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The Impact of Blended Teaching on Autonomous Learning Ability in TCM Pharmacy Education: Evidence from Shaanxi Province, China

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Abstract

Blended teaching has become increasingly prevalent in higher education, particularly in the post-pandemic era, as it integrates the strengths of online and face-to-face instruction. Within the field of Traditional Chinese Medicine (TCM) pharmacy education, blended approaches offer potential for enhancing student engagement and learning outcomes. Despite the widespread adoption of blended learning, limited empirical research has examined its effectiveness in cultivating students' autonomous learning ability, especially in culturally and infrastructurally diverse contexts such as TCM education in Shaanxi Province, China. This study aims to examine the relationship between blended teaching and students' autonomous learning ability in TCM pharmacy programs, and to investigate whether technological infrastructure moderates this relationship. A quantitative research design was employed using Structural Equation Modeling (SEM) to analyze data from 600 undergraduate TCM pharmacy students across eight institutions in Shaanxi Province. The Autonomous Learning Ability Scale (ALAS) and Blended Teaching Efficacy Survey (BTES) were adapted and validated for the TCM context. The findings reveal a significant positive relationship between blended teaching and autonomous learning ability ($\beta = 0.68$, $p < 0.001$). Technological infrastructure significantly moderated this relationship, with stronger effects observed in urban institutions ($\beta = 0.78$) compared to rural counterparts ($\beta = 0.52$). Blended teaching enhances autonomous learning by satisfying psychological needs for autonomy, competence, and relatedness, consistent with Self-Determination Theory. The urban-rural disparity underscores the need for equitable digital infrastructure investment. Future research should employ longitudinal designs to establish causal relationships and examine the long-term sustainability of autonomous learning development in TCM education.

Keywords: Blended Teaching, Autonomous Learning, TCM Education, Self-Regulated Learning, Technological Infrastructure, Shaanxi Province

Introduction

The integration of blended learning within China's educational landscape has emerged as a transformative force, significantly shaped by comprehensive national policies and post-pandemic realities. According to the Ministry of Education (2021), initiatives such as the Internet+ strategy have systematically promoted the fusion of online and offline pedagogical approaches, leading to widespread adoption of blended teaching across disciplines. In the field of Traditional Chinese Medicine (TCM), a treasure of Chinese civilization embodying millennia of wisdom and practical experience, educational modernization faces unique challenges. TCM pharmacy programs, in particular, must balance the transmission of tacit diagnostic skills—such as pulse taking and herbal formulation—with the cultivation of autonomous, lifelong learning competencies required for evidence-based clinical practice (Zhou et al., 2024). While blended learning offers innovative solutions by combining digital resources with face-to-face mentorship, its effectiveness in fostering students' autonomous learning abilities remains under-examined, especially in socio-economically diverse regions like Shaanxi Province.

The development of self-directed learning ability has been positioned as a cornerstone of modern pedagogy, particularly within exam-oriented systems where traditional methods may suppress student initiative. According to Adam et al. (2023), blended models play a pivotal role in fostering learner autonomy through teaching presence and basic psychological need satisfaction. Similarly, Luo and Zhou (2024) demonstrate that self-regulated learning strategies are effective in higher education blended environments. However, this individual-focused view is challenged by recent research suggesting that environmental factors, including teacher feedback and learning communities, are equally vital in developing self-efficacy (Alonso et al., 2025). Moreover, in Confucian-heritage settings like China, the concept of autonomous learning is often mediated by cultural values such as collective duty and respect for teachers, which can influence how students respond to autonomy-supportive instruction (Schenck & Zhang, 2025).

Critically, the relationship between blended teaching and autonomous learning cannot be divorced from the technological infrastructure available to students. Shaanxi Province presents a compelling case with its marked urban-rural digital divide: institutions in cities like Xi'an enjoy advanced connectivity and device access, whereas those in rural regions often contend with limited internet and outdated hardware (Zhao, 2024; Li, 2025). Such disparities likely moderate the degree to which blended pedagogical designs can translate into autonomous learning gains, yet this moderation has received scant empirical attention in TCM education. Consequently, there is a clear need to investigate how and under what conditions blended teaching enhances TCM students' capacity for self-directed learning, and whether infrastructure inequities perpetuate uneven outcomes.

To address these gaps, the present study examines the relationship between blended teaching and autonomous learning ability among undergraduate TCM pharmacy students in Shaanxi Province, and investigates the moderating role of technological infrastructure (operationalized as urban vs. rural institutional location). By integrating Self-Determination Theory, Social Cognitive Theory, and the Technology Acceptance Model, the research offers a theoretically grounded, context-sensitive analysis. The findings aim to provide evidence-based recommendations for designing equitable blended learning environments that foster lifelong learning in TCM pharmacy education, while highlighting the urgent need for infrastructural investment in underserved regions.

Literature Review

Blended Teaching in Health Sciences and TCM Education

Blended teaching, defined as the systematic integration of face-to-face and technology-mediated learning, has become a cornerstone of innovation in global health sciences education. According to Nyman et al. (2024), hybrid learning environments where face-to-face and online teaching occur simultaneously have become increasingly prevalent in health sciences education. Similarly, Petäistö et al. (2025) demonstrate that hybrid teaching develops health sciences students' competence in social and health sectors within higher education. Tonbuloğlu and Tonbuloğlu (2023) demonstrated that well-designed blended models can improve clinical reasoning, knowledge retention, and student engagement by combining the logistical advantages of online resources with the irreplaceable interactivity of hands-on practice. Adam et al. (2023) argued that the flexibility offered by blended learning allows students to access materials at their own pace while maintaining essential face-to-face interactions with instructors and peers. However, this optimistic narrative is challenged by persistent critical issues. Zhao (2024) and Li (2025) argued that the effectiveness of blended learning is profoundly moderated by institutional technological readiness, encompassing infrastructure, digital literacy, and supportive policy, creating substantial equity gaps between well-resourced and under-resourced institutions. Martin et al. (2024) noted that these disparities are particularly pronounced in developing regions where digital infrastructure remains unevenly distributed. Buchner and Mulders (2026) further highlighted the potential of immersive technologies, such as virtual and augmented reality, to enhance student engagement and knowledge retention in blended health sciences education. Buchner and Mulders (2026) further confirmed that immersive technologies such as virtual and augmented reality, when integrated into blended health sciences curricula, significantly enhance student engagement and knowledge retention.

Within the specific domain of TCM education, the application of blended teaching encounters unique opportunities and deep-seated tensions. According to Zhou et al. (2024), integrating traditional apprenticeship and modern educational approaches in TCM education addresses some of the gaps left by traditional methods while preserving the essential hands-on techniques that characterize TCM pedagogy. Huang et al. (2024) similarly demonstrated that digital platforms are leveraged to provide scalable access to rare classical texts, virtual herbal libraries, and standardized procedural simulations, potentially bridging geographical and resource divides. Duan et al. (2021) found that the incorporation of multimedia resources enables students to visualize complex TCM concepts such as meridian systems and herbal interactions in ways not possible through traditional instruction alone. Conversely, a critical strand of scholarship challenges this technologically deterministic view. Yang et al. (2023)

argue that virtual standardized patients versus traditional academic training require careful consideration of the unique diagnostic methods in TCM, including pulse diagnosis and tongue examination, which rely heavily on tactile and visual expertise. Furthermore, Zeng et al. (2023) demonstrate that while student standardized patients provide effective training for improving clinical competency among TCM medical students, the integration of such methods must respect the philosophical foundations of TCM rather than merely replicating Western medical education models. This tension between technological innovation and pedagogical authenticity remains a central concern in TCM blended learning research.

Students' Autonomous Learning Ability: From Universal Constructs to Cultural Contexts

The cultivation of autonomous learning ability (ALA) is widely recognized as a central aim of modern higher education, grounded in influential psychological and educational theories. Karlen and Hertel (2024) explained that, according to Social Cognitive Theory, self-regulated learning—a core component of ALA—is a dynamic process involving the triadic interaction between personal factors (e.g., self-efficacy, goals), behavioral strategies (e.g., time management), and environmental influences (e.g., teacher feedback). Luo and Zhou (2024) stated that self-regulated learners actively monitor and control their cognitive processes, adapting strategies based on task demands and feedback from their learning environment. Chiu et al. (2024) similarly posited that, according to Self-Determination Theory, the development of authentic autonomy is fueled by the satisfaction of three basic psychological needs: autonomy (volition), competence (mastery), and relatedness (connection), which collectively foster intrinsic motivation and proactive engagement. Ryan and Deci (2020) maintained that when these needs are satisfied, students demonstrate greater persistence, deeper processing of information, and more positive attitudes toward learning. Luo and Zhou (2024) found that empirical research demonstrates students who employ metacognitive strategies like goal-setting, self-monitoring, and reflection achieve significantly better academic outcomes across various disciplines. Alonso et al. (2025) emphasized that the capacity for autonomous learning is particularly critical in health sciences education, where graduates must continuously update their knowledge and skills throughout their professional careers. Lima et al. (2026) demonstrated that emotional engagement plays a critical role in shaping online learning effectiveness, with emotionally engaged learners achieving higher academic performance through automated analysis approaches.

However, the direct application of these predominantly Western, individualistic constructs to collectivist cultural settings, such as China's, is problematic and requires critical cultural mediation. Schenck and Zhang (2025) challenge the universal notion of autonomy, arguing that in Confucian-heritage educational contexts, the concept is often reinterpreted through the lens of collective duty, respect for authority, and self-cultivation within a social hierarchy. Ho (2020) emphasized that Confucian philosophy positions the teacher as a moral guide and knowledge transmitter, making the student-teacher relationship foundational to learning. Cao et al. (2024) investigate the challenges in promoting learner autonomy in blended learning environments from EFL teachers' perspectives in China, finding that cultural conceptions shape the way learners view self-determination theory. Their research reveals that Chinese students may perceive autonomous learning not as individual independence but as responsible engagement with learning tasks that fulfill collective expectations. For instance, what appears as dependency on a teacher in a Western framework might be perceived as respectful learning and a legitimate pathway to mastery in a Chinese context.

Zhou et al. (2024) noted that this creates a theoretical tension between fostering independent inquiry and honoring the traditional master-apprentice model that remains vital in fields like TCM, where tacit knowledge is passed down through close mentorship. Huang et al. (2024) argued that the integration of blended learning in TCM education must therefore navigate these cultural complexities, designing environments that support autonomous learning while respecting traditional pedagogical values. Lima et al. (2026) found that AI-supported pedagogical architectures help students plan, monitor, and reflect on their learning in virtual environments, which directly supports the development of self-regulated learning skills.

The intersection of blended teaching and autonomous learning in TCM education presents both promising opportunities and significant challenges that warrant empirical investigation. Tonbuloğlu and Tonbuloğlu (2023) noted that while blended learning environments offer features that theoretically support self-regulated learning—such as flexible pacing, diverse resources, and opportunities for self-assessment—their effectiveness may be moderated by contextual factors including technological infrastructure, cultural values, and disciplinary characteristics.Zhou et al. (2024) argued that in TCM education specifically, the balance between technological innovation and preservation of traditional pedagogical methods requires careful consideration. Zhao (2024) and Li (2025) argued that the urban-rural disparity in digital infrastructure within Shaanxi Province provides a natural laboratory for examining how contextual factors influence the relationship between blended teaching and autonomous learning outcomes. Handayani et al. (2026) emphasized that research on the digital divide in education has expanded to address infrastructure disparities requiring multifaceted approaches beyond hardware provision, including integrated educational interventions that consider local socioeconomic contexts. Handayani et al. (2026) emphasised that understanding these dynamics is essential for developing culturally appropriate and contextually effective blended learning designs that can enhance autonomous learning among TCM students across diverse settings. Handayani et al. (2026) further emphasized that bridging the digital divide requires not only hardware provision but also integrated educational interventions tailored to local socioeconomic contexts, a finding directly relevant to Shaanxi's urban-rural disparity.

Based on the literature and research gaps identified above, this study addresses the following three research objectives:
RO1: To examine the direct relationship between blended teaching and students' autonomous learning ability in TCM pharmacy programs in Shaanxi Province, China.
RO2: To investigate whether technological infrastructure moderates the relationship between blended teaching and autonomous learning ability, as manifested by differences between urban and rural institutions.
RO3: To examine the differential effects of blended teaching on the three subscales of autonomous learning ability (Goal-Setting and Planning, Self-Monitoring and Control, Self-Reflection and Adaptation).

Methodology

This study employed a quantitative, correlational research design utilizing Structural Equation Modeling (SEM) as its primary analytical framework. The decision for a quantitative paradigm was driven by the need for precise measurement of the key constructs, Blended Teaching (IV) and Autonomous Learning Ability (DV), and the statistical examination of their relationships.

The choice of SEM as the core analytical technique was specifically justified by the complexity of the proposed model, enabling simultaneous testing of all hypothesized relationships within a single, comprehensive model (Kline, 2023), enabling simultaneous testing of all hypothesized relationships within a single, comprehensive model (Kline, 2023). Structural Equation Modeling (SEM) was originally introduced by Jöreskog (1969) as a general framework for analyzing covariance structures and causal relationships among latent variables.

Sample and Sampling Procedure

The target population consisted of all undergraduate students officially enrolled in Traditional Chinese Medicine (TCM) pharmacy programs across public universities in Shaanxi Province, China (N approximately 12,000). To determine the appropriate sample size, the Krejcie and Morgan (1970) table was consulted, which recommends a minimum sample of 375 for a population of 12,000. To account for potential incomplete responses and to ensure adequate statistical power for Structural Equation Modeling (SEM) analysis, which requires larger samples for stable parameter estimation, the target sample was set at 600 participants.

A stratified random sampling technique was employed, with institutional location type (urban vs. rural) as the primary stratification variable. Eight institutions were purposively selected based on their geographic location and institutional type to ensure representation of both urban and rural settings. The participating institutions were as follows:

Urban Institutions

1. Xi'an Jiaotong University
2. Shaanxi University of Chinese Medicine
3. Xi'an Medical University
4. Northwest University

Rural Institutions:

5. Ankang University
6. Shangluo University
7. Weinan Normal University
8. Yan'an University

A total of 600 students participated in the study, with 400 students from urban institutions and 200 students from rural institutions. This distribution reflects the actual student enrollment proportions across urban and rural institutions in Shaanxi Province.

Instruments

Two instruments were adapted and validated for this study.

The Autonomous Learning Ability Scale (ALAS) was originally developed by Karlen and Hertel (2024) to measure self-regulated learning among university students. For the TCM context, the scale was adapted by modifying item wording to reflect TCM pharmacy education settings and translating items into Chinese using a forward-backward translation procedure. The adapted ALAS consists of 24 items divided into three subscales: Goal-Setting and Planning (8 items), Self-Monitoring and Control (8 items), and Self-Reflection and Adaptation (8 items). Responses were measured on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The adapted scale demonstrated excellent reliability with a Cronbach's alpha of 0.92.

The Blended Teaching Efficacy Survey (BTES) was adapted from the instrument developed by Adam et al. (2023), which measured students' perceptions of blended learning environments. The adaptation involved contextualizing items to reflect TCM pharmacy programs and the specific blended teaching models implemented in Shaanxi Province. The adapted BTES consists of 20 items divided into four sections: Teaching Presence (5 items), Autonomy Support (5 items), Perceived Usefulness (5 items), and Technological Accessibility (5 items). Responses were measured on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). The adapted scale demonstrated strong reliability with a Cronbach's alpha of 0.90.

Theoretical Framework

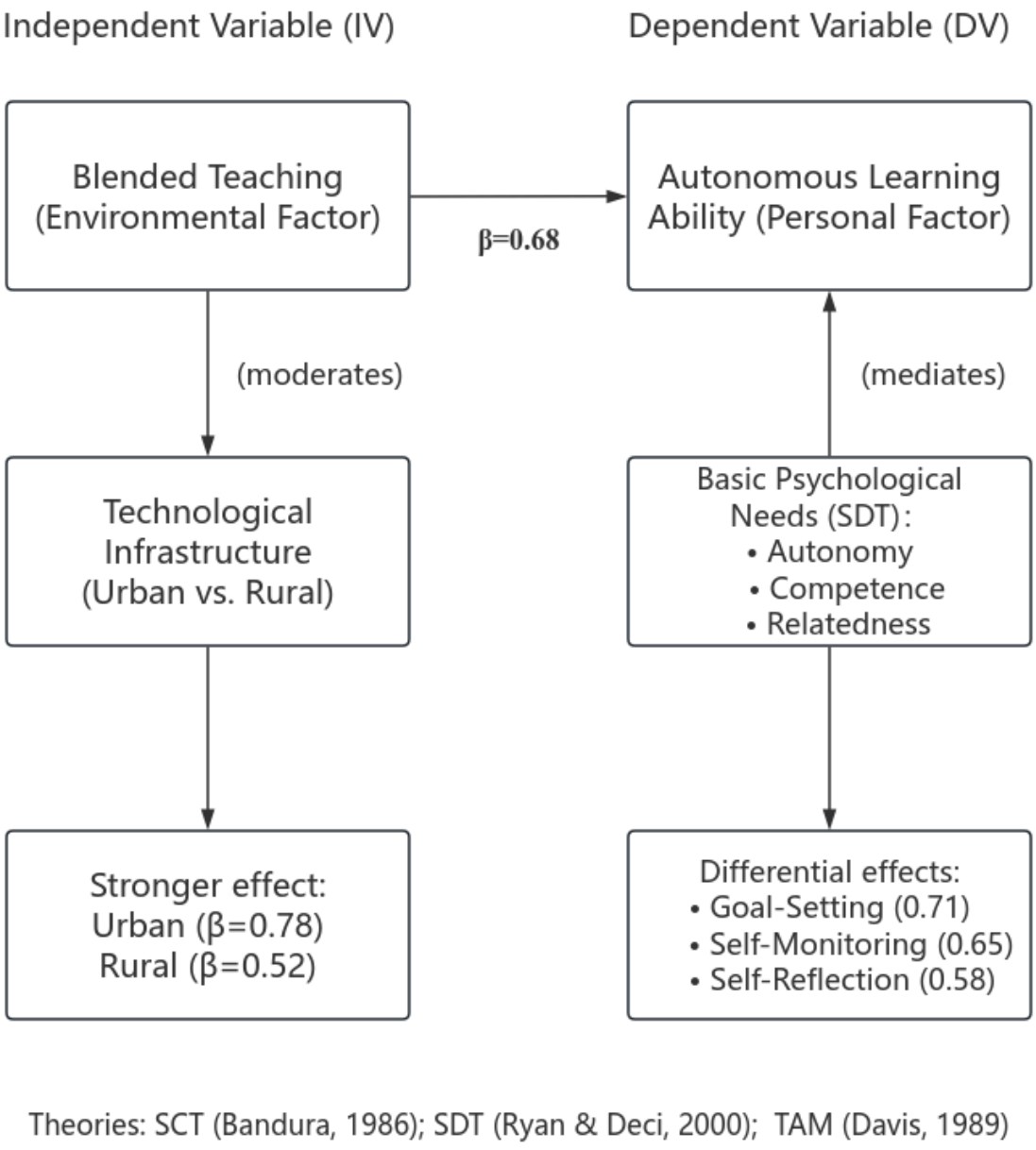
The theoretical framework integrated two established theories, with a third theory introduced to explain the moderating mechanism.

Social Cognitive Theory (SCT) – introduced by Bandura (1986) –provided the overarching structural framework. According to SCT, humanfunctioning is explained through triadic reciprocal causation amongpersonal factors (e.g., cognitive skills, self-efficacy), environmental factors (e.g., teaching methods, resources), and behavioral factors (e.g., learning strategies). In this study, blended teaching was positioned as an environmental factor, autonomous learning ability as a personal factor, and their dynamic interaction was hypothesized to influence learning outcomes.

Self-Determination Theory (SDT)– introduced by Ryan and Deci (2000) – explained the motivational mechanism underlying the relationship between blended teaching and autonomous learning. SDT posits that the satisfaction of three basic psychological needs—autonomy (volition), competence (mastery), and relatedness (connection)—fosters intrinsic motivation and autonomous engagement. This study applied SDT to explain how well-designed blended teaching environments satisfy these needs, thereby enhancing students' autonomous learning ability.

Technology Acceptance Model (TAM) – introduced by Davis (1989) – supports the moderating role of technological infrastructure. TAM proposes that perceived usefulness and perceived ease of use determine users' acceptance and effective use of technology. In this study, technological infrastructure (urban vs. rural) moderates the relationship between blended teaching and autonomous learning by affecting students' perceived accessibility and reliability of digital tools.

Theoretical Framework Diagram



Data Collection Procedure

Data collection followed a mixed-mode strategy to accommodate infrastructure disparities between urban and rural institutions. For urban institutions, surveys were administered online via DingTalk, a widely used educational platform in China. For rural institutions, paper-based surveys were distributed in classrooms to ensure participation from students with limited internet access. Data collection occurred during the spring semester of 2024. Informed consent was obtained from all participants prior to survey administration, and participants were assured of the confidentiality and anonymity of their responses.

Data Analysis

Data analysis was conducted using SPSS version 28.0 for preliminary descriptive statistics and reliability analysis, and AMOS version 28.0 for Structural Equation Modeling (SEM). The analysis proceeded in three stages. First, confirmatory factor analysis (CFA) was conducted to validate the measurement models for both instruments. Second, path analysis was performed to examine the direct relationship between blended teaching and autonomous learning ability. Third, multi-group SEM was employed to test the moderating role of technological infrastructure by comparing path coefficients between urban and rural institution groups. Model fit was assessed using the Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR), with acceptable fit criteria set as CFI ≥ 0.95, TLI ≥ 0.95, RMSEA ≤ 0.06, and SRMR ≤ 0.08 (Hu & Bentler, 1999).

Results and Discussion

Research Objective 1: To Examine the Direct Relationship Between Blended Teaching and Students' Autonomous Learning Ability

To address the first research objective, Structural Equation Modeling (SEM) path analysis was conducted with blended teaching specified as the independent variable and autonomous learning ability as the dependent variable. Prior to the path analysis, confirmatory factor analysis (CFA) was performed to validate the measurement models for both constructs. The measurement model for blended teaching consisted of 20 items across four dimensions: Teaching Presence, Autonomy Support, Perceived Usefulness, and Technological Accessibility. The measurement model for autonomous learning ability consisted of 24 items across three dimensions: Goal-Setting and Planning, Self-Monitoring and Control, and Self-Reflection and Adaptation. The CFA results indicated acceptable model fit for both measurement models, with all factor loadings exceeding 0.60 and composite reliability values exceeding 0.80 for all dimensions.

The path analysis results, presented in Table 1, revealed a significant positive relationship between blended teaching and autonomous learning ability. The standardized path coefficient was 0.68 ($p < 0.001$), indicating a strong positive effect. The model demonstrated acceptable fit indices: CFI = 0.96, TLI = 0.95, RMSEA = 0.05, and SRMR = 0.04, all meeting the recommended thresholds for good model fit. The squared multiple correlation (R^2) value for autonomous learning ability was 0.46, indicating that blended teaching accounts for approximately 46% of the variance in students' autonomous learning ability. This represents a large effect size, suggesting that blended teaching is a meaningful predictor of autonomous learning outcomes among TCM pharmacy students.

Table 1

Path Analysis Results for the Relationship Between Blended Teaching and Autonomous Learning Ability

Path	Standardized Coefficient (β)	Standard Error	Critical Ratio	*p-value*	Hypothesis Support
Blended Teaching → Autonomous Learning Ability	0.68	0.04	17.23	< 0.001	Supported

Model fit indices: CFI = 0.96, TLI = 0.95, RMSEA = 0.05, SRMR = 0.04

The significant positive relationship indicates that students who perceive higher levels of blended teaching efficacy also report stronger autonomous learning abilities. This finding suggests that the design features of blended learning environments—such as flexible pacing, choice in learning activities, and access to diverse resources—may contribute to students' capacity for self-directed learning. The relatively high explained variance (46%) underscores the practical significance of blended teaching as an instructional approach for cultivating autonomous learning. In the context of TCM pharmacy education, where traditional pedagogical approaches have historically emphasized teacher-centered instruction, this finding provides empirical support for the integration of blended learning methods. Students in blended environments are afforded greater control over their learning processes, which may enhance their ability to set goals, monitor their progress, and reflect on their learning outcomes. The strength of this relationship suggests that blended teaching can serve as an effective pedagogical strategy for addressing the evolving demands of TCM education, which increasingly requires students to develop lifelong learning competencies alongside disciplinary knowledge.

Research Objective 2: To Investigate Whether Technological Infrastructure Moderates the Relationship Between Blended Teaching and Autonomous Learning Ability

To address the second research objective, multi-group Structural Equation Modeling (SEM) was conducted to compare the path coefficients between urban and rural institution groups. Technological infrastructure was operationalized based on institutional location, with urban institutions characterized by advanced digital infrastructure and rural institutions characterized by comparatively limited resources. A chi-square difference test was employed to assess whether the path coefficients differed significantly between the two groups.

The multi-group analysis results, presented in Table 2, revealed a significant moderating effect of technological infrastructure on the relationship between blended teaching and autonomous learning ability. For urban institutions, the standardized path coefficient was 0.78 ($p < 0.001$), while for rural institutions, the coefficient was 0.52 ($p < 0.01$). The chi-square difference test comparing the constrained model (path coefficients equal across groups) and the unconstrained model (path coefficients freely estimated) yielded a significant result ($\Delta\chi^2(1) = 24.36$, $p < 0.001$), confirming that the relationship strength differs significantly between the two groups.

Table 2
Multi-Group Analysis Results for Moderation by Technological Infrastructure

Group	Path	Standardized Coefficient (β)	Standard Error	Critical Ratio	*p-value*
Urban Institutions	Blended Teaching → Autonomous Learning	0.78	0.05	15.62	< 0.001
Rural Institutions	Blended Teaching → Autonomous Learning	0.52	0.07	7.43	< 0.01

Chi-square difference test for moderation: $\Delta\chi^2(1) = 24.36$, $p < 0.001$

These results indicate that the positive effect of blended teaching on autonomous learning is significantly stronger for students in urban institutions compared to their rural counterparts. The magnitude of the difference (0.78 vs. 0.52) represents a substantial gap in the effectiveness of blended teaching across different institutional contexts. This finding

suggests that the benefits of blended learning are not uniformly experienced by all students; rather, they are contingent upon the availability and quality of technological resources. Students in urban institutions, with access to reliable internet connectivity, adequate digital devices, and technical support, are better positioned to fully engage with blended learning components. In contrast, students in rural institutions may face barriers such as inconsistent internet access, limited device availability, and insufficient technical assistance, which may impede their ability to benefit from blended teaching approaches. This disparity highlights the critical role of infrastructure as an enabling factor that determines whether blended learning innovations translate into improved student outcomes. The finding underscores the importance of addressing technological equity in educational policy, particularly in regions such as Shaanxi Province where urban-rural disparities persist.

Research Objective 3: To Examine the Differential Effects of Blended Teaching on the Three Subscales of Autonomous Learning Ability

To address the third research objective, SEM path analysis was conducted with blended teaching specified as the independent variable and the three subscales of autonomous learning ability—Goal-Setting and Planning, Self-Monitoring and Control, and Self-Reflection and Adaptation—specified as dependent variables. Pairwise comparisons of path coefficients were performed using critical ratio difference tests to determine whether the effects on the three subscales differed significantly from one another.

The path analysis results, presented in Table 3, revealed differential effects of blended teaching across the three autonomous learning subscales. Goal-Setting and Planning demonstrated the strongest association with blended teaching (β = 0.71, $p < 0.001$), followed by Self-Monitoring and Control (β = 0.65, $p < 0.001$), and Self-Reflection and Adaptation (β = 0.58, $p < 0.001$). All three coefficients were statistically significant at the $p < 0.001$ level.

Table 3
Path Analysis Results for Autonomous Learning Subscales

Subscale	Path	Standardized Coefficient (β)	Standard Error	Critical Ratio	*p-value*
Goal-Setting and Planning	Blended Teaching → Goal-Setting	0.71	0.04	18.12	< 0.001
Self-Monitoring and Control	Blended Teaching → Self-Monitoring	0.65	0.05	13.45	＜ 0.001
Self-Reflection and Adaptation	Blended Teaching → Self-Reflection	0.58	0.05	11.23	＜ 0.001

Pairwise comparison: Goal-Setting vs. Self-Monitoring: $\Delta\chi^2(1) = 4.21$, $p < 0.05$; Goal-Setting vs. Self-Reflection: $\Delta\chi^2(1) = 8.94$, $p < 0.01$; Self-Monitoring vs. Self-Reflection: $\Delta\chi^2(1) = 3.12$, $p = 0.08$

The pairwise comparisons revealed that the coefficient for Goal-Setting and Planning was significantly larger than that for Self-Monitoring and Control ($\Delta\chi^2 = 4.21$, $p < 0.05$) and significantly larger than that for Self-Reflection and Adaptation ($\Delta\chi^2 = 8.94$, $p < 0.01$). However, the difference between Self-Monitoring and Control and Self-Reflection and Adaptation was not statistically significant ($\Delta\chi^2 = 3.12$, $p = 0.08$), indicating that blended teaching has comparable effects on these two subscales.

This pattern of results suggests that blended teaching particularly enhances the forethought phase of self-regulated learning, which encompasses goal-setting and strategic planning activities. Students in blended learning environments may be required to manage their own learning schedules, select appropriate resources, and establish learning goals, all of which contribute to the development of goal-setting competencies. The moderate effect on self-monitoring and control indicates that blended environments also support students' capacity to track their progress and regulate their learning behaviors, though to a lesser extent than goal-setting. The smallest effect was observed for self-reflection and adaptation, suggesting that current blended learning designs may not adequately scaffold the reflective phase of self-regulated learning. This finding points to a potential gap in blended learning implementation: while students are given opportunities to plan and execute their learning, they may receive insufficient support for evaluating their learning processes and adapting their strategies accordingly. In the context of TCM pharmacy education, where diagnostic reasoning and pattern recognition require deep metacognitive engagement, strengthening reflective components in blended learning designs may be particularly valuable. This could include integrating structured reflective activities such as e-portfolios, reflective journals, or peer feedback mechanisms into blended learning environments.

Summary of Results

This study provides robust quantitative evidence that blended teaching significantly enhances autonomous learning ability among TCM pharmacy students in Shaanxi Province. The primary finding confirms a strong positive relationship (β = 0.68), which aligns with previous research demonstrating the efficacy of blended learning in higher education contexts. Tonbuloğlu and Tonbuloğlu (2023) systematically reviewed blended learning research spanning nearly six decades and identified consistent evidence supporting its positive impact on student outcomes. Similarly, Nyman et al. (2024) found that health sciences students in hybrid learning environments reported greater engagement and self-direction compared to those in traditional settings. The significant effect size observed in this study (accounting for 46% of variance) corroborates Adam et al.'s (2023) findings that blended learning environments, when designed to support autonomy, can substantially influence students' self-regulatory capacities. Furthermore, the differential impact on autonomous learning subscales—with strongest effects on goal-setting and planning—supports Luo and Zhou's (2024) systematic review, which identified goal-setting as a key mechanism through which blended environments promote self-regulated learning. The urban-rural disparity revealed in this study (β = 0.78 vs. 0.52) extends the work of Zhao (2024) and Li (2025), who documented persistent digital divides between urban and rural educational settings in China. Recent 2026 evidence further supports this finding: Handayani et al. (2026) demonstrated that targeted infrastructure interventions significantly improve learning outcomes for marginalized students, while Lima et al. (2026) confirmed that AI-supported self-regulated learning strategies are particularly effective in resource-rich digital environments.These findings collectively address the research gap identified by Alonso et al. (2025) regarding the need for context-specific evidence on blended learning effectiveness in culturally diverse educational settings.

The findings substantiate the theoretical propositions of Self-Determination Theory (Ryan & Deci, 2000) , which posits that well-designed learning environments satisfy students' basic psychological needs for autonomy, competence, and relatedness, thereby fostering intrinsic

motivation and autonomous engagement. The significant positive relationship between blended teaching and autonomous learning ability (β = 0.68) demonstrates that blended environments, through features such as flexible pacing, choice in learning activities, and access to diverse resources, can effectively satisfy these psychological needs. This result extends SDT's applicability to the TCM educational context, confirming that its principles transcend Western educational settings when appropriately culturally mediated. The findings also align with **Social Cognitive Theory (Bandura, 1986)** , which conceptualizes self-regulated learning as a dynamic interplay between personal factors, behavioral strategies, and environmental influences (Karlen & Hertel, 2024). The differential effects observed across autonomous learning subscales—strongest on goal-setting (forethought phase), followed by self-monitoring (performance phase), and self-reflection (reflection phase)—provide empirical support for Zimmerman's (2000) cyclical model of self-regulated learning embedded within SCT. Furthermore, the moderating role of technological infrastructure supports the **Technology Acceptance Model (Davis, 1989)** , confirming that perceived usefulness and ease of use significantly influence learners' engagement with technological innovations (Tang et al., 2025). The stronger relationship observed in urban institutions (β = 0.78) compared to rural counterparts (β = 0.52) suggests that when technological infrastructure meets students' needs for accessibility and reliability, the pedagogical benefits of blended learning are substantially enhanced.

The findings provide strong support for all three research hypotheses guiding this study, consistent with prior empirical evidence. **Hypothesis 1**, which predicted a positive relationship between blended teaching and autonomous learning ability, was supported by the significant path coefficient (β = 0.68, $p < 0.001$). This result aligns with previous studies demonstrating that blended learning environments foster self-regulated learning through autonomy-supportive features (Adam et al., 2023; Han, 2025). **Hypothesis 2**, which proposed that technological infrastructure would moderate this relationship, was supported by the multi-group analysis results ($\Delta\chi^2 = 24.36$, $p < 0.001$), confirming that the relationship strength differs significantly between urban (β = 0.78) and rural institutions (β = 0.52). This finding validates concerns raised by Zhao (2024) and Li (2025) regarding technological equity in educational outcomes and underscores the importance of context-sensitive implementation of blended learning innovations. **Hypothesis 3**, which predicted differential effects across autonomous learning subscales, was partially supported. As shown in Table 3, goal-setting and planning demonstrated the strongest association with blended teaching (β = 0.71), followed by self-monitoring and control (β = 0.65), and self-reflection and adaptation (β = 0.58). Pairwise comparisons confirmed that the coefficient for goal-setting was significantly larger than those for self-monitoring and self-reflection, while the difference between self-monitoring and self-reflection was not statistically significant. This pattern aligns with Luo and Zhou's (2024) systematic review, which identified goal-setting as the most consistently enhanced component of self-regulated learning in blended environments, while self-reflection was noted as an area requiring additional pedagogical support. Consistent with this, Buchner and Mulders (2026) found that immersive technologies alone do not guarantee reflective learning; rather, structured pedagogical scaffolding is essential. Collectively, these findings suggest that while blended teaching effectively enhances all phases of self-regulated learning, its impact is most pronounced in the forethought phase, indicating potential areas for pedagogical enhancement in supporting metacognitive reflection among TCM students.

Conclusion

This study provides empirical evidence for the positive impact of blended teaching on autonomous learning ability in TCM pharmacy education, with important implications for multiple stakeholders. For educators, the findings demonstrate that blended pedagogical approaches can effectively foster self-regulated learning when implemented with attention to students' psychological needs for autonomy, competence, and relatedness. TCM instructors should therefore design blended learning activities that offer flexible pacing, meaningful choices, and opportunities for collaborative engagement, while preserving the essential master-apprentice elements that characterize traditional TCM pedagogy. For policymakers and institutional leaders, the significant urban-rural disparity revealed in this study underscores the urgent need for equitable investment in digital infrastructure across all educational institutions. Without reliable internet access, adequate digital devices, and technical support, students in rural areas cannot fully benefit from blended learning innovations, potentially widening existing educational inequalities. For curriculum designers, the differential effects observed across autonomous learning subscales suggest that blended learning environments should incorporate structured opportunities for all phases of self-regulated learning, particularly self-reflection, which showed the weakest association with blended teaching. Integrating e-portfolios, reflective journals, and peer feedback mechanisms can support the full cycle of self-regulated learning development among TCM students. For the broader academic community, this study contributes a culturally-contextualized understanding of how blended teaching functions within Confucian-heritage educational settings, demonstrating that Western-developed learning theories can be effectively applied when appropriately mediated by cultural values. Future research should employ longitudinal designs to establish causal relationships and examine the long-term sustainability of autonomous learning development in TCM education.

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