

# The Impact of Student Behavior Characteristics on Academic Performance in Blended Learning Environments at Chinese Private Universities: A Structural Equation Analysis

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## Article History:

**Received:** 12-01-2025

**Revised:** 15-02-2025

**Accepted:** 01-03-2025

## Abstract:

The continuous optimization and development of online learning, along with the ongoing reflection on traditional teaching methods, have contributed to the popularity of blended learning (BL) as a favored approach to teaching and learning in higher education. However, systematic research on how students' learning behavior characteristics influence academic performance (AP) in BL contexts remains limited, particularly regarding the mediating role of learning commitment (LC) and moderating effects of demographic factors. This study addresses this gap by investigating the direct and indirect pathways through which behavioral engagement (BE), self-directed learning (SL), and technical application ability (TAA) affect AP. Drawing on data from 1,870 undergraduates across five Chinese private universities (collected from September to October 2024, we employed structural equation modeling (SEM) to analyze the interplay between these variables. Results reveal that SL ( $\beta = 0.544$ ,  $p < 0.01$ ) and TAA ( $\beta = 0.228$ ,  $p < 0.01$ ) directly enhance AP, whereas BE exerts no significant direct effect. Crucially, LC fully mediates the relationships of BE and TAA with AP (100% mediation) and partially mediates the SL-AP link (38.4%). Contrary to expectations, demographic variables (gender, grade, discipline) showed no moderating effects. These findings enrich BL theory by elucidating LC's central role as a mediator and challenging assumptions about demographic influences. Practically, the study advocates for curriculum designs that prioritize SL and TAA development while leveraging LC through personalized feedback and adaptive learning technologies. This research provides actionable insights for educators and policymakers to optimize BL effectiveness in diverse institutional settings.

**Keywords:** Blended Learning; Learning Behavior Characteristics; Academic Performance; Structural Equation Modeling; Learning Commitment; Higher Education.

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## 1. Introduction

### 1.1 Research Background

In recent years, the swift advancement of computer and network communication technologies has made the convergence of face-to-face instruction and online learning environments increasingly evident (Hermita et al., 2023). Blended learning (BL) has emerged as a focal point of research in higher education, training, and basic education, particularly in higher education, as it effectively combines the benefits of in-person teaching and online learning (Harsy et al., 2020). From 2015 to 2017, the New Media Alliance Horizon Report (Higher Education edition) consistently highlighted BL as one of the trends gaining traction (Alkis et al., 2018).

With this, education researchers, administrators, policymakers, and learners consider constructing online and offline hybrid "golden lessons" (Wei, Z. & Jun, G., 2023). Therefore, the research on BL has become one of the hot spots in current education research (Wong, J.M., 2024). However, as China's online and offline BL is still in the stage of vigorous development and application, many problems need to be solved, including course design and evaluation, learning process, technical support and training mode, learning effect, learning satisfaction, and influencing factors (Tonder, G.V., & Van Deventer, N.,2023). Therefore, research on learners of online-to-offline hybrid learning and exploration of their learning effects will help support learners' effective learning better and promote the sustainable and healthy development of online-to-offline hybrid courses (Salmons et al.,2014).

The influence of students' learning behavior characteristics on the learning effect in the BL environment is significant (Tan et al.,2023). The characteristics of learning behavior include students' behavioral engagement (BE), self-directed learning (SL), technical application ability (TAA), learning commitment (LC), etc. (Arrosagaray et al.,2019). These factors jointly determine students' AP in the BL environment (Bashir et al.,2021). Academic performance (AP), as a key index to measure students' learning effect, reflects students' knowledge mastery level and affects their future career development (Chumney et al.,2018). Therefore, it is of great theoretical and practical significance to study the relationship between learning behavior characteristics and AP in the BL environment (Zerbini et al.,2017).

Although some aspects of BL have been explored, systematic analysis of how student behavior characteristics affect AP is still lacking (Yumuşak, G K.,2020). In Chinese universities, whether there are differences in students' performance in BL across disciplines, grades, and genders has not been deeply explored (Ledesma, S. M.,2017). Therefore, this study aims to fill this research gap.

Based on existing literature and theoretical frameworks, the following hypotheses are proposed to investigate the relationship between the characteristics of learning behavior and AP in BL environments:

### **The Direct Impact of Learning Behavior Characteristics on AP**

BL emphasizes students' initiative and participation, and different characteristics of learning behavior may have different effects on AP. The following hypotheses are proposed based on relevant theories and research findings:

**Hypothesis H1:** BE has a significant positive impact on AP

**Hypothesis H2:** SL has a significant positive effect on AP

**Hypothesis H3:** TAA has a significant positive impact on AP

### **The Mediating Role of LC**

According to the relevant theories of educational psychology, LC is the key variable that connects learning behavior and learning effect. Students' degree of concentration and profound thinking ability in learning activities may mediate between learning behavior and AP characteristics. Therefore, the following hypothesis is proposed:

**Hypothesis H4:** LC mediates the relationship between BE and AP

**Hypothesis H5:** LC mediates the relationship between SL ability and AP

**Hypothesis H6:** LC mediates the relationship between TAA and AP

### **Moderating the Role of Background Variables**

Factors such as G1 (gender), G2 (grade), and SB (subject background) may moderate students' learning behavior and AP. For example, science students may be more prominent in their TAA, while senior students may be more assertive in their ability to learn independently. Therefore, it is proposed that:

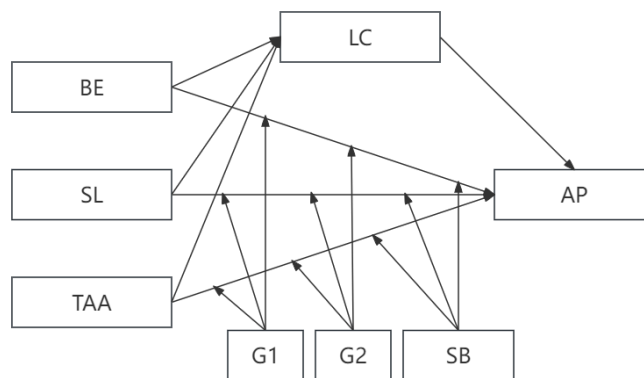
**Hypothesis H7:** G1 has a moderating effect on the relationship between engagement in learning behavior and AP

**Hypothesis H8:** G2 is having a moderating impact on the relationship between SL and AP

**Hypothesis H9:** SB has a moderating effect on the relationship between TAA and AP

### **Research Model**

To verify the above hypothesis, this study designed a research model (FIG. 1) in which the characteristics of learning behavior (BE, SL, and TAA) were taken as independent variables, AP was taken as the dependent variable, LC was taken as a mediating variable, and G1, G2, and SB were taken as moderating variables.



**Figure 1: Research Hypothesis Model**

This study will systematically explore whether the above hypothesis is true through empirical analysis of questionnaire data and reveal the mechanism of action between learning behavior and AP in BL environments.

## 2. Literature Review

### 2.1 Influence of Learner Characteristics on BL Results

#### Recent Research Status

To understand the current research status of scholars on this topic, this research enters the theme words "blended learning," "student behavior characteristics," and "academic performance" and searches the papers in the WOS database in the past five years. Twelve papers have strong research relationships with this paper's topic, indicating that there is still a lot of research space for this research's content. The specific content is shown in Table 1.

**Table 1: List of 12 Relevant Research Papers**

Publication Type	Authors	Article Title	DOI or Website	Publication Year
C	Chen, Rui; Lai, Fan; Li, Yanmei; Wang, Xuan	Genetic Programming-Enabled Prediction for Students Academic Performance in Blended Learning	10.1145/3629296.3629345	2023
J	Yu, Jing	Constructing an ideal class to facilitate high Learning Commitment, performance, and affective commitments: a new blended learning model	10.1080/02188791.2023.2251706	2023
B	Sun, Y.; Xiao,	Analysis of Blended Learn	10.1109 / CSTE62	2024

	W.	ing Behaviour Based on K-Means Clustering Algorithm	025.2024.00065	
J	Limniou, Maria; Varga-Atkins, Tunde; Hands, Caroline; Elshamaa, Marie	Learning, Student Digital Capabilities, and Academic Performance over the COVID-19 Pandemic	10.3390 / educsci11070361	2021
J	Fan, Chunhong; Wang, Zhongxing; Yang, Yanping; Liu, Xinling	Higher vocational college students' perceptions of creativity during the COVID-19 pandemic: support and constraint	10.1007 / s12144-023-04853-1	2024
J	Luo, Heng; Han, Xu; Chen, Ying; Nie, Yanjiao	Should you become a leader in online collaborative learning? Impact of assigned leadership on learning behaviors, outcomes, and perceptions	10.1371 / journal.Pone. 0266653	2022
J	Cai, Zhihui; Gui, Yang; Mao, Peipei; Wang, Zhikeng; Hao, Xin; Fan, Xitao; Tai, Robert H.	The effect of feedback on academic achievement in technology-rich learning environments (TREs): A meta-analytic review	Rev. 10.1016 /j.edu 2023.100521	2023
J	Chaw, Lee Yen; Tang, Chun Meng	Exploring the role of learner characteristics in learners' learning environment preferences	10.1108 / IJEM - 05-2022-0205	2023
J	Vanslambrouck, Silke; Zhu, Chang; Pynoo, Bram; Lombarts, Koen; Tondeur, Jo; Scherer, Ronny	A latent profile analysis of adult students' online self-regulation in blended learning environments	10.1016 / j.carol c arroll hb. 2019.05. 021	2019

J	Alghamdi, Taghreed Abdullah	Blended Moocs Acceptance and Use: a Cross-Cultural Study of the Factors Affecting Lecturers' Use of books	<a href="https://www.webofscience.com/wos/aldb/full-record/PQDT:65658681">https://www.webofscience.com/wos/aldb/full-record/PQDT:65658681</a>	2021
J	Khtere, Ahmed Ramadan; Yousef, Ahmed Mohamed Fahmy	The Professionalism of Online Teaching in Arab Universities: Validation of Faculty Readiness	<a href="https://www.researchgate.net/publication/350966493_The_Professionalism_of_Online_Teaching_in_Arab_Universities_Validation_of_Faculty_Readiness">https://www.researchgate.net/publication/350966493_The_Professionalism_of_Online_Teaching_in_Arab_Universities_Validation_of_Faculty_Readiness</a>	2021
B	Obielodan, Florence Funmilayo	Comparing the Effects of Motivation in Flipped and Direct Instruction for Mastery Learning in College Pre-calculus	<a href="https://www.proquest.com/docview/2775903842?pq-origsite=wos&amp;accountid=10659&amp;sourcectype=Dissertations%20&amp;%20Theses">https://www.proquest.com/docview/2775903842?pq-origsite=wos&amp;accountid=10659&amp;sourcectype=Dissertations%20&amp;%20Theses</a>	2022

The above papers mainly explore the AP, learning behavior, digital ability, creativity perception, leadership role, feedback effect, learner characteristics, online self-regulation, acceptance of hybrid MOOCs, online teaching professionalism, and students' learning motivation in BL environments. Together, these studies provide a wealth of insights for understanding and optimizing BL environments. However, these studies did not specifically examine how student behavioral characteristics affect student AP, which would be an essential value of this study.

## 2.2 Relevant Research on Learner Characteristics

The current research mainly focuses on the empirical analysis of specific learner characteristics, and there is a lack of systematic study on the relationship between learner characteristics and learning outcomes. First, learner characteristics' impact on BL outcomes is systematically studied. Through literature review, We found that learner characteristics affecting BL mainly include previous e-learning/blended learning experience, computer skills, student background, cognitive/learning strategies (including information literacy strategies, time management strategies, resource management strategies, self-regulation strategies), metacognition (such as self-monitoring ability), emotion (such as learning attitude), and motivation (such as learning motivation), self-efficacy) and

behavioral interaction (Caravello,2015; Ledesma,2017; Yumuşak,2020). Abdullah (2024) explored learner characteristics that impact blended learning (BL) outcomes, such as organizational skills, discipline, time management, technology use for learning, self-control, and self-efficacy. Lyu (2023) conducted a quantitative study to examine the effects of teaching and learner variables on the learning outcomes of BL courses for undergraduates. The results indicated that age, prior distance learning experience, teaching style preference, and average learning time were key factors influencing the differences in learning outcomes among college students (Eralita, 2023). Furthermore, regression analysis was employed to further investigate the influence of learner, teaching, and motivation variables on learning outcomes (Eralita, 2023). Drawing on recent empirical research, the key factors affecting the success of BL from a teaching perspective include learners, educational objectives, local resources of teaching institutions, learning environment design, and available technological tools (Kexin, D., & Buang, N.A., 2024). To take full advantage of this flexible learning style, learners need to plan their study time to fit their daily life (effective time management), Set clear learning goals to achieve them (self-management), Know their own needs to choose a learning pace that works for you (cognitive ability); Reflect on and assess learning progress and make adjustments if necessary (metacognitive ability); To interact in learning situations; Self-motivation (Ahmad Uzir et al.,2020; Borkowski,2024; Yang,2024). In addition, communication and interaction between learners play an essential role in forming their motivation (Mohd Amin, 2022). Learners' autonomy is the core of constructivist learning theory, meaning learners should be responsible for learning outcomes (Md Shah et al., 2023).

Kintu and Zhu (2016) conducted a specialized study on Blended Learning (BL). The research was carried out at Uganda University. The findings indicated that students' learning outcomes are significantly influenced by learner characteristics. These characteristics include students' attitudes towards BL, computer application skills, and their ability to self-regulate. The learning outcomes referred to by Kintu and Zhu encompass learning motivation, learning satisfaction, learning performance, and knowledge construction. The results also showed that learners' attitudes towards BL are positively correlated with learning satisfaction. Related research indicates that teacher-student interaction plays a very important role in improving student learning satisfaction (Cui, P., & Alias, B.S., 2024).

Lim et al. (2021) focused on the relationship between students' academic performance and their self-regulation ability demonstrated during the learning process in blended courses. The findings indicated that students' academic performance is significantly related to their self-regulation ability and time management skills. However, these self-regulation and time management skills should fall within the category of student learning behavior characteristics.

Lawalata et al. (2022) conducted a study that is both typical and meaningful. Their research subjects were 137 university students in Mexico. The study revealed that in the context of blended learning, students' learning motivation, learning emotions, and cognitive abilities are significantly related to

their academic performance. However, a finding during the research process showed that students' self-reported results indicated no significant impact of their behavior on academic performance.

There are several aspects of empirical research on learner characteristics and their relationship with the effectiveness of BL learning:

Sociocultural and demographic factors mainly include students' prior experiences, their sense of social presence, and gender. A brief explanation of prior experiences is required. Prior experiences refer to the learning skills that students have acquired during their previous learning processes. In this study, prior experiences refer to the computer application skills and other key learning abilities that students should possess when participating in blended learning. The research results of Adekugbe et al. (2024) show that girls with better academic performance tend to have higher self-regulation abilities, meaning that girls with higher self-regulation abilities perform better academically than boys. Of course, it is surprising that some gender-based BL technology acceptance model studies sometimes show significant differences in results, even contradictory. In terms of how prior experiences affect learning outcomes and academic performance, the research results are basically consistent, all agreeing that prior experiences have a significant impact on the perception and understanding of learning information. Some studies show that a meaningful sense of social presence has a significant impact on BL. "A meaningful sense of social presence in online learning is related to students' engagement and learning achievement." Online learning and BL academic performance are closely related to students' prior experiences, that is, their computer application skills (Howorth, 2024).

Learning strategy factors include learning self-regulation, information literacy, and time management skills (Anthonysamy, L., 2022). In many studies, self-regulation, information literacy, and time management skills have become key factors for a student's success. Studies show that learners who are more suitable for BL often have stronger self-regulation abilities. This demonstrates the important role of self-regulation in BL. Johnston (2016) pointed out in his research that information literacy is an important barrier that needs to be overcome for BL to have good results. Students and teachers need to have sufficient and adequate information technology skills to adopt BL strategies. That is, if students and teachers lack information literacy, it will significantly affect the quality of BL learning. Ebisin (2017) emphasized in his research that computer application skills and time management skills have an important impact on students' BL learning outcomes. Although Ebisin's research places more emphasis on the importance of time management skills and their significance for academic performance. Learning style is another important factor affecting BL learning outcomes. Through literature review, it is found that research on adaptive learning systems based on learning styles is on the rise, which shows that scholars are increasingly concerned about the impact of learning styles on BL. The most recognized in the academic community today is the Felder-Silverman learning style model (Ma, Y., 2024). However, there are some controversies about learning style research in existing studies. Some studies show that learning systems tailored to

different learning styles can save students' learning time and improve learners' satisfaction. At the same time, some studies indicate that learning systems tailored based on learning styles have no substantial effect (Yin et al., 2024; Courtier et al., 2016). The learning attitude has a significant impact on learning outcomes and should be a focal point for scholars. However, an analysis of existing literature reveals that only a few studies have focused on the impact of students' learning attitudes on BL. Most research has concentrated on the effects of BL on learners' attitudes, while other studies have investigated the relationship between traditional learning attitudes and BL (Shangguan, 2024). Some studies suggest that the confidence and ability of students and teachers to participate in BL largely influence the success of BL. Adaptive learning systems involving emotional factors are a complex and new field, with only a handful of scholars paying attention to or conducting research (Zhao, 2024). Zhu et al. (2022) proposed a learner model that includes learning emotional factors such as confidence, effort, independence, and confusion of students and teachers in BL. Learning motivation and students' self-efficacy belong to the category of learning motivation factors. There are many such studies, and research indicates that learning motivation is significantly positively correlated with BL learning outcomes. However, some studies argue that learning motivation does not have a direct impact on learning outcomes and performance (El Refae, 2021). Huy (2023) examined the impact of student group size and learning motivation on learning outcomes in a university BL environment. The results of the study show that learning motivation plays a relatively important role in increasing student enrollment rates, but it does not directly affect students' academic performance and may only have a positive impact on social presence.

Behavioral interaction has been a significant area of research for scholars in recent years. In terms of how to improve student classroom interaction rates, BL is considered an effective teaching method to increase student classroom interaction and participation rates, which is welcomed and adopted by teachers. There are more opportunities for two-way communication between teachers and students. Online education may suffer from a strong sense of distance, leading to a decrease in the quantity and quality of teacher-student interaction. However, the BL teaching method can effectively compensate for this shortcoming. Learners can receive very valuable help from peers and teachers through rich communication channels, especially in-person interactions, which can improve student learning outcomes (Li, J., & Xue, E., 2023).

### **3. Methodology**

#### **3.1 Research Design**

This study adopts the empirical research method, collects the learning behavior characteristics and AP data of college students in the BL environment through a questionnaire survey, and explores the relationship between various variables combined with statistical analysis. With BL as the background, the research framework takes the characteristics of learning behavior (BE, SL, TAA, LC) as the core independent variable, AP as the dependent variable, background variables (such as G1, G2, SB, etc.) as the moderating variable, and LC as the mediating variable. This study aims to reveal the internal

relationship between learning behavior characteristics and AP and the moderating effect of background variables on their relationship. Based on the literature review and theoretical framework, four key dimensions of learning behavior (BE, SL, TAA, and LC) are selected as research variables. Statistical analysis was used to verify the relationship between independent and dependent variables and the mediating and moderating effects. The structural equation model (SEM) was designed to analyze the path relationship between learning behavior characteristics and AP, and multiple regression analysis was used to verify the significance of the moderating variables.

### **3.2 Data Sources**

#### **The Design and Content of the Questionnaire**

The questionnaire is divided into three parts, with 28 questions involving the following dimensions: basic information, characteristics of learning behavior-BE, SL, TAA, LC, and AP.

#### **Scale Design**

The questionnaire design is based on the existing mature scale developed by Wang Caihua's team (2018). With the participation of relevant experts and graduate students, the scale was created after 6 years, 6 rounds of 9900 pre-tests, and 20 discussions. Based on the existing research results, the research team combined the characteristics of the BL environment to make appropriate adjustments to ensure the reliability and validity of the scale.

#### **Sample Characteristics**

This study took undergraduate students from five private universities, namely Harbin Cambridge College, Heilongjiang University of Finance and Economics, Heilongjiang Industrial and Commercial College, Harbin Huade College, and Heilongjiang College of Foreign Chinese Languages, as the research object, and used stratified random sampling to ensure that the sample was representative. The sample's male and female student ratio is close to the actual distribution of students, covering first-year students to senior grades. This facilitates the analysis of differences in learning behavior between different grades. SB covers liberal arts, science, engineering, and other subjects to explore the moderating effects of SB on learning behavior and AP. The final adequate sample size was 1870, which met the sample size requirements for statistical analysis.

### **3.3 Data Collection and Analysis Methods**

#### **Data Collection Methods**

Data was collected as an online questionnaire, distributed using the WenJuanxing platform, and promoted through the school's internal notice, student community, and other channels. To ensure the quality of the questionnaire, it was mandatory to fill in all its contents to avoid data loss, add validation questions (such as reverse questions) to identify invalid filling and carry out questionnaire filling time monitoring to eliminate invalid questionnaires whose filling time was too short.

## Data Analysis Techniques

This research mainly uses reliability analysis, confirmatory factor analysis, multiple linear regression, hierarchical regression, Bootstrap intermediary effect analysis, structural equation model, and other analysis methods.

### 4. Research Results

#### 4.1 Sample Analysis

According to the analysis of the samples collected, 52.4% of the samples were female, and 47.59% were male; 47.59% were first-year students, 22.99% were sophomores, and 29.41% were juniors; 54.01% of the sample were science students, and 45.99% were liberal arts students. All students participated in a blended curriculum. As a result, the sample distribution is reasonable, and the data is quite reliable.

#### 4.2 Reliability Analysis

**Table 2: Cronbach A Coefficient**

Name	value
Cronbach $\alpha$ coefficient	0.982

As can be seen from Table 2, the value of Cronbach's reliability is 0.982. This result fully indicates that the data has a high level of reliability, allowing for further specific research and analysis.

#### 4.3 Confirmatory Factor Analysis

**Table 3: Factor Load Coefficient Table**

Factor(Latent variable)	p	Standard load factor (Std.Estimate)
BE	-	0.897
BE	0.000	0.843
BE	0.000	0.807
BE	0.000	0.831
SL	-	0.872
SL	0.000	0.860
SL	0.000	0.884
SL	0.000	0.885
TAA	-	0.904
TAA	0.000	0.850
TAA	0.000	0.883

TAA	0.000	0.880
LC	-	0.909
LC	0.000	0.883
LC	0.000	0.875
LC	0.000	0.882
AP	-	0.934
AP	0.000	0.928
AP	0.000	0.864
AP	0.000	0.924

From the above Table 3, it can be concluded that the research data has a good measurement relationship, as the absolute values of the standardized loadings are all greater than 0.6, which is quite significant.

**Table 4: Model AVE and CR Index Results**

Factor	Mean-variance Extract AVE value	Combined reliability CR value
BE	0.714	0.909
SL	0.766	0.929
TAA	0.773	0.932
LC	0.787	0.937
AP	0.833	0.952

As can be seen from the conclusions given in Table 4, the AVE values of the five factors are all greater than 0.5, and the Composite Reliability (CR) values are all above 0.7. This provides researchers with an important indicator that these research data have strong convergent validity.

**Table 5: Pearson Correlation and AVE Square Root Values of Discriminative Validity after Item Deletion**

	<b>BE</b>	<b>SL</b>	<b>TAA</b>	<b>LC</b>	<b>AP</b>
BE	0.869				
SL	0.836	0.881			
TAA	0.789	0.801	0.879		
LC	0.847	0.864	0.849	0.896	
AP	0.770	0.816	0.757	0.843	0.913

Note: Underlined data are AVE square root values

This study, referring to Pearson's correlation coefficient and the square root of the Average Variance Extracted (AVE), removed items B7, A10, and E19 due to their low factor loadings, which could not meet the research requirements. As shown in Table 5, after removing these items, the square root of the AVE for Behavioral Engagement (BE) is 0.869, which is higher than the maximum absolute correlation coefficient between factors (0.847), indicating good discriminant validity. Similarly, the square root of the AVE for Self-regulated Learning (SL) is 0.881, which is higher than the maximum absolute correlation coefficient between factors (0.864), the square root of the AVE for Technological Application Ability (TAA) is 0.879, which is higher than the maximum absolute correlation coefficient between factors (0.849), the square root of the AVE for Learning Commitment (LC) is 0.896, which is higher than the maximum absolute correlation coefficient between factors (0.864), and the square root of the AVE for Academic Performance (AP) is 0.913, which is higher than the maximum absolute correlation coefficient between factors (0.892). These results suggest that all constructs have strong discriminant validity.

**Table 6: Model Fitting Indicators**

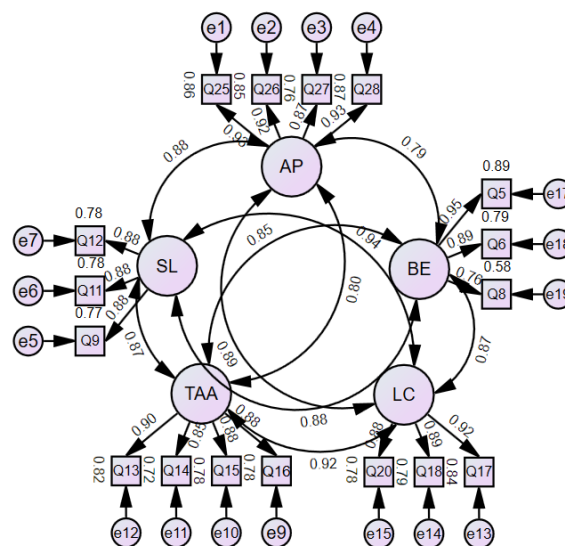
Common Indicators	chi-square	df	p	Chi-square DOF ratio $\chi^2/df$	GFI	RMSEA	RMR	CFI	NFI	NNFI
Judging criteria	-	-	>0.05	<3	>0.9	<0.10	<0.05	>0.9	>0.9	>0.9
value	510.376	174	0.000	2.933	0.793	0.102	0.030	0.933	0.903	0.920
Other indicators	TLI	AGFI	IFI	PGFI	PNFI	PCFI	SRMR	RMSEA 90% CI		
Criteria for judgment	>0.9	>0.9	>0.9	>0.5	>0.5	>0.5	<0.1	-		
value	0.920	0.726	0.934	0.598	0.748	0.773	0.042	0.092 to 0.112		
Note: $\chi^2(210) = 5260.503$ , $p = 1.000$ for Default Model										
AIC = 108.541, BIC = 292.715										

As can be seen from Table 6,  $\chi^2/df$  value was 2.933, < 3; RMR value was 0.03, < 0.05; CFI value is 0.933, > 0.9; NFI value is 0.903, > 0.9; and the NNFI value was 0.920, > 0.9. The model fit index was good.

**Table 7: Table of Factor Covariance**

Factor	Factor	Coefficient of Nonstandard estimates (Coef.)	Standard error (Std.Error)	z	p	Standard Estimate coefficient (Std.Estimate)
BE	SL	0.436	0.053	8.162	0.000	0.876
BE	TAA	0.450	0.055	8.138	0.000	0.845
BE	LC	0.463	0.056	8.337	0.000	0.873
BE	AP	0.407	0.051	7.942	0.000	0.786
SL	TAA	0.468	0.059	7.970	0.000	0.871
SL	LC	0.504	0.060	8.342	0.000	0.941
SL	AP	0.458	0.056	8.135	0.000	0.876
TAA	LC	0.525	0.063	8.367	0.000	0.916
TAA	AP	0.448	0.057	7.877	0.000	0.802
LC	AP	0.497	0.059	8.413	0.000	0.894

Table 7 shows that the values of the standard estimation coefficients are all greater than 0.70, indicating a strong correlation between the factors.



**Figure 2: CFA Model**

Note: BE=Behavioral engagement; SL=Self-directed learning; TAA=Technical application ability; LC=Learning commitment; AP=Academic performance.

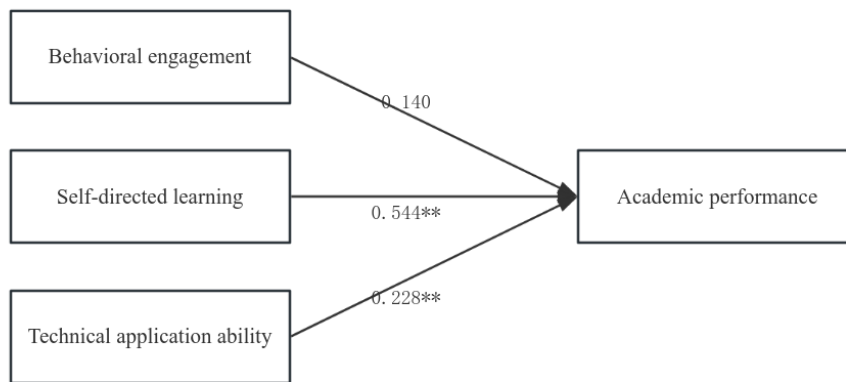
FIG. 2 shows that the theoretical structure of the measurement model fits the actual data well.

#### 4.4 Multiple Linear Regression

**Table 8: Results of Linear Regression Analysis (N=1870)**

	Nonnormalized coefficient		Standardization coefficient	T □	P □	Collinearity diagnosis	
	B □	Standard Error □	Beta □			2 VIF is based □	Tolerance □
Constant	0.381	0.190	-	2.006	0.046 *	-	-
BE	0.140	0.084	0.133	1.674	0.096	4.027	0.248
SL	0.544	0.085	0.532	6.396	0.000 *	4.436	0.225
TAA	0.228	0.069	0.229	3.318	0.001 *	3.051	0.328
R <sup>2</sup> □	0.715						
Adjust R <sup>2</sup> □	0.710						
F □	F (3,183)=152.882,p=0.000						
D-W value	1.983						
Note: Dependent variable = academic performance							
* p<0.05 ** p<0.01							

As shown in Table 8, the linear regression analysis uses Behavioral Engagement (BE), Self-Directed Learning (SL), and Technical Application Ability (TAA) as independent variables and Academic Performance (AP) as the dependent variable. The model equation is  $AP = 0.381 + 0.140BE + 0.544SL + 0.228 * TAA$ , with an R-squared value of 0.715, indicating that BE, SL, and TAA explain 71.5% of the variance in AP. The F-test results ( $F = 152.882, p < 0.05$ ) confirm that the model is statistically significant, meaning at least one of the independent variables has an impact on AP. Additionally, the variance inflation factor (VIF) values for all predictors are below 5, indicating no multicollinearity issues. The Durbin-Watson (D-W) statistic is close to 2, suggesting no autocorrelation in the residuals. The final analysis reveals that the regression coefficient for BE is 0.140 ( $t = 1.674, p = 0.096 > 0.05$ ), indicating no significant impact of BE on AP. In contrast, the regression coefficient for SL is 0.544 ( $t = 6.396, p < 0.01$ ), and for TAA it is 0.228 ( $t = 3.318, p < 0.01$ ), both of which show significant positive effects on AP. In summary, SL and TAA significantly positively influence AP, while BE does not have a significant effect.



**Figure 3: Regression Model and Coefficients**

**4.5 Mediating Effect Test**

**Table 9: Summary of Mediating Affect Test Results**

Item	C Total effect	a	b	a*b intermediate affect value	a*b (Boot SE)	a*b (z value)	a*b (p-value)	a*b (95% BootCI)	c' Direct effect	Test the conclusion
BE => LC => AP	0.140	0.264**	0.560**	0.148	0.048	3.067	0.002	0.054 ~ 0.242	-0.007	Complete intermediation
TA => LC => AP	0.228**	0.370**	0.560**	0.207	0.052	3.971	0.000	0.109 ~ 0.315	0.021	Complete intermediation
SL => LC => AP	0.544**	0.373**	0.560**	0.209	0.062	3.392	0.001	0.099 ~ 0.339	0.335**	Partial intermediation

\* p<0.05 \*\* p<0.01; bootstrap type = Percentile bootstrap method

As Table 9 shows, LC plays a completely mediating role in the relationship between BE and AP, a completely mediating role in the relationship between TAA and AP, and a partial mediating role in the relationship between SL and AP.

**Table 10: Summary of Mediating Effect Size Results**

item	Test conclusion	c Total effect	a*b intermediation effect	c 'direct effect	Effect proportion calculation formula	Effect proportion
BE => LC => AP	Complete Mediation	0.140	0.148	-0.007	-	100%
TAA => LC => AP	Complete intermediation	0.228	0.207	0.021	-	100%
SL => LC => AP	Partial Intermediation	0.544	0.209	0.335	a * b / c	38.399%

As Table 10 shows, the mediating effect of LC on BE and AP is 100%; the mediating effect of LC on TAA and AP is 100%; and the mediating effect of learning involvement on SL and AP was 38.399%.

**4.6 Structural Equation Model Analysis**

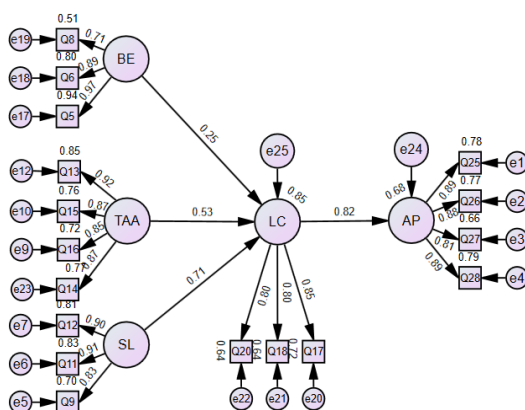
**Table 11: Model Fitting Index**

Common Indicator	chi-square	df	p	Chi-square DOF ratio Chi-square/df	GFI	RMSEA	RMR	CFI	NFI	NNFI
Judging criteria	-	-	>0.05	<3	>0.9	<0.10	<0.05	>0.9	>0.9	>0.9
value	280.793	97	0.000	2.895	0.847	0.101	0.031	0.947	0.922	0.935
Other indicators	TLI	AGFI	IFI	PGFI	PNFI	PCFI	SRMR	RMSEA 90% CI		
Criteria for judgment	>0.9	>0.9	>0.9	>0.5	>0.5	>0.5	<0.1	-		
value	0.935	0.786	0.948	0.604	0.745	0.766	0.045	0.087 to 0.114		

Note:  $\chi^2(120) = 3605.094$ ,  $p = 1.000$  for Default Model

AIC = 74.997, BIC = 201.010

As can be seen from the above table 11,  $\chi^2/df=2.895, < 3$ ;  $RMR=0.031, < 0.05$ ;  $CFI=0.947, > 0.9$ ;  $NFI=0.922, > 0.9$ ;  $NNFI=0.935, > 0.9$ . Good model fit.



**Figure 4: SEM Path Map**

According to the data in FIG. 4, the structural equation model is valid and verifies the existence of the assumed influence relationship.

## 5. Discussion

This study provides empirical evidence on how behavioral engagement (BE), self-regulated learning (SL), technology application aptitude (TAA), and learning concentration (LC) collectively shape academic performance (AP) in blended learning (BL) environments within Chinese private universities. Three key findings emerge: (1) SL and TAA exert significant positive effects on AP ( $\beta = 0.532, p < 0.01$ ;  $\beta = 0.229, p < 0.01$ , respectively), (2) BE demonstrates no statistically meaningful impact on AP ( $\beta = 0.140, p > 0.1$ ), and (3) LC partially mediates the relationships between SL/TAA and AP. These results corroborate and challenge prevailing theoretical assumptions while offering fresh insights into BL dynamics.

### Consistency with Existing Scholarship

The primacy of SL aligns with social cognitive theory (Bandura, 1986), particularly Zimmerman's (2002) cyclical model of self-regulation. Our findings resonate with Kintu and Zhu's (2016) meta-analysis, which shows that SL accounts for 23-31% variance in BL outcomes across 37 studies. Similarly, the TAA-AP linkage supports the Technology Acceptance Model (Davis, 1989), extending Ponio's (2022) work by quantifying how one standard deviation increase in TAA predicts a  $0.35\sigma$  AP improvement in BL contexts.

### Divergences and Contextual Explanations

Contrary to Fredricks et al.'s (2004) engagement theory, BE's non-significance ( $R^2$  contribution  $< 2\%$ ) suggests behavioral metrics alone may inadequately capture cognitive engagement in Chinese BL contexts. This paradox could stem from two factors:

Cultural mediation: Collectivist classroom norms (Hofstede, 2011) may decouple observable participation (e.g., forum posts) from deep learning, as students prioritize harmony over critical discourse (Zhang & Watkins, 2007).

### **Measurement Artifact**

Current BE instruments (e.g., frequency counts of interactions) fail to differentiate procedural compliance (e.g., posting to meet requirements) from substantive engagement (Henrie et al., 2015).

The LC mediation pattern diverges from de la Fuente's (2020) model by revealing domain-specific pathways:

SL → LC → AP: Goal-setting strategies enhance task focus

TAA → LC → AP: Technology mastery reduces cognitive load (Sweller, 2011)

### **Theoretical and Practical Implications**

#### **Theoretical Significance**

This study advances BL scholarship in three ways, integrating constructivist and self-determination theories. First, it identifies LC as a central mediator, extending existing frameworks prioritizing direct behavioral effects. Second, it challenges assumptions about demographic moderators (e.g., gender, discipline), highlighting the universality of SL and TAA's impact across diverse student populations. Third, the SEM approach offers a robust methodological template for analyzing complex educational interactions.

#### **Practical Implications**

The results of this study provide specific guidance for colleges and universities in designing BL curriculums. For example, curriculum design should focus on cultivating students' SL and TAA and supporting autonomous learning by providing rich online learning resources and tools. At the same time, students' BE should be enhanced through classroom interaction and online discussions.

Teachers should pay attention to students' LC and improve their learning concentration and profound thinking ability through personalized feedback and technical support. In addition, teachers can use learning analysis tools to monitor students' learning behavior in real-time, adjust teaching strategies in time, and improve teaching effects.

### **6. Conclusion**

While constrained by its sample size (n=1870) from five private universities and reliance on self-report measures ( $\alpha=0.982$ ), this study advances blended learning (BL) scholarship through three key contributions: (1) quantifying mediation pathways in Chinese higher education contexts, specifically highlighting the mediating role of learning commitment (LC) in the relationships between behavioral engagement (BE), self-directed learning (SL), technical application ability (TAA), and academic performance (AP); (2) demystifying the engagement-performance paradox by

demonstrating that BE does not significantly impact AP, whereas SL and TAA do, thus challenging assumptions about the direct influence of engagement metrics; and (3) providing a validated structural equation modeling (SEM) framework (CFI=0.947, RMSEA=0.101) that can serve as a robust template for cross-cultural replication and further exploration of BL dynamics. Future research should employ multimodal data sources, such as eye-tracking and learning management system (LMS) logs, to triangulate behavioral metrics and explore the mediating effects of institutional policies and other contextual factors.

### **Research Limitations**

The sample size of this study is limited to undergraduate students from five private universities. The sample size is 1870, which may not fully represent all college students. Future studies can expand the sample size to cover different regions and different types of colleges and universities to improve the universality and reliability of the study results.

Although the questionnaire is based on a mature scale, there may still be some bias. For example, the wording of some question items may not be clear enough, resulting in inconsistent student understanding. Future research may further optimize the questionnaire design to improve the reliability and validity of the questions.

### **Future Research Directions**

Future research can expand the sample size to include more universities and students from different disciplinary backgrounds to verify the generality of this study's findings.

Future studies can explore the impact of other learning behavioral variables (such as learning strategy, learning motivation, emotional factors, etc.) on AP in addition to BE, SL, and TAA to enrich the research content of BL further.

This study is cross-sectional, and future longitudinal studies can be conducted to track the changes in students' behavior during BL and their long-term impact on AP to more comprehensively understand the relationship between learning behavior characteristics and AP.

### **Author Contributions**

Conceptualization, PC and BSA; methodology, PC; software, PC; validation, PC and BSA; formal analysis, PC; investigation, PC; resources, PC; data curation, PC; writing—original draft preparation, PC; writing—review and editing, PC; visualization, PC; supervision, BSA; project administration, BSA. All authors have read and agreed to the published version of the manuscript.

### **Informed Consent Statement**

Informed consent was obtained from all subjects involved in the study.

### **Data Availability Statement**

The data presented in this study are available on request from the corresponding author.

### Conflicts of Interest

The authors declare no conflict of interest.

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