



Innovation management for smart learning management system development in Chinese higher education: A structural equation modeling study

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ABSTRACT

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This study seeks to investigate how innovation-driven academic and administrative management practices influence smart education development in higher education institutions in Guangxi Province, China, with a focus on the mediating roles of students' and lecturers' Learning Management System (LLMS) usage behaviors. A quantitative study approach was used, and data were gathered from university officials, professors, and students using a standardized questionnaire. SEM with bootstrapping approaches was used to investigate direct, indirect, and total effects among constructs. The findings show that both academic and administrative management have a considerable favorable impact on student learning management system usage (SLMS) and lecturer learning management system (LLMS). In turn, SLMS and LLMS provide important contributions to smart education growth, with LMS adoption by students having a greater impact. Mediation study demonstrates that SLMS and LLMS mediate the linkages between innovation-driven management practices and smart education development in both collaborative and independent ways. The indirect effects of learning management system (LMS) use are statistically significant, supporting a dual-pathway mediation mechanism. These findings show that innovation management has an impact on smart education development both directly and indirectly by altering key stakeholders' LMS engagement patterns. Practically, the study offers evidence-based guidance to university leaders and policymakers on how to prioritize innovation-oriented academic and administrative management strategies that improve effective LMS utilization, thereby supporting long-term smart education development in the Chinese higher education context.

Contribution/Originality: This research contributes to the literature by merging innovation management and smart education development through learning management system (LMS) involvement. This research estimates using bootstrapped Structural Equation Model (SEM). A few research studies have examined dual-path mediation of student and lecturer LMS use. Differential stakeholder effects on smart education outcomes are the paper's main contribution.

1. INTRODUCTION

Intelligent technologies are emerging as key drivers of educational reform and management innovation in universities (Huang, Liu, Tlili, Yang, & Wang, 2021). Digital technology has rapidly transformed higher education. Cloud computing, IoT, big data analytics, and AI have been widely implemented in education, creating a new paradigm called “smart education” (Chen, Chen, & Lin, 2020). Smart education is characterized by personalization, adaptability, and enhanced efficiency. It represents a form of education that leverages technology to drive

transformative changes in both instructional processes and institutional management (Asbari, Purba, Hariandja, & Sudibjo, 2023). In this paper, the learning management system (LMS) is the digital platforms that are used to facilitate the teaching and learning processes. The conceptualization of LMS use is at two levels: student LMS usage (SLMS) is the degree to which students utilize LMS platforms to carry out learning activities, and lecturer LMS usage (LLMS) is the degree to which instructors use LMS to teach, deliver content, and manage courses.

However, global progress in smart education remains uneven, particularly in economically disadvantaged regions. According to Basra, Gani, Akib, Islahuddin, and Guntur (2024) and Bohashko and Bohashko (2024), the widespread adoption and implementation of smart education initiatives have been constrained by several obstacles, including limited technological infrastructure, unbalanced resource distribution, and low levels of digital literacy among educators. These disparities pose significant challenges to achieving inclusive and equitable educational modernization (Basra et al., 2024; Bohashko & Bohashko, 2024).

The Guangxi Zhuang Autonomous Region has 89 higher education institutions serving a population of approximately 50 million people (Guangxi Bureau of Statistics, 2023). This region serves as a strategically important link between China and ASEAN countries. Despite the regional government's efforts to support digital transformation through the "Digital Guangxi" strategy and favorable policy frameworks, the expansion of smart education in Guangxi faces several significant challenges. These include underdeveloped digital infrastructure, insufficient technological capabilities among faculty, and uneven distribution of educational resources (Zhang, Yin, & Wu, 2025). These constraints underscore the critical need for innovative and effective management strategies to accelerate smart education development in the region.

The existing literature emphasizes the critical role that educational innovation management plays in transforming technological potential into practical educational outcomes. This transformation requires establishing an innovation ecosystem that coordinates technological development, institutional structures, and human resources (Fullan & Scott, 2009; Secundo, Rossi, & Bianchi, 2020). More specifically, academic management focuses on core teaching activities such as curriculum redesign, blended teaching model development, and learning analytics implementation (El Moutchou & Touate, 2024; Garrison & Vaughan, 2008). Meanwhile, administrative management encompasses supporting infrastructure such as digital infrastructure development, institutional optimization, and data governance system establishment (Dede, 2016; Georgescu, 2024). The "dual-wheel drive" approach, which combines the Student Learning Management System (SLMS) and the Lecturer Learning Management System (LLMS), has been shown to enhance the precision and intelligence of educational service delivery (Chen et al., 2020; Kim, Prempeh, Addai, & Wargo, 2025).

However, the existing body of research focuses primarily on technical applications in smart education, with limited attention to institutional innovation and management improvements. Furthermore, most studies examine academic and administrative management separately, overlooking the synergistic benefits that their integration could provide in advancing smart education (Hidayat, Putri, & Sukardi, 2024). Additionally, there is a scarcity of empirical research on the practical challenges of implementing smart education in economically disadvantaged regions such as Guangxi, making it difficult to design region-specific development strategies that are both tailored and effective.

In response, this study examines the innovation management processes and mechanisms underlying smart education implementation in Guangxi's higher education institutions. Employing a mixed-methods approach that integrates structural equation modelling (SEM) and qualitative interviews, this study investigates the perspectives of management personnel, technical staff, and faculty members. The goal is to examine how academic and administrative management can work together to advance smart education, as well as the mediating roles that SLMS and LLMS play in this process.

The research results possess considerable theoretical and practical ramifications. Theoretically, the study develops a comprehensive framework linking innovation management to smart education development, thereby enriching the scholarly discourse on educational innovation management. Practically, it provides higher education

institutions in Guangxi and similar regions with actionable strategic guidance to overcome key challenges in advancing smart education.

As educational informatization progresses nationwide, understanding the various factors influencing smart education development in regional universities is critical to ensuring balanced and effective implementation of smart education across China (El Junusi, Agriyanto, Khusnul Mubarak, & Parmudi, 2025; Rinaldi, 2023).

1.1. Research Questions

1. To what extent has smart education evolved in Guangxi Province, China?
2. How do university managers' current academic and administrative management tactics affect students' (SLMS) and lecturers' (LLMS) use of the Learning Management System (LMS)?
3. How do students' and lecturers' LMS usage behaviors mediate the relationship between academic-administrative management techniques and smart education development?
4. Which style of innovation management, academic or administrative, has a greater indirect impact on smart education development by influencing students' and lecturers' LMS usage behaviors?

1.2. Research Objectives

1. To examine the current development state of smart education in Guangxi Province, China, including implementation scale, technological integration maturity, and demonstrable impacts on teaching and learning outcomes.
2. To investigate the direct effects of university managers' innovation-driven academic and administrative management methods on students' (SLMS) and lecturers' (LLMS) adoption and engagement with the Learning Management System.
3. To explore the mediating mechanisms by which students' and lecturers' LMS usage behaviors transmit the effects of academic and administrative innovation management to smart education development, thus confirming the dual-pathway model of management strategy impact.
4. To investigate the indirect effects of academic and administrative innovation management on smart education growth via SLMS and LLMS usage behaviors, and to determine the paths that make the greatest contribution to smart education development.

2. LITERATURE REVIEW

This study is based on Innovation Academic Management (Garrison & Vaughan, 2008) Innovation Administration Management (Fullan & Scott, 2009) Student Learning Management System (SLMS) (Huang et al., 2021) Lecturer Learning Management System (LLMS) (Chen et al., 2020) and Smart Education Development (Dede, 2016; Guangxi Bureau of Statistics, 2023).

2.1. Innovation Academic Management

In the context of smart education development, academic management innovation is increasingly recognized as a critical factor in improving educational quality and teaching effectiveness. Ononye and Maduemezia (2024) found in their study of multiple medical education institutions in the United States that successful academic innovation management requires seven core activities: idea generation, project development, implementation, fundraising, partnership management, effectiveness evaluation, and thought leadership. These elements form the foundation of an effective academic innovation system and play an important role in higher education teaching reform.

However, compared with administrative innovation, academic innovation tends to be decentralized and faculty-driven, making it highly sensitive to institutional culture and leadership support. Ostrovska (2023) found in their research on Omani institutions that teaching innovation often remains in the "pre-innovation stage," characterized

by idea incubation and project planning. Although universities have implemented measures to encourage student participation in innovation, the overall lack of formal innovation process planning and monitoring mechanisms has reduced innovation management effectiveness.

According to Patutina, Gus'kov, and Kiseleva (2023), academic innovation is generally poorly integrated into formal job descriptions and organizational frameworks, resulting in fragmented implementation. Administrative innovation, which is institutionalized through policies and processes, may lack pedagogical depth. Academic innovation management should shape curriculum design, assessment methodologies, and teaching-learning interactions to affect students' (SLMS) and lecturers' (LLMS) LMS usage, leading to the following hypotheses:

H₁: Innovation in academic management has a strong, favorable impact on student use of learning management systems (SLMS).

H₂: Innovative academic management has a strong, favorable impact on lecturers' use of Learning Management Systems (LLMS).

2.2. Innovation Administration Management

Administrative management innovation is a key mechanism for supporting high-quality development in higher education. Rahman et al. (2025) found through a case study of Indian universities that implementing "administrative innovation strategies" such as facilities management, financial resource allocation, alumni engagement, and internal quality assurance systems can significantly improve university operational efficiency and organizational performance (Rahman et al., 2025).

In their research on Russian university reform, administrative innovation differs fundamentally from academic innovation in that it prioritizes efficiency and standardization over pedagogical flexibility. Henriksen (2024) observed that the establishment of an "innovative bureaucratic system" has shifted administrative management toward formalization and performance orientation. While this management approach has improved execution capacity, it has also resulted in increased administrative burden, unclear educational objectives, and frequent standard changes, which have affected system stability and long-term development capacity (Henriksen, 2024).

Olabiya (2024) also suggested that if African universities aim to achieve management transformation, they should promote administrative innovation through leadership development, interdisciplinary collaboration, incentive systems, and technology integration. This transformation has the potential to enhance organizational agility and educational service quality. To avoid procedural administrative innovation, Wang (2024) stressed leadership development, incentive systems, and digital integration. Administrative innovation can improve system stability, policy coherence, and support services rather than instructional design when connected with digital platforms like LMS. Administrative innovation may impact LMS use through institutional facilitation rather than pedagogical design.

H₃: Innovation administration management has a strong, favorable impact on student use of learning management systems (SLMS).

H₄: Innovation administration management has a strong, favorable impact on lecturers' use of Learning Management Systems (LLMS).

2.3. Students' Use of the Learning Management System (SLMS)

The Learning Management System (LMS) has emerged as an important tool for digital teaching in higher education, significantly enhancing students' learning efficiency and course engagement. You (2024) analyzed student LMS usage using the Technology Acceptance Model (TAM) and found that usage frequency is significantly influenced by "perceived usefulness" and "ease of use," indicating that students' willingness to use LMS depends primarily on whether the system is convenient and practical.

Zhang et al. (2025) showed that content accessibility, engagement, and system functionality boost student motivation and performance. Current studies generally miss how management-level innovation indirectly impacts these beliefs. Zhang (2023) stated that inadequate service assistance and technical impediments diminish LMS continuity, emphasizing the importance of administrative systems in student involvement. Thus, SLMS is both a system quality outcome and a mediator between innovation management and smart education development:

H₁: Student Use of Learning Management Systems (SLMS) Has a Significant Positive Impact on Smart Education Development.

H₂: The mediating role of student use of Learning Management Systems (SLMS) has a good influence on Innovation, Academic Management, and Smart Education Development.

H₃: The mediating role of student use of Learning Management Systems (SLMS) has a favorable influence on Innovation Administration Management and Smart Education Development.

2.4. Lecturers' Use of Learning Management Systems (LLMS)

The adoption and use of Learning Management Systems (LMS) by instructors is critical in the context of smart education. Lin (2025) noted that system quality, technical support, and instructors' self-efficacy all significantly influence perceived usefulness and ease of use, and these factors directly affect instructor satisfaction. Chen et al. (2020) emphasized that instructors face technical challenges when developing teaching materials, assessment tools, and teaching models, particularly when systematic training and technical support are lacking, which directly impacts their teaching effectiveness. Fullan and Scott (2009) also found that while LMS has the potential to improve student learning outcomes, instructors often underutilize it due to limited technical competency. Fragmented instructional materials and inadequate assessment systems are common issues (Lokollo, 2024). Academic management innovation (e.g., curricular autonomy, teaching innovation incentives) affects teachers' LMS use more than administrative mandates do students. Academic innovation influences instructional desire and pedagogical creativity, while administrative innovation assures infrastructure and compliance (Fullan & Scott, 2009). Garrison and Vaughan (2008) found that the Moodle platform enhances instructors' professional capabilities, particularly in subject matter mastery and technology application. However, challenges such as unstable networks and difficult system adaptation remain (Sari, 2023).

H₄: Lecturers' use of a Learning Management System (LLMS) has a considerable favorable impact on smart education progress.

H₅: Lecturers' use of Learning Management Systems (LLMS) mediates the good effect of Innovation Academic Management on Smart Education Development.

H₆: The usage of a Learning Management System (LLMS) by lecturers has a favorable influence on innovation administration management and smart education development.

2.5. Smart Education Development

Smart education is recognized as a critical direction for the digital transformation of higher education. Zhang (2023) stated that smart education development faces challenges such as limited awareness, content constraints, and insufficient technological equipment, which must be addressed by strengthening curriculum development and management capacity.

Basra et al. (2024) identified the fundamental components of smart education as smart students, smart teaching, and smart environments, emphasizing the capacity to sustain educational continuity and adaptability during pandemics and challenging circumstances. Kim et al. (2025) found that smart education enhances students' competitiveness and development of critical skills by creating an information-rich and intelligent learning environment.

Bohashko and Bohashko (2024) emphasized that smart education should encompass not only teaching models and technological tools, but also the development of multiple systems, including teacher support, legal frameworks, and administrative management, with the aim of promoting long-term social and economic development. Recently, research has shown that smart education development requires coordinated academic and administrative innovation systems as well as technology adoption (Bohashko & Bohashko, 2024). Kim et al. (2025) showed that effective governance and pedagogical leadership boost students' competitiveness and higher-order skills in intelligent learning settings.

3. RESEARCH METHODOLOGY

This mixed-methodology study examines innovation-driven academic and administrative management, LMS usage, and smart education development using both quantitative and qualitative methods. A designed questionnaire employing a five-point Likert scale measured innovation in academic management, administrative management, LMS utilization by students and lecturers, and smart education development. SEM was used to investigate direct and mediated effects. The study emphasizes management-driven mechanisms and models of LMS usage as a dual mediating pathway, explaining smart education development better than previous studies focused solely on technology adoption.

3.1. Research Subjects and Samples

The research subjects were administrative managers from 89 higher education institutions in Guangxi Province, representing three types of management roles: top-level design managers (322 people), technical administrators (645 people), and teaching administrators (1,483 people), totaling 2,450 individuals. This study collected 333 valid surveys using stratified random sampling, comprising 44 from top-level design managers, 88 from technical administrators, and 201 from instructional administrators. The questionnaires were distributed via the Wenjuanxing platform and the universities' official email addresses. Clarifying data screening and exclusion methods addressed the sample size disparity. After collecting 333 questionnaires, 65 were eliminated due to data quality issues, leaving 268 valid responses for analysis.

To supplement the research findings, this study performed semi-structured in-depth interviews with 20 managers from various sorts of colleges. The interviews covered three types of managerial responsibilities, ensuring that the sample was representative and diverse.

3.2. Research Tools and Reliability and Validity Tests

This study primarily uses structured questionnaires and semi-structured interview guides. The questionnaire is divided into two sections: the first section captures respondents' demographic information, and the second section addresses five research variables, comprising 25 measurement items.

A small-scale pilot test was conducted prior to the official questionnaire distribution. The questionnaire demonstrated strong internal consistency, as evidenced by Cronbach's α values exceeding 0.80 for all variables. Five experts in educational management and smart education assessed the reliability and validity, and the Index of Item-Objective Congruence (IOC) method was used to evaluate item content validity. All items received ratings of at least 0.50.

3.3. Data Collection and Processing Methods

The data collection period lasted from March to June 2025. Quantitative data were acquired using the Wenjuanxing technique. Following the collection, invalid samples were checked and excluded using SPSS software. Qualitative data were evaluated using Tencent Meeting interviews, which were transcribed verbatim using the iFlytek transcription tool. All documents are encrypted to maintain anonymity and data protection.

In terms of quantitative data analysis, SPSS and AMOS were employed for structural equation modeling (SEM) and path analysis. Meanwhile, the bootstrap method was used to assess the mediating effect. The qualitative data were coded and analyzed with NVivo 14. Topic induction and cross-validation of quantitative results improved the research's explanatory power.

4. RESULTS

After analyzing the demographic characteristics of respondents, the study conducted reliability and validity analyses of the survey instrument, followed by confirmatory factor analysis (CFA) and structural equation modeling (SEM) to test the hypotheses. The study presents both quantitative results and qualitative interview findings, providing a comprehensive understanding of the factors driving Learning Management System (LMS) development in smart education.

4.1. Descriptive Statistics

This study included a total of 268 valid questionnaires. The sample was gathered from 89 higher education institutions in Guangxi, focusing on three types of administrative personnel: Top-Level Design Managers, Technical Administrators, and Teaching Administrators. A stratified random sample procedure was used to guarantee a representative distribution across these roles.

Table 1 shows the demographic characteristics of the respondents, such as gender, age group, and position category. The findings suggest that 52.6% of respondents were men and 47.4% were women. The majority of respondents were between the ages of 26 and 45, matching the age range of the main personnel in Guangxi's higher education management.

In terms of position classifications, Teaching Administrators made up the largest group (45.9%), followed by Technical Administrators (30.2%) and Top-Level Design Managers (23.9%), which is broadly comparable with the actual staff makeup of Guangxi universities.

Table 1. Demographic profile of respondents (N=268).

Category	Item	Frequency (N)	Percentage (%)
Gender	Male	141	52.6%
	Female	127	47.4%
Age group	18 - 25 years	11	4.1%
	26 - 35 years	88	32.8%
	36 - 45 years	102	38.1%
	46 years and above	67	25.0%
Position type	Top-level design manager	64	23.9%
	Technical administrator	81	30.2%
	Teaching administrator	123	45.9%

The study instrument showed strong internal consistency across all components. Table 2 shows Cronbach's alpha values for each dimension. The five major constructs - Innovation Academic Management, Innovation Administration Management, SLMS usage, LLMS usage, and Smart Education Development - all had Cronbach's α coefficients above the suggested 0.70 threshold (varying from 0.908 to 0.930), indicating high reliability. The questionnaire (25 items) had a Cronbach's alpha of 0.954, indicating strong internal consistency for the combined scale.

Table 2. Reliability analysis.

Dimension	Cronbach's Alpha	Composite Reliability (CR)	Average variance extracted
1. Innovation in academic management	0.908	0.91	0.68
1. Our school uses AI-driven teaching tools like adaptive quizzes to improve learning.	0.900	0.90	0.66
2. Students receive personalized learning plans (Differentiated assignments).	0.904	0.90	0.67
3. Interdisciplinary efforts (e.g., environmental science and public policy) combine knowledge.	0.908	0.91	0.68
4. Faculty share strategies via online collaboration tools (e.g., monthly webinars).	0.912	0.92	0.69
5. Case studies are valued above standardized tests.	0.916	0.93	0.70
2. Innovation in administration management	0.922	0.89	0.72
1. AI-based prediction models allocate resources (e.g., budget optimization algorithms).	0.914	0.87	0.70
2. Educational governance policies meet ISO 21001 requirements.	0.918	0.88	0.71
3. Technology ethical audits for bias and privacy hazards occur annually.	0.922	0.89	0.72
4. Departments share digital platforms like Microsoft Teams.	0.926	0.90	0.73
5. Leadership adapts to technology using agile methods.	0.930	0.91	0.74
3. Student LMS use (SLMS)	0.915	0.87	0.70
1. Quiz outcomes affect content.	0.907	0.85	0.68
2. Videos, simulations, and interactive texts offer content.	0.911	0.86	0.69
3. Badges and leaderboards encourage involvement.	0.915	0.87	0.70
4. I get dashboard updates and fast notifications after submissions.	0.919	0.88	0.71
5. Critical thinking seminars and team projects are taught.	0.923	0.89	0.72
4. Lecturer LMS use (LLMS)	0.912	0.93	0.74
1. AI-generated course templates meet various student needs.	0.904	0.91	0.72
2. Lecturers use online and print resources.	0.908	0.92	0.73
3. The system provides weekly student engagement data.	0.912	0.93	0.74
4. Open-source algorithms and other tools abide by transparency requirements.	0.916	0.94	0.75
5. Lecturers share strategies via Slack channels.	0.920	0.95	0.76
5. Smart education development	0.930	0.9	0.69
1. VR simulations solve real-world problems in classrooms	0.922	0.88	0.67
2. Teachers and AI create student-specific learning programs.	0.926	0.89	0.68
3. All students can take free MOOCs like Coursera.	0.930	0.90	0.69
4. Digital literacy and AI ethics are taught.	0.934	0.91	0.70
5. Rural students receive subsidized devices and internet.	0.938	0.92	0.71
Total	0.954	0.95	0.71

4.2. Confirmatory Factor Analysis (CFA)

A CFA was conducted to validate the measurement model for five latent constructs: Academic Management Innovation, Administrative Management Innovation, Student LMS Usage (SLMS), Instructor LMS Usage (LLMS), and Smart Education Development. Multiple indicators were employed for each construct, and model fit and convergent validity were assessed. All factor loadings were substantial and significant (standardized loadings exceeding 0.70), indicating that the observed indicators accurately reflect their underlying latent constructs. Composite Reliability (CR) values for each construct ranged from 0.87 to 0.93, and Average Variance Extracted

(AVE) values all exceeded 0.65, surpassing standard acceptable thresholds. These results indicate that the measurement model demonstrates strong convergent validity and reliability.

The overall model fit of the CFA was excellent. The chi-square to degrees of freedom ratio (CMIN/DF) was 2.10, well below the recommended threshold of 3.0. Other fit indices met or exceeded recommended standards, including the Incremental Fit Index (IFI) of 0.955, the Comparative Fit Index (CFI) of 0.954, the Tucker-Lewis Index (TLI) of 0.950, and the Normed Fit Index (NFI) of 0.910. The Root Mean Square Error of Approximation (RMSEA) was 0.042, below the 0.05 threshold, indicating good correspondence between the model and data. Table 3 demonstrates that the measurement model accurately represents the data and supports subsequent structural analysis.

Table 3. Model fitting for validation factor analysis.

Fit Index	Value	Recommended Value
CMIN/DF	2.1	< 3.00
NFI	0.91	> 0.90
TLI	0.95	> 0.90
CFI	0.954	> 0.90
IFI	0.955	> 0.90
RMSEA	0.042	< 0.05

Table 3 presents the goodness-of-fit statistics for the validated factor model. All indices (NFI, TLI, CFI, IFI, RMSEA) are within acceptable ranges, indicating that constructs are accurately measured and the model is good.

4.3. Structural Equation Modeling (SEM)

Structural equation modeling was then used to investigate the hypothesized causal links between constructs. The theoretical model proposed that innovative management techniques (academic and administrative) affect LMS usage behaviors (by students and lecturers), hence driving smart education progress. The SEM study employed Maximum Likelihood estimation in AMOS to analyze both direct effects and mediating pathways based on the hypotheses.

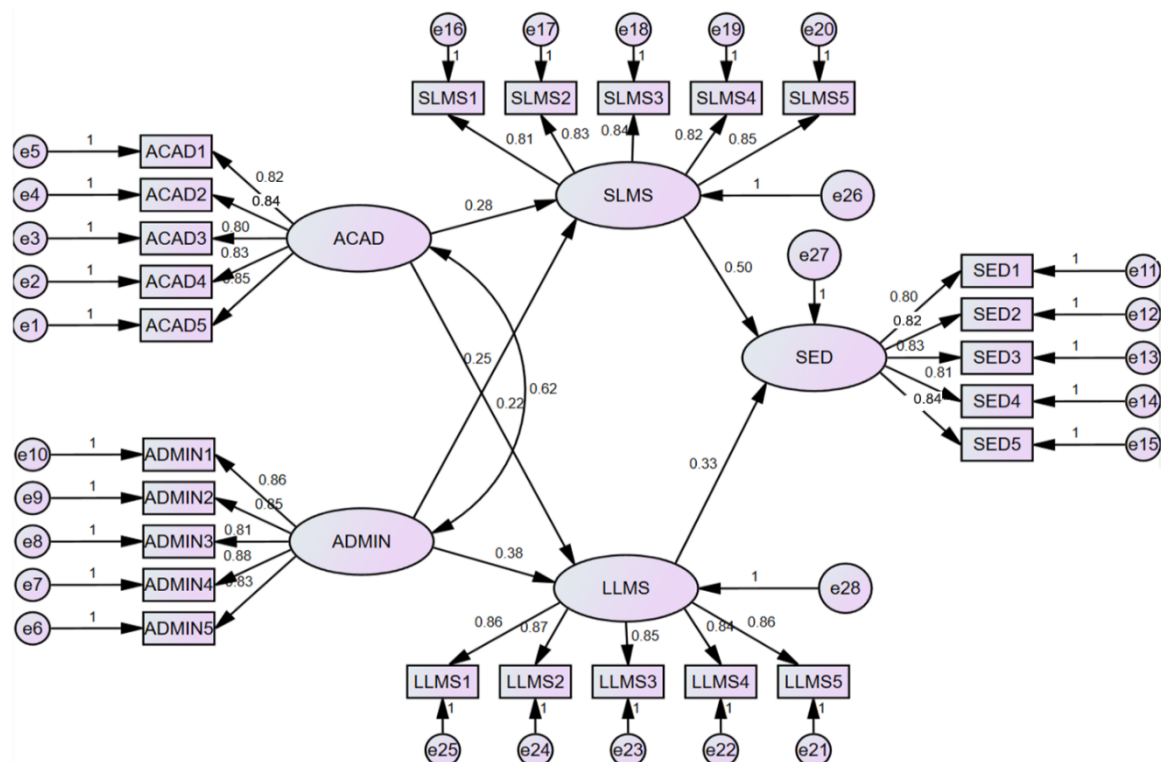


Figure 1. Validation analysis model.

The structural model's fit matched the CFA results, indicating a satisfactory overall fit. The model fit indices for the structural model were the same as those given for the CFA (since the measurement model was incorporated into the structural model), and no additional modification indices were required. After determining a reasonable model fit, we moved on to hypothesis testing for the structural routes. Figure 1 illustrates the structural equation model used to investigate academic management (ACAD), administrative management (ADMIN), student LMS usage (SLMS), lecturer LMS usage (LLMS), and smart education development. SEM analysis, measurement indicators, and standardized path coefficients are shown.

4.4. SEM Results

The SEM results supported all of the provided hypotheses for direct correlations (H1-H6). Table 4 presents the standardized path coefficients, standard errors, critical ratios (C.R.), and significance levels for each predicted path. All standardized coefficients were positive and statistically significant ($p < 0.01$ for all, with the majority at $p < 0.001$), showing that the effects were as expected.

Notably, Innovation Academic Management improved both student and lecturer LMS utilization. Academic innovation management had a significant impact on both students' and lecturers' use of LMS (H1: $\beta = 0.28$, $p = 0.003$; H2: $\beta = 0.22$, $p < 0.001$). This shows that academic-focused innovation (e.g., curriculum design, pedagogical assistance) motivates both students and professors to become more actively involved with the LMS. Similarly, Innovation Administration Management had a strong positive impact on the SLMS and LLMS indicators. Administrative innovation, such as IT infrastructure and policy support, was linked to increased LMS usage among students (H3: $\beta = 0.25$, $p < 0.001$) and lecturers (H4: $\beta = 0.38$, $p < 0.001$). The strong correlation ($\beta = 0.38$) between administrative management and lecturer LMS use highlights the need for strong institutional support and resources to help faculty use teaching management systems.

In turn, more use of the LMS was connected to better smart education outcomes. Active student engagement with LMS technologies significantly improves learning outcomes and data-driven educational practices (H5: $\beta = 0.50$, $p < 0.001$). Lecturer LMS usage (LLMS) had a positive and substantial impact on smart education development (H6: $\beta = 0.33$, $p = 0.002$), while the effect size was slightly smaller than that of student usage. This suggests that, while both student and lecturer interactions with the LMS are important, student-centered LMS engagement may have a greater direct impact on promoting smart education initiatives. All direct hypotheses reached significance and were thus accepted, as indicated in Table 4.

Table 4. Hypothesis result for structural equation modelling.

Hypothesis	Path	Estimate	S.E.	C.R.	P-value	Result
H1	ACAD Mgt $\rightarrow$ SLMS	0.28	0.095	2.947	0.003 **	Accepted
H2	ACAD Mgt $\rightarrow$ LLMS	0.22	0.044	5.000	<0.001 ***	Accepted
H3	ADMIN Mgt $\rightarrow$ SLMS	0.25	0.042	5.952	<0.001 ***	Accepted
H4	ADMIN Mgt $\rightarrow$ LLMS	0.38	0.048	7.917	<0.001 ***	Accepted
H5	SLMS $\rightarrow$ Smart Ed Dev	0.50	0.056	8.929	<0.001 ***	Accepted
H6	LLMS $\rightarrow$ Smart Ed Dev	0.33	0.103	3.204	0.002 **	Accepted

Note: ACAD Mgt = Innovation academic management; Admin Mgt = Innovation administrative management; SLMS = Students' LMS usage; LLMS = Lecturers' LMS usage; Smart Ed Dev = Smart education development. (** $p < 0.01$; *** $p < 0.001$).

Table 4 shows Structural Equation Modelling results. All hypothesized routes (H1-H6) were statistically significant, supporting the model. Innovation in academic administration significantly affected LMS utilization by students ($\beta = 0.28$, $p < 0.01$) and lecturers ($\beta = 0.22$, $p < 0.001$). Research indicates that innovative administrative management positively impacts student and lecturer LMS utilization ($\beta = 0.25$, $p < 0.001$; $\beta = 0.38$, $p < 0.001$).

Students' LMS usage positively impacts smart education development ($\beta = 0.50$, $p < 0.001$), while lecturers' LMS usage also contributes significantly ($\beta = 0.33$, $p < 0.01$). The results show that LMS usage patterns are crucial to turning innovation-driven management practices into smart education outcomes.

4.5. Mediating Effects

To investigate the mediating roles of student and instructor LMS usage (SLMS and LLMS) between innovation management and smart education outcomes, we conducted a bootstrapping mediation analysis with 5,000 resamples using the SPSS PROCESS macro. The analysis examined whether SLMS and LLMS effectively transmit the effects of academic and administrative management innovation to Smart Education Development (hypotheses H7-H10).

The mediation results indicated that both student and instructor LMS usage serve as significant mediators in the model. Table 5 presents the bootstrapped path coefficients for indirect effect models, including total, direct, and indirect effects for each hypothesized pathway. The confidence intervals are 95% bias-corrected (BootLLCI and BootULCI). All total effects of innovation management on smart education development were significant, and all corresponding indirect effects via SLMS and LLMS were positive and significant (with confidence intervals that did not include zero).

Furthermore, although the direct effects of innovation management on smart education development were smaller in magnitude, they remained significant after controlling for the mediators. This indicates a partial mediation model in which innovation management enhances smart education outcomes both directly and indirectly through increased LMS adoption.

Academic Management Innovation had a significant total effect on Smart Education Development ($\beta = 0.480$, $p < 0.001$). The direct effect ($\beta = 0.150$), indirect effect via SLMS ($\beta = 0.180$), and indirect effect via LLMS ($\beta = 0.150$) were all significant.

The bootstrapped 95% confidence intervals for each indirect pathway did not include zero (e.g., indirect via SLMS: LLCI 0.124, ULCI 0.256), supporting H7 and H9. This indicates that academic management innovation enhances smart education outcomes partly by increasing student engagement with LMS (H7) and supporting instructor use of LMS (H9).

Similarly, Administrative Management Innovation had a significant total effect on Smart Education Development ($\beta = 0.450$, $p < 0.001$). The indirect effect through student LMS usage was $\beta = 0.200$ (BootLLCI 0.143, BootULCI 0.269), and through instructor LMS usage was $\beta = 0.130$ (BootLLCI 0.088, BootULCI 0.185), both statistically significant, supporting H8 and H10. Administrative management innovation continued to exert a significant direct effect on outcomes ($\beta = 0.120$). These findings suggest that administrative innovation, such as investing in IT infrastructure, providing training, and implementing supportive policies, enhances smart education primarily by increasing LMS engagement among both students and faculty, while also maintaining a modest direct effect on educational development.

The mediation study offers compelling evidence that LMS usage by students and instructors represents a significant pathway linking innovation management approaches to successful smart education development. All hypotheses H7–H10 are supported, as the mediated pathways are significant.

The presence of significant direct and indirect effects indicates that while innovation management has some direct impact on smart education (for example, through other channels such as organizational culture or policy environment), a substantial portion of its influence is channeled through student and instructor adoption and use of LMS.

Table 5. Mediating effect results.

H	Effect	Path	Effect value	Boot SE	Boot LLCI	Boot ULCI	Result
H7, H9	Total effect	AMgt → Smart Ed Dev	0.480	0.050	0.381	0.579	Accepted
	Direct effect	AMgt → Smart Ed Dev	0.150	0.040	0.074	0.234	
	Indirect effect (via SLMS)	AMgt → Smart Ed Dev	0.180	0.030	0.124	0.256	
	Indirect effect (via LLMS)	AMgt → Smart Ed Dev	0.150	0.020	0.104	0.206	
H8, H10	Total effect	AdMgt → Smart Ed Dev	0.450	0.045	0.362	0.538	Accepted
	Direct effect	AdMgt → Smart Ed Dev	0.120	0.035	0.056	0.184	
	Indirect effect (via SLMS)	AdMgt → Smart Ed Dev	0.200	0.028	0.143	0.269	
	Indirect effect (via LLMS)	AdMgt → Smart Ed Dev	0.130	0.018	0.088	0.185	

Note: BootLLCI = Bootstrapped lower limit of 95% confidence interval; BootULCI = Upper limit. All indirect effects are significant as the confidence intervals do not include zero.

These findings support a dual-pathway mediation model: Academic Management Innovation and Administrative Management Innovation both contribute to Smart Education Development through two pathways, student LMS usage and instructor LMS usage. The academic management pathway (via SLMS) appears slightly more effective in terms of academic outcomes, while the administrative pathway (via SLMS and LLMS) underscores the importance of institutional support in technology adoption. In conclusion, the quantitative findings provide strong evidence that effective innovation management in both academic and administrative domains promotes increased use of learning management systems by students and faculty, thereby advancing smart education development in Guangxi universities.

4.6. Qualitative Interview Results

To contextualize and support the quantitative findings, 15 key stakeholders (university administrators, IT directors, and senior faculty) were interviewed using a semi-structured format. The interview responses were coded and analyzed to identify recurring themes regarding LMS adoption and smart education implementation in Guangxi. The qualitative findings were largely consistent with the survey results, highlighting both enabling and constraining factors in innovation management for smart education.

Supportive Factors: A prominent theme was the importance of leadership and policy support in promoting LMS usage. Several interviewees indicated that strong commitment from university leadership (e.g., clear strategic vision for digital learning, budget allocation for LMS improvements) created an environment in which faculty felt encouraged to adopt the LMS. One senior administrator stated, "Our university's president championed the smart campus initiative, which made it easier to get faculty buy-in for using the LMS in teaching." Professional development and training were also identified as critical. Both IT staff and faculty noted that workshops on innovative pedagogical strategies (blended learning, data analytics via LMS) increased instructors' confidence and competence, leading to greater LMS usage. Younger faculty members were frequently cited as early adopters who influenced colleagues; their enthusiasm for new technologies fostered positive peer effects. Additionally, interviewees identified infrastructure improvements (such as campus Wi-Fi expansion and new computer laboratories) as administrative management innovations that directly enhanced LMS accessibility for both students and staff.

Obstacles: Despite these positive factors, the interviews revealed persistent challenges that support the quantitative results' indication of partial mediation (suggesting room for improvement beyond LMS usage). Resistance to change among some older faculty was a common concern. Interviewees found that several experienced instructors were reluctant to fully adopt the LMS, preferring traditional teaching methods. As one instructor candidly

stated, "I've been teaching for 25 years without an LMS; it's hard to suddenly change my routine unless I see clear benefits." This underscores the need for more tailored academic management strategies to engage veteran faculty. Another challenge was uneven digital literacy among users; while students are generally tech-savvy, not all instructors (or even some students in less urbanized areas) felt comfortable using advanced LMS features. This was compounded by technical limitations; participants from smaller institutions reported that frequent system outages and insufficient technical support staff made it difficult to rely on the LMS, indicating gaps in administrative management. Resource constraints were also mentioned: at some institutions, limited funding resulted in outdated technology and few incentives for innovation, hindering the full utilization of smart education tools.

Cultural and Regional Context: A nuanced theme addressed Guangxi's regional context. Some respondents noted that bilingual or multilingual environments (e.g., Mandarin and Zhuang) require flexible LMS content and that local content development is slow. Furthermore, government initiatives such as the "Digital Guangxi" strategy were identified as external drivers pushing institutions toward smart education, yet bureaucracy and unclear guidelines sometimes impede local innovation efforts.

Overall, the interview findings provide qualitative validation and depth to the SEM results. They demonstrate that innovation management for LMS advancement is most effective when leadership support, training, and infrastructure improvements converge, leading to increased LMS engagement. Simultaneously, the identified obstacles, human resistance, capacity gaps, and resource limitations, help explain why the direct effects of innovation management on outcomes, while significant, are not universal. These findings indicate that, beyond promoting LMS usage, cultural and logistical barriers must be addressed to fully realize smart education development. The integration of quantitative and qualitative results creates a comprehensive picture: Guangxi's smart education progress is driven by innovative management practices and active LMS use, but sustained success will require ongoing support, capacity building, and adaptation to local contexts.

5. DISCUSSION

This study investigates the mechanism of interaction between creative management and LMS usage behavior in the development of smart education in Guangxi's colleges and universities.

1. Both innovative academic management and innovative administrative management have a strong, favorable impact on LMS usage by students and teachers.

The research findings reveal that both innovative academic management and innovative administrative management have a strong, favorable impact on LMS usage by students and teachers, supporting H1 to H4. innovative academic and administrative management internalize platform use into everyday practice through twin logics of restructuring work and securing enabling conditions: on the academic side, aligning curriculum, pedagogy, and system design with the LMS makes core teaching-learning activities executable, traceable, and improvable on the platform; on the administrative side, technical services and policy supports, stable infrastructure, service guarantees, and normative requirements, reduce uncertainty and provide sustained backing. The two streams are complementary: one places instructional tasks inside the platform, the other ensures the platform is usable and governable, thereby turning managerial intent into stable usage habits for both students and teachers. Interview evidence likewise highlights leadership support, faculty development, and infrastructure construction as repeatedly cited contextual drivers of adoption.

2. Both students' and teachers' LMS usage behaviors promote the development of smart education.

Meanwhile, the H5 and H6 tests show that both students' and teachers' LMS usage behaviors promote the development of smart education, implying that LMS has become an important medium for the digitalization of teaching, management refinement, and service intelligence. Once sustained LMS behavior becomes the norm, the platform shifts from a "tool" to the operating backbone of smart education: teaching and learning processes are digitized and proceduralized, enabling personalization and evidence-based improvement; academic and administrative

services are platformed and coordinated, driving managerial refinement and service intelligence; and data and practice iterate within a single system, advancing course-level and institutional performance in tandem. In short, the normalization of usage behavior converts smart education from concept and policy into workable instructional and managerial practice.

3. LMS plays a partial mediating function between innovative management and the development of smart education.

Further mediating impact analysis results confirmed that H7 to H10 usage behaviors, specifically LMS, play a partial mediating function between innovative management and the development of smart education. This suggests that the effectiveness of innovative management is not only dependent on managerial excellence, but also on the process of behavioral transformation in teaching practice. The interview data confirm the above-mentioned path mechanism in a practical sense. Management systems, technological support, and the cultural environment are commonly regarded as critical driving forces in the promotion of smart education.

Finally, this study's innovative management, LMS utilization, and smart education development logical chain have been proven. The findings show that LMS usage behaviors bridge innovation-driven academic and administrative management into smart education outcomes. This integrated mechanism demonstrates that smart education development is driven by management system innovation and user behavior, not only technology. Therefore, this study provides theoretical support and empirical evidence for the continual optimization of smart education in higher education institutions, particularly in Chinese universities' digital transition.

6. CONCLUSION

This study investigates the impact of innovative management on the use of Learning Management Systems (LMS) in the development of smart education in Guangxi colleges and universities, and it reveals the critical role of academic and administrative innovative management in promoting LMS usage behavior among students and teachers. This study's strength lies in its systematic proposal of a dual-path intermediary mechanism of innovative management in smart education, as well as its clarification of the key elements that universities must consider when promoting smart education, such as leadership support, teacher training, infrastructure upgrades, and policy coordination.

6.1. Theoretical Contribution

This study proves that innovation-driven academic and administrative administration drives smart education development in higher education, not technology. Empirically validating students' and lecturers' learning management system usage confirms a coherent management-behavior-outcome mechanism that links innovative management techniques to smart education outcomes. This dual-path approach explains how user behavior turns management system innovation into educational value, advancing innovation management and smart education literature.

6.2. Practical and Policy Implications

Universities should improve digital literacy training for senior faculty through focused professional development, peer mentoring, and instructional design support. Academic leaders should advocate deeper LMS integration for tailored and efficient learning.

University administrators should modernize digital infrastructure, maintain system stability, and offer incentives like research funding and career progression to encourage LMS usage. Decentralized decision-making can boost departmental technology flexibility.

Government agencies should reinforce digital education policies, clarify data security and privacy legislation, and invest more. Smart education projects should be sustained by public-private partnerships.

6.3. Limitations

This study contains flaws. First, the empirical data were obtained from Guangxi Province higher education institutions, which may limit their applicability. Second, the study used self-reported questionnaire data, which may bias responses. Third, cross-sectional research cannot capture dynamic innovation management and smart education development changes over time.

6.4. Future Research Directions

Future research may compare economic development, technology infrastructure, and regulatory contexts across provinces or nations to see how these affect smart education outcomes. To understand how universities' dynamic capabilities change with technology, longitudinal studies are recommended.

The model could be improved by studying moderating variables such as government incentives, industry–university partnership, school autonomy, and organizational culture. Future studies should also address digital equity and university-type disparities to enable inclusive smart education policy.

6.5. Contribution to Sustainable Development

By promoting equitable access to digital education, improving teaching quality, and supporting sustainable educational development in higher education institutions, this study supports the UN Sustainable Development Goals, particularly Quality Education (SDG 4) and Industry, Innovation, and Infrastructure (SDG 9).

Innovation-driven academic and administrative administration drives smart education development in higher education, according to this study. Empirically validating students' and lecturers' learning management system usage confirms a coherent management–behavior–outcome process that transforms innovative management approaches into smart education outcomes. The findings highlight the need to combine instructional innovation with administrative assistance to improve LMS participation and sustain university digital transformation. This study provides theoretical and practical evidence to optimize smart education development in higher education institutions.

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