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An Investigation into the Factors Influencing University Students' Learning Outcomes in the Context of Digital Transformation

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Abstract. Digital transformation in higher education profoundly influences students' learning outcomes through multiple mechanisms. Based on a moderated structural equation model, this study utilises survey data from 508 university students across various regions in 2026 to verify the mechanisms through which digital transformation affects students' learning outcomes. The findings reveal that by introducing high-quality technology and digital resources, universities have significantly broken down the temporal and spatial constraints of learning and provided reliable and timely cognitive feedback; however, the direct impact pathways of technological resources, teaching staff's digital teaching capabilities, and standardised institutional digital processes on stimulating student motivation and promoting the effective use of digital tools are all insignificant. Consequently, whilst the current digital transformation in higher education institutions has achieved significant results in providing technical support and procedural convenience, it is difficult to directly influence the perceived final learning outcomes unless technology, teaching staff and institutional frameworks are effectively integrated and transformed into incentives for student motivation and in-depth usage behaviour.

Keywords: higher education, university digitalization, learning outcomes, structural equation modelling

1. Introduction

In the context of global digital transformation, the digitalisation of higher education has become a key component of China's modernisation strategy. Recent data indicate that investment in university digitalisation continues to grow rapidly, with digital platforms, online resources, and smart campus infrastructure widely implemented.

Despite this expansion, the relationship between digital investment and students' learning outcomes remains unclear. On the one hand, digital technologies have improved access to learning resources and broken temporal and spatial constraints. On the other hand, issues such as underutilisation of resources and the misalignment between technological input and educational outcomes persist, raising concerns about the effectiveness of digital transformation.

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Therefore, this study aims to examine how digital transformation in higher education influences students' learning outcomes. By analysing the mechanisms linking digital resources, institutional processes, and learning behaviours, this research seeks to provide empirical evidence for optimising digital resource allocation and promoting a more student-centred digital education system.

2. Literature review

As digitalisation advances, the digital transformation of higher education institutions has become a prevailing trend, with its importance increasingly prominent. Existing research explores the impact of digitalisation on students' learning outcomes from multiple perspectives, including policy guidance, infrastructure, data utilisation, and specific technologies. Lei Chaozhi [1] emphasises that only by integrating information technology into educational and teaching activities can high-calibre talent with innovative capabilities be cultivated. Chen Yingying et al. [2] highlight that the use of digital teaching materials by teachers can significantly enhance student engagement and learning outcomes. Ren Hang et al. [3] argue that data-driven approaches are a key focus in higher education digital transformation. Liu Hejian [4] notes that enhancing contextual, triggering, and enabling factors positively influences digitalisation in research management. Liu Yong et al. [5] find that virtual technology has the greatest impact on vocational learning outcomes, with moderate effects at undergraduate and postgraduate levels.

Digital transformation in higher education is shaped by technological infrastructure, institutional frameworks, and user adaptability, creating complex implications for student outcomes. Luo Lin et al. [6] emphasise that over-reliance on digital devices may impair learning outcomes, while outdated or limited resources reduce user experience. Fan Yanghe et al. [7] note that management system issues lead to 'high input but low efficiency' in ideological and political courses, focusing more on documentation than education. Dan Jinfeng et al. [8] further point out that despite abundant data, its accuracy, reliability, and relevance are often questionable, and teachers face obstacles in accessing effective student development information.

3. Analysis of mechanism pathways

3.1. Analysis of the path mechanisms through which the degree of digital transformation in higher education institutions influences learning outcomes

The degree of digitalisation in higher education institutions may influence learning outcomes through three mechanisms: firstly, the adoption of technology and digital resources to meet students' learning needs; secondly, the competence and professional development of teaching staff, who utilise digital resources to enhance students' learning outcomes; and thirdly, standardised digital processes within the institution, which ensure the proper use of digital resources to improve learning outcomes. The combination of these three aspects forms a transmission chain of 'digital factors – digital learning behaviours and psychology – learning outcomes'. Based on this, the following hypothesis is proposed:

H1: The introduction of high-quality technology and digital resources directly influences students' learning outcomes

H2: Teachers' digital competencies directly influence students' learning outcomes

H3: The standardisation of digital processes within higher education institutions directly influences students' learning outcomes

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3.2. Interaction mechanism of mediating variables

There are four factors through which higher education institutions' digital achievements influence learning behaviour and psychology, and learning outcomes are consequently affected. Firstly, the characteristic of overcoming temporal and spatial constraints enables high-quality technology and digital resources to exert their influence, thereby affecting learning outcomes. Secondly, students' learning motivation is stimulated; digital resources and teachers' application of these resources mobilise students' enthusiasm for learning, thereby influencing learning outcomes.Thirdly, the effective utilisation of resources: the appropriate use of digital resources by teachers, alongside the introduction of technical resources by the institution and the establishment of standardised digital processes, influences the effectiveness of resource utilisation, which in turn affects learning outcomes. Fourthly, reliable and timely cognitive feedback: standardised digital processes influence students' learning outcomes through feedback. Based on this, the following hypothesis is proposed:

H4: The introduction of high-quality technology and digital resources enhances learning outcomes by overcoming spatial and temporal constraints

H5 The introduction of high-quality technology and digital resources influences learning outcomes by stimulating students' motivation to learn

H6 Teachers' digital competence influences learning outcomes by stimulating student motivation

H7 Standardised digital processes within schools constitute effective feedback, thereby influencing learning outcomes

The mechanism through which the degree of digital transformation in higher education institutions influences learning outcomes is illustrated in Figure 1:

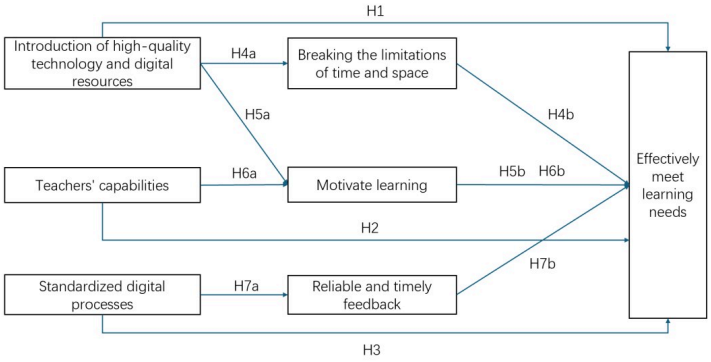

Figure 1. Conceptual diagram

4. Research design

4.1. Data sources

This study conducted an online questionnaire survey targeting university students from institutions across the country. After manually matching the 715 returned samples and excluding invalid questionnaires—such as those with unidentifiable respondents or excessive consistency in responses—a final valid sample of 508 respondents was obtained. The composition and distribution of the sample are shown in Table 1. Among these, there were 254 male respondents and 254 female respondents (50% each).In terms of disciplinary distribution, there were 17 students (3.35%) in Philosophy, 38 (7.48%) in Economics, 39 (7.68%) in Law, 36 (7.09%) in Education, 62 (12.20%) in Literature, 25 (4.92%) in History, Natural Sciences: 46 (9.06%), Engineering: 78 (15.35%),

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Agricultural Sciences: 25 (4.92%), Medicine: 47 (9.25%), Management: 62 (12.20%), and Arts: 33 (6.50%).

4.2. Variable measurement

To ensure reliability and validity, the variable setup in this study drew upon relevant domestic literature and was supplemented and modified in accordance with the research objectives. Specifically, the measurement of 'university digitalisation level' referenced the 'maturity model' proposed by Yuan Zijuan [9], whilst the measurement of 'effective usage' drew upon the scale developed by Zhang Tingting [10]; for the measurement of 'faculty competence', we drew upon the views of Luo Lin et al. [6] Regarding perspectives on the opportunities and challenges of digitalisation in ideological and political education courses, the study drew upon Luo Lin et al. [6], when assessing factors influencing learning behaviour and psychology through digitalisation. It also drew upon Chen Yingying et al.

Regarding the impact of motivation to use digital teaching materials on learning engagement, as well as Hang and others regarding the role of data innovation in knowledge dissemination. Prior to the formal distribution of the questionnaire, this study conducted a small-scale pilot survey using university students from a university in southern China as the sample, with the aim of testing the validity of the questionnaire and making adjustments to it. In the scale section of the questionnaire, all variables employed a five-point Likert scale (where '1' indicates 'strongly disagree' or 'very dissatisfied', and '5' indicates 'strongly agree' or 'very satisfied'), including reverse-scored items.

Table 1. Sample distribution

Name	Type	Num	Present(%)
Gender	Male	254	50
	Female	254	50
Distribution by subject	Philosophy	17	3.35
	Economics	38	7.48
	Law	39	7.68
	Education	36	7.09
	Literature	62	12.2
	History	25	4.92
	Science	46	9.06
	Engineering	78	15.35
	Agricultural Sciences	25	4.92
	Medicine	47	9.25
	Management	62	12.2
	Arts	33	6.5

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Table 1. (continued)

Level of education	Currently studying for a diploma	114	22.44
	Currently studying for a bachelor's degree	268	52.76
	Master's student	76	14.96
	PhD student	49	9.65
	Other	1	0.2
City where the university is located	Tier 1 cities	143	28.15
	New Tier 1/strong Tier 2 cities and provincial capitals	168	33.07
	Other prefecture-level cities	193	37.99
	Hong Kong, Macau and Taiwan	3	0.59
	Other	1	0.2
Type of higher education institution	Universities participating in the 'Double First-Class' initiative	141	27.76
	Central government-affiliated undergraduate universities	81	15.94
	Provincial undergraduate universities	186	36.61
	Higher vocational (college) institutions	96	18.9
	Other	4	0.79
Total		508	100

The reliability and validity of the items measuring the main variables are shown in Table 2. Reliability was assessed using Cronbach's α, which measures the internal consistency of the sample. The sample's Cronbach's α was 0.888, which is greater than 0.6, and the change in the α coefficient following the removal of items was not significant, indicating that the scale data possess high reliability. This study utilised the KMO value and factor loadings to assess validity. The KMO value was 0.895; a KMO value above 0.8 indicates that the research data is highly suitable for factor extraction, whilst factor loadings are used to assess the correspondence between factors and items. As shown in Table 2, regarding factor commonality, two items—teaching competence and stimulating learning motivation—exhibit factor commonality values below 0.4, suggesting that the information conveyed by these items cannot be effectively expressed.

Table 2. Scale design and reliability and validity testing

Core Concepts	Operationalised Variables	Reliability (Cronbach's α with items removed)	Validity (Factor Loadings)	Variable Categories
Adoption of Technology and Digital Resources	Hardware and software facilities (5 items)	0.845	0.961 0.055	Explanatory variables
Teaching staff competence	Teaching quality (5 items)	0.904	0.316 0.014	Explanatory variable

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Table 2. (continued)

Standardisation of digital processes	Process Development (5 items)	0.846	0.966	0.042	Explanatory variables
Breaking the constraints of time and space	Device usage (4 items)	0.843	0.97	0.061	Mediating variables
Motivation to learn	Learning experience (5 items)	0.900	0.329	0.354	Mediating variables
Effective use	Resource effectiveness (5 items)	0.922	0.097	0.952	Mediating variables
Reliable and timely cognitive feedback	Feedback summary (4 items)	0.846	0.934	0.214	Mediating variables
Effectively meets learning needs	Experience outcomes (4 items)	0.844	0.965	.081	Outcome variable

5. Empirical analysis

5.1. Structural equation model

Prior to the structural equation modelling, correlation analysis was conducted to examine the relationships among variables. The results indicated that the main variables were significantly correlated in expected directions, supporting the suitability of subsequent SEM analysis.

The structural equation model was constructed and fitted using SPSSAU; the model fit indices are shown in Table 3. It can be seen that all fit indices are favourable, and the overall fit is satisfactory.

Table 3. Results of overall model fit tests

Common Measures	χ^2/df	RMSEA	RMR	CFI	NFI
Criteria	<3	<0.10	<0.05	>0.9	>0.9
Value	1.083	0.013	0.028	0.999	0.982

5.1.1. Direct effects

Table 4. Summary of model regression coefficients

X	→	Y	Unstandardised regression coefficients	SE	z (CR value)	p	Standardised regression coefficient
Introduction of high-quality technology and digital resources	→	Effectively meets learning needs	0.593	0.012	51.438	0	0.53
Teaching staff capabilities	→	Effectively meets learning needs	0.054	0.056	0.964	0.335	0.024
Standardised digitisation process	→	Effectively meets learning needs	0.477	0.012	39.643	0	0.425

The results of the direct effects analysis are shown in Table 4. The Pvalues for the pathways from the introduction of standardised high-quality technical and digital resources and digital processes to the effective fulfilment of learning needs are less than 0.05, indicating a significant effect; therefore,

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hypotheses H1 and H3 are supported. However, the p-value for the path from teaching staff competence to the effective fulfilment of learning needs was greater than 0.05, indicating that the effect was not significant. Consequently, there is no significant relationship between teaching staff competence and learning outcomes, and Hypothesis H2 was not supported.

5.1.2. Mediating effects

Table 5. Summary of model regression coefficients

X	→	Y	Unstandardised regression coefficients	SE	z (CR value)	p	Standardised regression coefficient
Introduction of high-quality technology and digital resources	→	Breaking the limitations of time and space	0.104	0.011	9.557	0	0.103
Teacher competence	→	Breaking the limitations of time and space	-0.029	0.054	-0.536	0.592	-0.013
Standardised digital processes	→	Breaking the limitations of time and space	0.923	0.01	94.261	0	0.898
Breaking the limitations of time and space	→	Effectively meet learning needs	0.952	0.019	50.079	0	0.975

The results of the mediation analysis are presented in Table 5. The introduction of high-quality technology and digital resources has a significant effect on the role of overcoming spatial and temporal constraints, and the role of overcoming spatial and temporal constraints has a significant effect on learning outcomes; the Pvalues for both are well below 0.05. Hypothesis H4 is thus confirmed.

Table 6. Summary of model regression coefficients

X	→	Y	Unstandardised regression coefficients	SE	z (CR value)	p	Standardised regression coefficient
Introduction of high-quality technology and digital resources	→	Motivate learning	-0.524	0.133	-3.931	0	-12.465
Teacher competence	→	Motivate learning	-8.318	0.007	-1258.37	0	-8.718
Standardised digital processes	→	Motivate learning	0.17	0.135	1.263	0.207	4.38
Motivate learning	→	Effectively meet learning needs	25.643	0.001	40037.1	0	0.979

The results of the mediation analysis are presented in Table 6. The introduction of high-quality technology and digital resources has a significant effect on stimulating learning motivation; teaching staff competence has a significant effect on stimulating learning motivation; and stimulating students' learning motivation has a significant effect on meeting students' learning needs. The P-values for all three are well below 0.05. Hypotheses H5 and H6 are thus confirmed.

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Table 7. Summary of model regression coefficients

X	→	Y	Unstandardised regression coefficients	SE	z (CR value)	p	Standardised regression coefficient
Introduction of high-quality technology and digital resources	→	Reliable and timely feedback	-1.676	0.018	-92.237	0	-1.572
Teacher competence	→	Reliable and timely feedback	-0.134	0.14	-0.952	0.341	-0.054
Standardised digital processes	→	Reliable and timely feedback	2.512	0.016	155.487	0	2.562
Reliable and timely feedback	→	Effectively meet learning needs	0.985	0.019	50.786	0	0.982

The results of the mediation analysis are presented in Table 7. A standardised digitalisation process has a significant impact on reliable and timely cognitive feedback (p-value far less than 0.05), and reliable and timely cognitive feedback also has a significant impact on meeting students' learning needs (p-values also far less than 0.05). Hypothesis H7 is thus confirmed.

6. Research conclusions and recommendations

6.1. Research conclusions

This study finds that digital transformation in higher education influences students' learning outcomes primarily through technological resources and institutional processes. High-quality digital resources and standardised digital processes significantly improve learning outcomes, while the direct effect of teachers' digital competence is not significant.

The results further reveal that digital transformation operates through key mediating mechanisms, including the removal of temporal and spatial constraints, the stimulation of learning motivation, and the provision of timely feedback. Among these, flexibility in learning and personalised feedback play particularly important roles in enhancing learning effectiveness.

Overall, the findings suggest that simply increasing technological investment is insufficient. Effective integration of technology, institutional processes, and student engagement is essential to fully realise the benefits of digital transformation.

6.2. Targeted recommendations

For higher education institutions, digital transformation involves two key aspects. Firstly, there must be a focus on introducing technology and digital resources, particularly high-quality ones. Allowing students to utilise digital resources independently, provided they are clear and effective, can better meet their learning needs. Secondly, standardised digital processes must be established. Once these are in place, digital resources can be effectively integrated, and users can receive timely feedback, which will help students improve their learning outcomes promptly and effectively.

Concurrently, in the short term, universities should focus on optimising the user experience of existing platforms and simplifying operational procedures to maximise the utilisation of existing resources. In the medium term, they should establish a training system to develop teachers' digital teaching capabilities. In the long term, they should build a data-driven, personalised learning support system to provide both teachers and students with more tailored service resources.

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For university lecturers, the key priority amidst the digital transformation of higher education is to integrate more digital resources into the classroom to enhance its appeal, thereby stimulating students' motivation to learn and improving their learning outcomes. As for university students, they should proactively embrace and cultivate their own digital learning skills, and make active use of digital resources.

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