**	(0.000888)	0.00608***	(0.00138)			0.0355	(0.0324)
	Model 11	−0.00357	(0.00293)			0.000114***	(3.80E−05)	0.0416	(0.0415)
Cluster 3	Model 12			0.00541**	(0.00276)	4.27e−05**	(2.00E−05)	0.0457	(0.0412)
	Model 13	0.00283**	(0.00122)	0.00723***	(0.00223)			0.0455	(0.0411)

Note. ① Data sourced from Stata 16; ② *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$, respectively; robust standard errors are reported in parentheses.

ability. The grouped regression results are presented in Table 5.

Overall, the combined effect of course cognitive objectives and learning attitude on academic performance is positive and significant. The regression coefficients differ across clusters, indicating heterogeneity in the influencing mechanisms among students with different levels of course cognition. Regarding H2, the positive and significant coefficients for learning attitude (e.g., Cluster 2 Model 10: $\beta = 0.00608$, $p < 0.01$; Cluster 3 Model 13: $\beta = 0.00723$, $p < 0.01$) support the mediating role of learning attitude between learning cognition and academic performance. Regarding H3, executive ability significantly predicted academic performance in Cluster 1 (Model 7: $\beta = 0.101$, $p < 0.05$), and the interaction between learning cognition and learning attitude was significant in Clusters 2 and 3 (e.g., Cluster 2 Model 8: $\beta = 7.79\text{e}{-05}$, $p < 0.01$; Cluster 3 Model 11: $\beta = 0.000114$, $p < 0.01$). This pattern is consistent with the proposed sequential mediation pathway. Therefore, H2 and H3 were supported.

Discussion

Consistent with H1, the results indicate that higher learning cognition (course cognitive objectives) is positively associated with GPA. This finding is broadly consistent with evidence that learning-related psychological factors and self-regulatory processes are reliable correlates of academic performance in higher education (Richardson et al., 2012; Zimmerman, 2000). In this study, the association was more salient among students with lower initial cognitive levels, suggesting that motivation-related orientation may be particularly consequential when coursework is experienced as challenging.

Regarding H2, learning attitude positively mediated the relationship between learning cognition and academic performance. This supports the view that positive learning attitudes translate cognitive engagement into better academic outcomes. The positive and significant coefficients for learning attitude across different clusters (e.g., Cluster 2 and Cluster 3 in Table 5) reinforce the robustness of this mediating pathway. Consistent with prior research (Chestnut & Johnson, 2025; Chung & Bing, 2025), students with more positive learning attitudes exhibited higher engagement and persistence, which in turn predicted higher GPA.

Supporting H3, executive ability and learning attitude served as sequential mediators linking learning cognition to academic performance. Executive ability can be interpreted as a behavioral mechanism that converts positive learning attitudes into sustained academic performance. Among higher-cognition learners, differences in planning,

persistence, and self-monitoring may become more decisive for converting potential into stable GPA. This aligns with review evidence on executive-function-related skills and achievement outcomes (Jacob & Parkinson, 2015) and with self-regulated learning accounts emphasizing goal implementation and monitoring (Zimmerman, 2000).

Regarding family background, the estimated effects of conventional SES indicators appear comparatively smaller once learning-process variables are included, which is compatible with the view that SES effects may partly operate through more proximal learning and psychological mechanisms and vary across contexts (Sirin, 2005).

Practical implications for higher education

For students with lower cognition levels, interventions should focus on reducing avoidable cognitive overload while strengthening task value and persistence. Operable measures include structured learning support that breaks complex assignments into staged goals with frequent formative feedback, and course design that explicitly signals cognitive objectives (e.g., when tasks require application/analysis rather than recall) to guide effort allocation. For students with higher cognition levels, the results suggest executive ability becomes a stronger differentiator; therefore, practical training on time-block planning routines, weekly goal-setting with progress checkpoints, and brief coaching on distraction control and setback management may improve planning, persistence, and self-monitoring, increasing the likelihood that cognitive advantages and positive attitudes translate into sustained GPA outcomes.

Limitations and future directions

This study has several limitations that should be acknowledged. The sample size was reduced after data screening, which may restrict the generalizability of the findings. In addition, the clustering approach showed limited discriminative power in categorizing student subgroups within the institution, and the relatively concentrated sample led to some redundancy in variable interpretation.

Future studies should employ more robust sampling strategies and advanced clustering techniques to enhance the reliability and general applicability of the results. Moreover, longitudinal research designs are recommended to better capture causal relationships among learning cognition, learning attitude, executive ability, and academic performance.

Conclusion

In conclusion, the findings of this study indicate that learning cognition influences academic performance both directly and indirectly through the sequential pathway of learning attitude and executive ability. The urban living environment also appears to positively shape students' learning motivation and cognitive styles, while the influence of family socioeconomic factors, such as household income and parental education, shows a weakening trend.

These results demonstrate that academic achievement is shaped by the sequential interplay of cognitive engagement, learning attitude, and executive control, where cognitive engagement fosters positive attitudes, which in turn enhance executive ability.

Overall, this study provides empirical evidence for understanding the psychological and behavioral mechanisms underlying college students' academic performance and offers practical reference for optimizing instructional strategies and student development programs in higher education.

Acknowledgement: Not applicable.

Funding Statement: This research was funded by the Philosophy and Social Sciences Research Project for Universities in Jiangsu Province (Project: "Responsibility and Awakening: Practical Research on the Construction of Learning Motivation Model for Underachieving Students"), grant number 2024SJYB0112, awarded to Fuqiang Li; the Key Project of Party Building and Ideological and Political Education Research of Nanjing University of Posts and Telecommunications (Project: "Research on Ideological and Political Work of Young Teachers in Universities in the New Era"), grant number XC2020003, awarded to Fuqiang Li; and the Teaching Reform Research Project of Nanjing University of Posts and Telecommunications (Project: "Exploration and Practice on the Construction of Labor Education Curriculum System in Universities in the New Era"), grant number JG06321JX21, awarded to Fuqiang Li.

Author Contributions: The authors confirm contribution to the paper as follows Conceptualization, Xiaohua Li and Fuqiang Li; methodology, Xiaohua Li; software, Xiaohua Li; validation, Xiaohua Li, Fuqiang Li and Wenjin Li; formal analysis, Xiaohua Li; investigation, Xiaohua Li; resources, Fuqiang Li; data curation, Xiaohua Li; writing—original draft preparation, Xiaohua Li; writing—review and editing, Fuqiang Li and Wenjin Li; visualization, Xiaohua Li; supervision, Fuqiang Li; project administration, Fuqiang Li; funding acquisition, Fuqiang Li. All authors reviewed and approved the final version of the manuscript.

Availability of Data and Materials: The data that support the findings of this study are derived from the China College Student Survey (CCSS) project. Restrictions apply to the availability of these data, which were used under license for this study, and so they are not publicly available. Data are available from the corresponding author, Fuqiang Li, upon reasonable request and with the permission of the CCSS project team.

Ethics Approval: This study was conducted in accordance with the ethical standards of the institutional research committee. Ethical approval was obtained from the Research Ethics Committee of Nanjing University of Posts and Telecommunications (Project Number: 2026B027). All participants were fully informed about the purpose of the study, and written informed consent was obtained prior to participation. Participation was voluntary,

and all data were used for research purposes only with strict anonymity and confidentiality ensured.

Conflicts of Interest: The authors declare no conflicts of interest.

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