

Research Article

The Impact of AI-Assisted Learning Engagement on English Proficiency Gains: The Serial Mediating Role of Intrinsic Motivation and Academic Self-Efficacy in Chinese Higher Education Contexts

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Abstract

This study examined how AI-assisted learning engagement influences English proficiency gains through the serial mediation of intrinsic motivation and academic self-efficacy among Chinese university students. A cross-sectional survey design was employed. A total of 456 undergraduate students were recruited from three comprehensive universities in eastern China. The hypothesized serial mediation model was tested using PROCESS model 6 program. The findings indicated that the influence of learning engagement with AI assistance on the enhancement of English proficiency was significant ($c' = 0.18$, $p < 0.05$), with a significant serial indirect effect through intrinsic motivation and academic self-efficacy (indirect effect = 0.10, 95% CI [0.039, 0.171]). The psychological mediators accounted for 55% of the total relationship, while the final model accounted for 52% of the variance in English proficiency outcomes. Overall, the results indicated that learning tools facilitated by AI contributed to educational effectiveness via autonomous motivation, which further enhanced learners' self-efficacy beliefs. This study makes an important contribution to the technology-mediated learning literature by demonstrating that the effectiveness of learning tools facilitated by AI depends on the learners' psychological processes rather than their technological features, which is particularly important for educational settings in higher education contexts.

Keywords

AI-assisted learning, intrinsic motivation, academic self-efficacy, serial mediation, English proficiency

1. Introduction

Artificial intelligence (AI) integration within China's higher education system has

reached an unprecedented level, with 48.46 million students enrolled across tertiary institutions that are increasingly employing AI-enhanced learning systems. As a result, leading institutions have responded by increasing the number of enrolling places within AI-related courses, with Tsinghua University and Peking University each adding 150 additional spots for undergraduate enrollment in 2025 to address the increasing need for AI-literate graduates. This trend reflects findings that 80% of entry-level positions view AI-related skills as advantageous, which significantly reshapes the learning demands associated with language skills.

In this technological context, English proficiency development has become increasingly complex as conventional approaches to the process are challenged by AI-facilitated applications. Research indicates that these applications significantly enhance cognitive and metacognitive strategies, which improve learning outcomes (Chen & Alibakhshi, 2026). However, the psychological mechanism by which students interact with these technologies and transfer the process to learning outcomes is not well understood. This is an essential concern in Chinese higher education, where over 100,000 English majors graduate to a context where technology is increasingly being used to perform translations.

To comprehend learners' engagement with AI technology, it is necessary to examine the underlying motivational and self-efficacy constructs. According to the literature, self-efficacy and academic buoyancy serially mediate the relationship between learner engagement and learning outcomes (Akbaba Eser et al., 2026). These psychological constructs have received attention for their mediating role between educational programs and English achievement among Chinese undergraduate non-majors (Liu & Sun, 2025). The relationship between learners' intrinsic motivation and self-efficacy is a complex mediation model, including learners' willingness to communicate in second language context (Zhao et al., 2025).

The present study is situated at the intersection of self-efficacy interventions and AI-enhanced methodologies of language learning. Previous research has established the efficacy of self-efficacy interventions in enhancing English learning confidence (Li et al., 2024), while subsequent work has demonstrated the potential of AI-enhanced methodologies in reducing anxiety as well as enhancing the language learning proficiency of Chinese EFL learners (Wang, 2025). The present research aims to investigate how AI-enhanced learning engagement influences English language learning through the mediation of intrinsic motivation and academic self-efficacy, thereby addressing a significant gap in the present body of knowledge on English language learning through technology in Chinese higher education systems.

2. Theoretical Framework and Hypothesis Development

2.1. AI-Assisted Learning Engagement: Cognitive-Behavioral Mechanisms in Language Acquisition

The cognitive-behavioral process of learning engagement enabled by AI technology is complex and multilayered. The Cognitive Load Theory offers an underlying theory to explain how AI technology optimizes learning engagement by effectively managing intrinsic, extraneous, and germane cognitive loads in the process of language learning. AI technology provides learners with adaptive feedback and content that reduces extraneous cognitive loads while enhancing germane processing capacity, which is vital for learning. Social Cognitive Theory offers an underlying theory to explain how AI technology works as learning models by exhibiting self-regulatory behaviors through adaptive feedback and goal setting, which learners model and emulate.

Research demonstrates that teacher presence has a significant effect on students' engagement with generative AI chatbots, particularly when technology aligns with instructional principles (Li et al., 2025). Evidence for the behavioral dimension can be identified from sustained interaction patterns in which technology offers learners opportunities for continuous practice without fear of being evaluated by others. The cognitive-behavioral process initiates the feedback loop for the students, where the rewarding experiences of interacting with technology improve the learners' perception of their ability to engage further with language learning.

2.2. Serial Mediation of Intrinsic Motivation and Academic Self-Efficacy

Self-Determination Theory specifies a temporal ordering in which autonomous motivation emerges first and academic self-efficacy follows. Satisfaction of the three psychological needs for autonomy, competence, and relatedness within the AI-assisted learning environment gives rise to intrinsic motivation, which functions as the initial psychological outcome of engaged practice. This motivational state sustains persistent interaction with language tasks and encourages the exploratory, challenge-seeking behaviors through which learners accumulate mastery experiences. Mastery experiences in turn operate as the primary source of self-efficacy judgments, since learners form beliefs about their future capabilities by drawing on repeated evidence of successful task execution. This ordering is empirically supported by findings that self-efficacy mediates the relationships among classroom anxiety, learning motivation, and English achievement (Shang & Ma, 2024). Cognitive Evaluation Theory closes the loop by specifying that competence feedback strengthens rather than weakens intrinsic motivation when it is received under conditions of

perceived autonomy, so that efficacy gains feed back into continued motivational investment and stabilize the proposed mediational ordering.

2.3. Theoretical Integration in Chinese Higher Education Contexts

Within the cultural and pedagogical context of Chinese higher education, certain features must be theoretically integrated to account for the complexities of AI-facilitated language learning. The collectivist cultural dimension influences autonomy and relatedness, which in turn shapes the manifestation of the principles of Self-Determination Theory without affecting its overall validity. The cultural emphasis on diligence and perseverance is supported by growth mindset theory and is conducive to the development of self-efficacy via mastery approaches. Motivational difficulties particular to the examination-driven education system highlight the challenges associated with extrinsic influences and point to the need to cultivate intrinsic motivation for language learning beyond assessment-oriented contexts. Research has revealed that the academic purpose of Chinese university English as a Foreign Language (EFL) students correlates with the target needs and self-efficacy (Wang et al., 2024). Collective self-efficacy, which is part of the Social Cognitive Theory, resonates with the Chinese cultural value of "harmony," and while self-efficacy beliefs are considered universal, their expression varies across cultural contexts. Taken together, these cultural considerations function as conceptual framing for the proposed model rather than as empirically tested moderating variables, their role being to situate the core psychological mediation pathways within the specific learning environment of Chinese higher education. The present study therefore treats the cultural backdrop as an interpretive context for the serial mediation model rather than as a separate empirical layer within the statistical analyses.

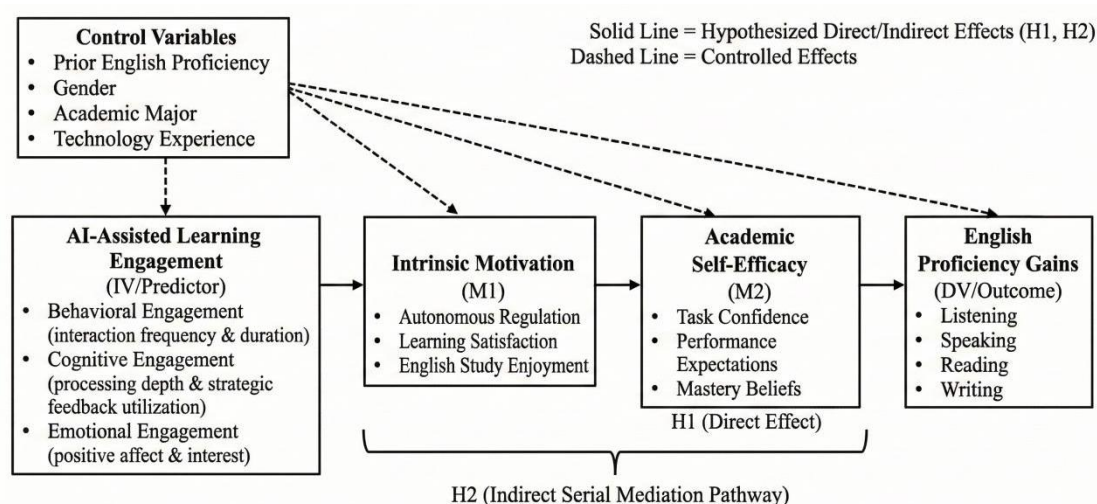
2.4. Research Hypotheses and Conceptual Model

Two main hypotheses are proposed based on this integrated theoretical framework: H1: AI-assisted learning engagement positively predicts English proficiency gains among Chinese university students. H2: Intrinsic motivation and academic self-efficacy sequentially mediate the relationship between AI-assisted learning engagement and English proficiency gains. This implies that learning engagement will increase intrinsic motivation, which will consequently strengthen academic self-efficacy, hence enhancing English language proficiency outcomes. This ordering rests on the SDT temporal logic outlined earlier and on mastery experience operating as the primary source of efficacy appraisals, such that engagement first activates autonomous motivation and is then translated into efficacy judgments through accumulated mastery. Previous studies indicated that the acceptance/behavioral engagement of AI learning among Chinese EFL learners would mediate through motivational mediation effects (Wang et

al., 2025). Figure 1 presents the hypothesized framework, in which solid arrows denote the direct and serial mediation pathways specified by H1 and H2, while dashed arrows denote the control effects of the four covariates on all endogenous variables. AI-assisted learning engagement enters the model as a three-dimensional predictor encompassing behavioral, cognitive, and emotional involvement, with intrinsic motivation and academic self-efficacy serving as sequential mediators through which engagement translates into English proficiency gains.

Figure 1

Serial Mediation Model of AI-Assisted Learning Engagement, Intrinsic Motivation, Academic Self-Efficacy, and English Proficiency Gains



3. Methodology

3.1. Research Design and Sample Characteristics

This study employed a cross-sectional survey method to explore the phenomenon of serial mediation effects of AI-assisted ELL among Chinese university students. Participants were selected through stratified random sampling to ensure diversity among academic majors of university students from three comprehensive universities located in the eastern region of China. Stratification proceeded along two dimensions, with academic major as the primary stratum and university affiliation as the secondary stratum. Within each major category, participant numbers reflected the enrollment composition of the three institutions, yielding 142 students from the humanities, 125 from the social sciences, 109 from the natural sciences, and 80 from engineering. Allocation across the three universities was kept approximately equal, so that no single campus dominated the final sample. The resulting disciplinary distribution aligns with the academic composition commonly observed among comprehensive

universities in eastern China, which supports sample representativeness for the target population of undergraduates enrolled in compulsory English courses. The target population of this study included university undergraduate students enrolled in compulsory English courses who had prior experience using AI-assisted tools such as ChatGPT, Grammarly, language learning systems, and intelligent tutoring tools during the 2024-2025 academic year.

Sample size was determined through power analysis for structural equation modeling. The results indicated that the minimum sample size required would be 384 in order to have 0.80 statistical power for detecting medium effects. The sample size for the study comprised 456 valid surveys. In terms of demographics, 58.3% of participants were female and 41.7% were male. The academic majors comprised those in the humanities (31.2%), social sciences (27.4%), natural sciences (23.9%), and engineering (17.5%). Participants ranged in age from 18 to 23 years, with a mean of 20.1 years and a standard deviation of 1.3. English proficiency ranged from intermediate to advanced levels, as determined by scores on standardized tests.

3.2. Measurement of AI Learning Engagement and Outcome Variables

Standardized measures adapted for AI-assisted language learning were employed to evaluate the key constructs. Within this study, AI-assisted learning engagement was operationally defined as the extent of learner involvement when using AI tools such as ChatGPT, Grammarly, language learning systems, and intelligent tutoring platforms for English study. The construct spans three dimensions, with behavioral involvement indexed by interaction frequency and duration, cognitive involvement indexed by processing depth and strategic feedback utilization, and emotional involvement indexed by positive affect and interest. The multidimensional scale for measuring engagement in AI-assisted learning included behavioral engagement (interaction rate, interaction length, and completion rate), cognitive engagement (depth of processing strategies, metacognitive monitoring, and feedback), and emotional engagement (interest, enjoyment, and positive emotions during interaction with AI). The construct of intrinsic motivation was examined from the perspective of the Self-Determination Theory, which included autonomous regulation, competence, and intrinsic learning enjoyment. The academic self-efficacy was assessed by domain-specific confidence measures related to English language ability, which included performance expectations and mastery beliefs. Improvement in English ability was assessed through pre- and post-test measures covering listening comprehension, speaking fluency, reading comprehension, and writing accuracy. Scores on the CET-4 or CET-6 obtained during the preceding semester served as the standardized anchor for prior English proficiency. The pre- and post-tests themselves consisted of parallel four-skill tasks developed by the research team,

with item types benchmarked against CET formats for the receptive and written productive skills and against CET-SET formats for the speaking component. Items were drawn from a shared pool to ensure difficulty equivalence across the two administrations, and two raters holding CET scoring credentials independently graded the productive tasks, with inter-rater reliability evaluated prior to final scoring. Raw scores were z-transformed and then mapped onto a 7-point scale so that the proficiency gain measure shared a common metric with the other constructs. Control variables included past English proficiency test scores, gender, academic major, and technology experience level. Prior English proficiency accounted for baseline language differences across participants. Technology experience accounted for variability in learners' familiarity with AI tools, which might otherwise confound observed engagement patterns. Gender and academic major controlled for systematic demographic and disciplinary variation. As presented in Table 1, all the scales demonstrated adequate reliability and construct validity based on pilot test data from 60 participants. Response formats used 7-point Likert scales to increase variability in responses.

Table 1

Measurement Instruments and Psychometric Properties

Construct	Items	Example Item	Cronbach's α	Source
AI Learning Engagement (Behavioral)	6	"I frequently use AI tools for English practice"	0.89	Adapted from Student Engagement Scale
AI Learning Engagement (Cognitive)	5	"I analyze AI feedback to improve my understanding"	0.86	Adapted from Cognitive Engagement Scale
Intrinsic Motivation	7	"I find English learning inherently satisfying"	0.91	Self-Determination Theory Scale
Academic Self-Efficacy	8	"I am confident in my English writing abilities"	0.88	Domain-Specific Self-Efficacy Scale
English Proficiency Gains	12	Pre-post listening/speaking/reading/writing tasks	0.93	Standardized Proficiency Assessment

Note. The emotional engagement facet described in the construct definition is captured through affect-related items embedded within the behavioral and cognitive subscales in Table 1, rather than through a standalone subscale.

3.3. Serial Mediation Analysis Framework

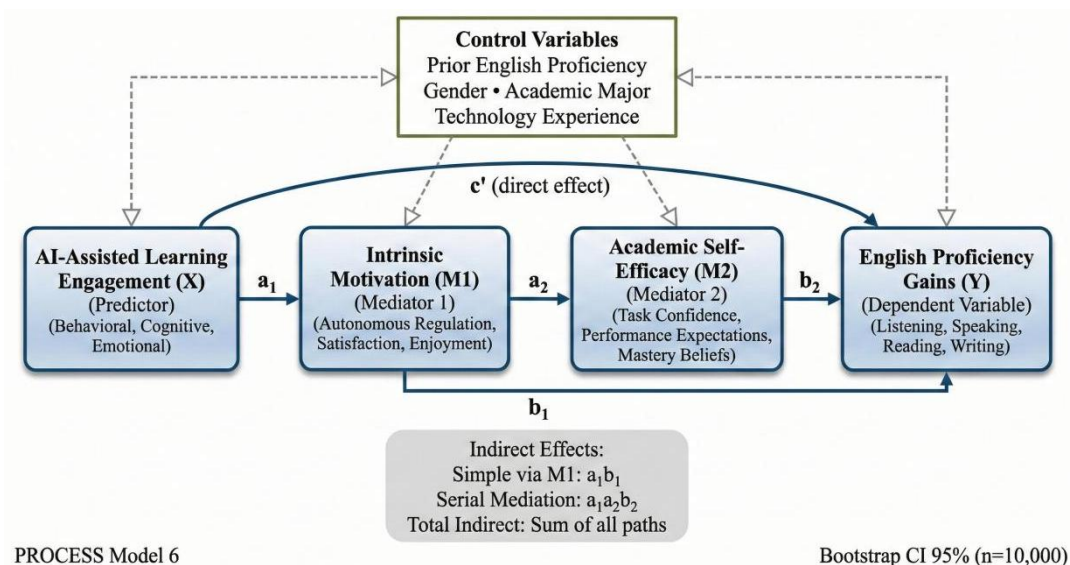
In the present study, the serial mediation analysis with Hayes' PROCESS macro program (Model 6) was employed to test the hypothesized serial mediation effect for the impact of AI learning engagement on English proficiency gain via intrinsic motivation and academic

self-efficacy. This analytical model followed the procedures for examining direct and indirect effects via bias-corrected bootstrapping with 10,000 resamples for generating reliable confidence intervals for the mediation effects. Serial mediation was based on the premise that there was a temporal order for the mediation effects, with intrinsic motivation preceding its effect on the development of academic self-efficacy.

The analysis process included the estimation of total indirect effects, specific indirect effects for each model (for simple mediation for M1, simple mediation for M2, serial mediation), and effect size estimation via partially standardized coefficients. The pattern of missing data was examined with Little's MCAR test, and listwise deletion was then applied. To check the assumptions of linearity, normality of residuals, and homoscedasticity, diagnostic plots were applied. To control for the possible effects that some variables might have on all the main variables, control variables were included simultaneously. To check for statistical significance, 95% CI excluding 0 was applied. Figure 2 illustrates the PROCESS Model 6 analytic structure, where a_1 denotes the path from AI-assisted learning engagement to intrinsic motivation, a_2 denotes the path from intrinsic motivation to academic self-efficacy, b_1 and b_2 denote the paths from each mediator to English proficiency gains, and c' denotes the direct effect of engagement on gains after partialling out both mediators. All indirect pathways are estimated with 95% bias-corrected confidence intervals generated from 10,000 bootstrap resamples.

Figure 2

Serial Mediation Analysis Framework with Bootstrap Confidence Intervals



3.4. Data Collection and Quality Control

Data were collected via an online survey that was conducted in two phases with the aid of the Qualtrics survey tool. This tool had quality control features embedded. The first phase

collected demographic information, control variables, and basic English proficiency measures. In the second part, the main study measures were collected following standardized exposure durations for the AI tools. Common method biases were addressed by separating the predictor and outcome variables, procedural remedies, and statistical remedies.

Participants were recruited through university-based emails and reminders, and course credits were offered as an incentive to maximize participation. Data cleaning involved excluding respondents who failed multiple attention checks and those whose responses fell outside ± 3.29 standard deviations. The ethical considerations included informed consent, confidentiality, and the right to withdraw. Univariate and multivariate outlier analyses were applied during data cleaning.

4. Results

4.1. Descriptive Statistics and Correlation Matrix

Descriptive statistics revealed that the major variables were normally distributed, as evidenced by the results of the skewness and kurtosis tests. As shown in Table 2, the mean values of all constructs ranged from moderate to high, with the highest reported for English proficiency gains ($M = 5.13$, $SD = 1.31$) and the lowest for intrinsic motivation ($M = 4.67$, $SD = 1.23$). Enough variance was achieved, as revealed by the range of the standard deviation, from 1.08 to 1.31. The correlation analysis revealed significant positive associations among all constructs, consistent with the requirements of a mediation test.

All constructs were significantly and positively intercorrelated, and the overall pattern of associations was consistent with the structure required for a serial mediation test. Correlations among the two psychological mediators and between each mediator and the outcome variable were the most pronounced in the matrix, while AI-assisted learning engagement showed moderate positive relations with all outcome variables within a correlation range of 0.44 to 0.52. Control variables related to the core constructs in the direction anticipated by theory, with prior English proficiency displaying the strongest associations among the covariates. Such correlation results formed the basis for the mediation analysis, which confirmed that there were sufficient interrelationships between the variables for the testing of serial mediation to be conducted.

Table 2

Descriptive Statistics and Correlation Matrix for Study Variables

Variable	M	SD	Skewness	Kurtosis	1	2	3	4	5	6	7	8
1. AI Learning Engagement	4.82	1.15	-0.89	0.67	-							

2. Intrinsic Motivation	4.67	1.23	-0.72	0.45	0.52***	-													
3. Academic Self-Efficacy	4.91	1.08	-1.02	1.23	0.48***	0.58***	-												
4. English Proficiency Gains	5.13	1.31	-1.20	1.40	0.44***	0.51***	0.56***	-											
5. Prior English Proficiency	4.75	1.18	-0.65	0.34	0.42***	0.38***	0.47***	0.45***	-										
6. Gender	1.42	0.49	0.33	-1.89	0.18**	0.22***	0.19**	0.16*	0.14*	-									
7. Academic Major	2.28	1.12	0.24	-0.98	0.12*	0.15*	0.13*	0.11	0.21**	0.08	-								
8. Technology Experience	4.56	1.35	-0.78	0.23	0.35***	0.29***	0.32***	0.28***	0.36***	0.09	0.17*	-							

Note. $N = 456$. $M = \text{Mean}$; $SD = \text{Standard Deviation}$. Gender: 1 = Male, 2 = Female. Academic Major: 1 = Humanities, 2 = Social Sciences, 3 = Natural Sciences, 4 = Engineering. All variables measured on 7-point Likert scales except demographic variables. $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

4.2. Measurement Model Validation and Reliability Assessment

The measurement model was further supported by the results of the confirmatory factor analysis. The goodness of fit indices of the four-factor model were satisfactory: $\chi^2/df = 2.14$, CFI = 0.94, TLI = 0.93, and RMSEA = 0.058, 90% CI = 0.049-0.067, SRMR = 0.065. All values are within the range of good fit indices. Factor loadings ranged from 0.72 to 0.89, indicating strong relationships between observed and latent variables. Cronbach's alpha coefficients indicated high internal consistency across all scales, with values of 0.89 for the behavioral subscale and 0.86 for the cognitive subscale of AI learning engagement, 0.91 for intrinsic motivation, 0.88 for academic self-efficacy, and 0.93 for English proficiency gains.

Composite reliability values were consistent with the Cronbach's alpha coefficients, ranging between 0.87 and 0.92. Average variance extracted ranged between 0.64 and 0.78. The values confirmed the convergent validity. Discriminant validity was confirmed using the Fornell-Larcker criterion. Square root of the average variance extracted values were found to be more than the values of correlation between the constructs. The measurement model exhibited sound psychometric qualities sufficient to support the subsequent structural analyses. Common method bias was assessed using the Harman single-factor test, which showed that the variance explained by a single factor was below 35%.

4.3. Serial Mediation Path Analysis: Direct and Indirect Effects

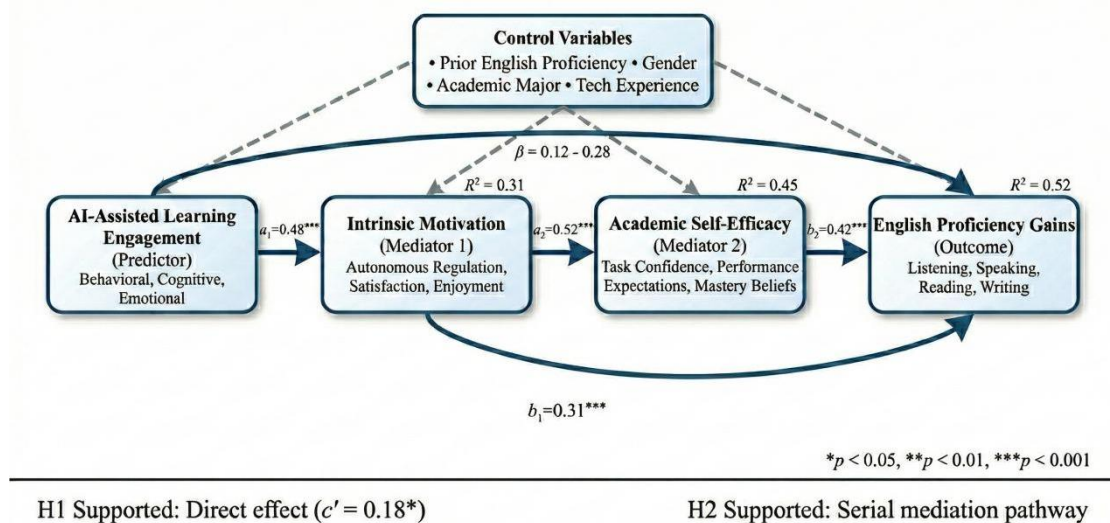
The outcome of the serial mediation analysis through PROCESS Model 6 showed significant support for the two hypotheses within the proposed framework. The direct effects supported that AI engagement in learning was a significant predictor of intrinsic motivation

($a_1 = 0.48$, $SE = 0.076$, $p < 0.001$, 95% CI [0.331, 0.629]), which was a significant predictor of academic self-efficacy ($a_2 = 0.52$, $SE = 0.071$, $p < 0.001$, 95% CI [0.381, 0.659]). Both mediators had a significant impact on the gain in English language proficiency, whereby intrinsic motivation had a moderate effect size in predicting English language gain ($b_1 = 0.31$, $SE = 0.089$, $p < 0.001$, 95% CI [0.136, 0.484]), and academic self-efficacy had a larger effect size in predicting English language gain ($b_2 = 0.42$, $SE = 0.082$, $p < 0.001$, 95% CI [0.259, 0.581]). The direct effect of AI engagement on English language gain remained significant but reduced ($c' = 0.18$, $SE = 0.084$, $p = 0.032$, 95% CI [0.016, 0.344]), supporting H1. The total effect of AI-assisted learning engagement on English proficiency gains was also significant ($c = 0.40$, 95% CI [0.251, 0.549]), encompassing both the direct effect and the indirect effects through the two psychological mediators.

Figure 3 visualizes the full path structure, with standardized coefficients and significance markers on each path, R^2 values reported at each endogenous variable, and dashed arrows conveying the direction and range of covariate effects. The significance levels shown in the figure correspond directly to the statistical conclusions reported in the preceding text. As expected, the control variables performed well in the model, with prior English proficiency being the strongest predictor of all endogenous variables. The model was found to have a high level of variance explained in the data, as indicated by the R^2 values of the endogenous variables: intrinsic motivation ($R^2 = 0.31$), academic self-efficacy ($R^2 = 0.45$), and English proficiency gain ($R^2 = 0.52$).

Figure 3

Serial Mediation Path Analysis with Standardized Coefficients and Significance Levels



4.4. Bootstrap Analysis and Effect Size Decomposition

Bias-corrected bootstrap analysis with 10,000 resamples was conducted, providing support for the indirect effect while accounting for non-normal distributions commonly encountered in indirect effect estimates. The results revealed that the total indirect effect was statistically significant (Effect = 0.22, BootSE = 0.058, 95% CI [0.112, 0.341]), which supported the idea that intrinsic motivation and academic self-efficacy would combine as a mediator for the effect between AI engagement and English proficiency. In addition, the indirect paths that comprised the total indirect effect were unique. Simple mediation via intrinsic motivation was statistically significant (Effect = 0.15, BootSE = 0.047, 95% CI [0.063, 0.247]), while the effect for the serial mediation via both mediators sequentially was smaller, yet statistically significant (Effect = 0.10, BootSE = 0.034, 95% CI [0.039, 0.171]).

As presented in Table 3, the results of the effect-size analysis showed that the serial mediation explained 12.3% of the total relationship between AI engagement and English proficiency, thus indicating not only a statistically significant effect but a practically significant effect. The partially standardized effects were helpful in making the results more meaningful, as the serial mediation effect, as indicated by the value of 'ab_ps' = 0.089, showed a significant change in the results in terms of English proficiency for every unit increase in AI engagement. The findings supported H1 because the direct positive link between AI engagement and the improvement in English proficiency was evident, 'c' = 0.18, $p < 0.05$. It also supported H2 because the serial mediation effect via intrinsic motivation and academic self-efficacy was evident, indirect effect = 0.10, 95% CI [0.039, 0.171], showing that the psychological factors significantly mediated the effectiveness of AI in learning the English language.

Table 3

Bootstrap Analysis Results and Effect Size Decomposition

Effect Type	Estimate	Boot SE	95% CI Lower	95% CI Upper	Effect Size	% of Total Effect
Total Effect (c)	0.40	0.076	0.251	0.549	-	100.0%
Direct Effect (c')	0.18	0.084	0.016	0.344	0.134	45.0%
Total Indirect	0.22	0.058	0.112	0.341	0.164	55.0%
Indirect via M1 only	0.15	0.047	0.063	0.247	0.112	37.5%
Serial Indirect (M1→M2)	0.10	0.034	0.039	0.171	0.074	12.3%
Completely Standardized Indirect	0.156	0.043	0.082	0.251	-	-

Note. *Bootstrap resamples = 10,000. CI = confidence interval. M1 = Intrinsic Motivation; M2 = Academic Self-Efficacy. All confidence intervals exclude zero, indicating statistical significance at $p < 0.05$. H1 (direct effect) and H2 (serial mediation) both supported.*

5. Discussion

The present study provides empirical support for the psychological mechanisms through which AI-assisted English learning operates among Chinese university students. The serial mediation analysis confirmed a significant direct effect of AI-assisted learning engagement on English proficiency gains ($c' = 0.18$, $p < 0.05$) alongside a significant serial indirect effect through intrinsic motivation and academic self-efficacy (indirect effect = 0.10, 95% CI [0.039, 0.171]). The two psychological mediators jointly accounted for 55% of the total relationship, and the full model explained 52% of the variance in proficiency outcomes, indicating that technology-mediated tools translate into measurable language gains primarily by engaging learners' motivational and efficacy-related processes rather than through technological features alone.

The sequential ordering specified in the model is consistent with the empirical pattern in the data. Engagement first produced a sizeable increase in intrinsic motivation ($a_1 = 0.48$), which in turn generated a comparable rise in academic self-efficacy ($a_2 = 0.52$), two coefficients similar in magnitude and aligned in direction. This pattern matches the temporal logic of Section 2.2, whereby satisfaction of the needs for autonomy, competence, and relatedness gives rise to intrinsic motivation, and sustained intrinsically motivated engagement accumulates into mastery experiences that then serve as the primary source of efficacy judgments. The intrinsic motivation to self-efficacy order therefore reflects a psychological sequence in which motivational experience plausibly precedes capability appraisal, an interpretation whose causal status rests on theoretical grounds given the cross-sectional design.

The strengths of the two indirect pathways differ in a way that warrants closer interpretation. Simple mediation through intrinsic motivation alone accounts for 37.5% of the total effect, whereas serial mediation through both mediators in sequence accounts for only 12.3%. Structurally, the serial path compounds three coefficients (a_1 , a_2 , b_2) while the simple path traverses only two (a_1 , b_1), so attenuation along the longer chain is expected on mathematical grounds. Substantively, intrinsic motivation contributes directly and meaningfully to proficiency gains ($b_1 = 0.31$, $p < 0.001$), suggesting that enjoyment, interest, and autonomous investment may translate into language performance without passing entirely through efficacy appraisal. The affective-motivational route thus appears to carry independent

weight on immediate language outcomes in AI-assisted settings, while the efficacy route may become more influential over extended periods of language development, a possibility the present design cannot test directly.

The empirical findings align in direction with the cultural framing set out in Section 2.3. An examination-oriented learning environment of the kind discussed there traditionally foregrounds external evaluation as the main driver of study behaviour, yet the psychological mediators together account for 55% of the total engagement-to-gain effect, and the two mediators together explain 52% of the variance in gain scores. Autonomous motivation and efficacy beliefs retain a leading role even where external assessment is highly salient. This correspondence should be read as conceptual consistency with the framing of Section 2.3 rather than as a statistical test of cultural moderation, since no cultural variable was modelled as a moderator in the present analyses.

The findings carry practical implications for instructional design in AI-assisted English courses. Granting learners genuine latitude in how they use AI tools, such as choosing ChatGPT conversation topics or deciding which Grammarly suggestions to accept, supports the autonomy component of Self-Determination Theory and allows intrinsic motivation to emerge during task engagement. Embedding short reflection tasks after each substantive round of AI feedback converts cognitive engagement into mastery experiences that learners can attribute to their own effort, the mechanism through which academic self-efficacy accumulates over time. Framing AI interactions as low-stakes rehearsal rather than graded performance lowers evaluative pressure, sustains emotional engagement, and keeps learners returning to the tool. These implications point toward course designs that treat psychological involvement as the first-order objective and relegate particular technical features of the tools to a supporting role.

Several limitations qualify these conclusions. The cross-sectional design cannot support strict causal inference, and the mediator ordering rests on theoretical temporal logic rather than on time-lagged data, so longitudinal designs are needed to test whether the motivation-to-efficacy sequence holds across repeated measurement waves. Sampling was confined to three comprehensive universities in eastern China, a setting that is culturally and institutionally homogeneous in important respects, and generalization to other educational systems should proceed with care. All substantive constructs were assessed through self-report; although the Harman single-factor test reported in Section 4.2 placed common method variance within an acceptable range (single factor variance below 35%), residual shared-source bias cannot be eliminated, and subsequent work could usefully integrate behavioral traces or observational indices alongside self-report to reduce this source of error.

6. Conclusion

The present study demonstrates that AI-assisted learning engagement supports English proficiency development among Chinese university students through a sequential psychological pathway running from intrinsic motivation to academic self-efficacy. The findings contribute to the educational technology literature by showing that the effectiveness of technology-mediated interventions derives from the cultivation of autonomous motivation in learners, which subsequently translates into strengthened efficacy beliefs and measurable language gains. At the level of instructional practice, the results indicate that motivational engagement deserves priority over isolated technical features when AI tools are integrated into language classrooms, with detailed strategies discussed in Section 5. The serial mediation model therefore offers a theoretical foundation for understanding how digital learning environments can sustain language learning through the fulfilment of psychological needs, and it reinforces the role of self-agency and self-determination in technology-based learning, particularly in educational contexts where extrinsic evaluative pressures are prominent. Given the cross-sectional scope of the present evidence, as acknowledged in Section 5, the persistence of this pathway across time and its generalizability to other cultural and educational contexts remain open questions for future research.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Conflict of interest

The authors declare that there is no Conflict of interest.

Ethics approval



Not applicable.

Consent to participate

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Consent for publication

All authors have given their consent.

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