Research Article

Digital leadership and behavioral adaptation in higher education: Examining teachers' digital competency and teaching performance

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ABSTRACT

Universities are confronted with significant potential and problems as a result of the rapid digital change brought about by the arrival of the Industry 4.0 era. In this regard, university administrators' and educators' roles and competences are changing to become more innovative and prepared for the digital age. This study looks at how administrators' digital leadership affects teachers' performance in the classroom and how teachers' digital competency functions as a mediator in Inner Mongolian Chinese colleges. Through the improvement of teachers' digital competency, administrators' digital leadership significantly improves teachers' teaching performance, both directly and indirectly, according to data gathered from 386 university instructors and analysed using Structural Equation Modelling (SEM) with AMOS. The results highlight how enhancing teachers' digital competency through focused and ongoing professional development can boost the benefits of digital leadership and raise the calibre of instruction. The theoretical knowledge of digital leadership mechanisms in higher education is enhanced by this study, which also offers useful suggestions for developing instructors who are proficient in digital technology and innovative educational university administrators. By contextualising these findings within Inner Mongolia while connecting them to global trends in digital education, the study also extends the international relevance of digital leadership research.

Keywords: digital leadership; teaching performance; digital competency; higher education

1. Introduction

All facets of society are experiencing a new era of digital transformation due to the quick development of digital technologies including big data, cloud computing, and the Internet of Things[1]. Universities around the world face both opportunities and problems as a result of the Information Industry Revolution 4.0[2]. Globally, this digital revolution in education is changing learning experiences, institutional administration, and teaching approaches[3,4]. In order to remain relevant and effective in the future, higher education institutions (HEIs) must raise digital transformation from a technology upgrade to a strategic and organizational necessity[5,6]. In light of the digital transformation of education, the demands placed on teachers and principals have evolved considerably.

A key idea in this change is digital leadership. The ability of institutional leaders to use digital technology, data, and innovations to accomplish organisational objectives, promote digital culture, and lead

institutions through change is known as "digital leadership"[7,8]. Digital leadership in educational institutions includes creating a clear digital vision, incorporating technology into strategic planning, managing resources, encouraging staff members to be digitally competent, and making sure that digital tools are used ethically, securely, and sustainably[9,10]. Therefore, effective digital leadership involves more than just managing technology; it also involves empowering educators to innovate in the classroom and transforming culture[11].

By creating supportive settings, communicating a common digital vision, and developing staff capability, administrators' digital leadership in higher education is essential to accelerate institutional digital maturity[12,13]. Effective digital leadership may encourage effective technology integration in the classroom and teacher engagement with digital pedagogies[14]. Despite the widespread recognition of the significance of administrators' digital leadership, there is still conflicting evidence on its direct impact on teaching effectiveness[15,16]. These discrepancies point to the necessity of investigating potential mediating elements that connect instructional outcomes and digital leadership. Teachers' digital competency could be one such mechanism.

Due to the fast digital revolution that followed the COVID-19 epidemic, teachers' digital competence (TDC) has become more and more important in higher education. According to Zhao et al. (2021) and Basilotta-Gómez-Pablos et al. (2022), it includes the capacity of educators to create and lead technology-enhanced learning environments that support students' digital competencies[17,18]. In order to improve pedagogy, teamwork, and creativity, TDC requires confident, critical, and responsible use of digital tools in addition to fundamental technical abilities[19,20]. However, research shows that many instructors in higher education still lack precise frameworks and direction for successfully integrating digital technology[21,22]. It is widely acknowledged that teachers' digital competency is now a basic necessity rather than an elective in order to use technology to enhance teaching performance, increase student engagement, and improve pedagogical practices[23-25]. Additionally, Suárez-Rodriguez et al.[26] found that digital competency can predict technology usage, and Gudmundsdottir and Hatlevik[27] found that incorporating teacher digital competency into the relationship between digital leadership and teaching performance helps better explain how digital leadership impacts teaching outcomes. TDC is viewed in this study as a crucial mediating factor that connects principals' digital leadership to teachers' instructional effectiveness, illustrating how contextual support makes it possible for individual technology proficiency to result in better learning results.

The Chinese Education Informatization 2.0 Action Plan (MOE, 2018) in China has called for a thorough enhancement of teachers' technological proficiency and digital competency[28]. The anticipated gains in teaching quality and results have not yet materialised, though, and the successful incorporation of digital technologies into instructional strategies is still uneven[29,30]. In places like Inner Mongolia, where resource and economic inequality make digital adoption even more difficult, this difference is particularly noticeable[31]. Due to disparities in economic development, China's provinces are at varying levels of the digital transformation of education[32]. According to reports, principals frequently lack sufficient training in digital leadership, and the majority of university instructors in the area lack systematic instruction in digital pedagogy[31]. As a result, many teachers are still reluctant or unprepared to use digital tools effectively, limiting their impact on teaching effectiveness even with the availability of technology infrastructure[33,34].

While prior studies confirm that digital leadership can indirectly influence teaching performance through competence building and cultural support, empirical evidence remains scarce in the Chinese higher education context[35]. Furthermore, the specific mediating role of teachers' digital competence—as the mechanism linking administrators' digital leadership and teaching performance—remains underexplored.

With an emphasis on the mediating function of teachers' digital competency, this study attempts to close this gap by investigating how the digital leadership of university administrators affects the teaching performance of instructors in Inner Mongolian universities. This study aims to elucidate the behavioural pathways via which digital transformation takes place in higher education institutions by basing the analysis on both leadership and competency theories.

RQ1: What are the prevailing principals' digital leadership practices in universities of Inner Mongolia, China?

RQ2: What are the influence of principals' digital leadership practices on teachers' teaching performance in universities of Inner Mongolia, China?

2. Literature perspective

2.1. Theoretical background

The Technology Acceptance Model (TAM) and Transformational Leadership Theory (TLT) are two complimentary theoretical stances that serve as the foundation for this investigation[36,37]. When combined, these theories offer a comprehensive perspective on how teachers' motivation, use of technology, and effectiveness in the classroom are influenced by university administrators' digital leadership approaches.

According to TAM, people's perceptions of the utility and usability of technology have an impact on their behavioural intentions towards adopting it. The strategic vision, resource allocation, and innovation promotion of administrators in higher education greatly influence these perceptions. Strong digital leadership by administrators fosters organisational environments that boost teachers' perceptions of the value of digital resources and their confidence in using them, which increases the integration of digital pedagogy[38].

Transformational Leadership Theory, which supports TAM, asserts that leaders have an impact on followers through idealised influence, intellectual stimulation, individualised concern, and inspirational motivation[39]. In the digital sphere, transformational administrators encourage teachers to try out new technology and provide an example of flexible, creative behaviour, which boosts their self-efficacy and effectiveness as educators. Therefore, digital leadership can be viewed as a transformational extension that prioritises pedagogical innovation and technological empowerment.

By combining these theories, we may better understand how teachers' digital competency, professional motivation, and instructional effectiveness are improved by administrators' digital leadership, which in turn mediates institutional modernisation. The study's hypotheses and interpretation of empirical data are also influenced by this dual-theoretical framework, which links leadership behaviours to observable teaching outcomes in the particular setting of Inner Mongolian universities.

2.2. Literature review

It is crucial to first define the term "digital leadership" in order to comprehend how administrators' duties are changing in the digital age. University administrators use digital tools to affect instructors' attitudes, pedagogical strategies, and teaching performance through a socially influenced process known as "digital leadership"[40]. This idea develops from more general e-leadership ideas. By emphasising strategic vision, cultural transformation, and facilitating efficient instruction in technologically advanced settings, this paradigm goes beyond simple technology adoption. Research indicates that when administrators actively engage in digital leadership, faculty engagement and instructional quality significantly improve, which in turn improves student learning outcomes and the institution's reputation[41].

Recent research has advanced our understanding of how digital leadership functions within intricate higher education environments by building on this conceptual framework. Universities need a high degree of coordination because they are intricate ecosystems of teaching, research, and innovation. Teachers, department heads, deans, and administrators must work closely together to accomplish this. As a result, digital leadership has developed into a strategic tool for coordinating these many levels of coordination and guaranteeing that institutional missions are translated into successful digital practices[42]. Leading higher education systems around the world have included the concepts of digital leadership. Countries like Finland, Singapore, and the Netherlands used this strategy to institutionalise reform cultures, enhance administration, and promote pedagogy. The story of Inner Mongolia illustrates how specific efforts might adapt digital leadership to local educational systems based on these global ideas. Under the autonomous region's "Digital Education Action Plan (2021-2025)," which requires 90% of principals to receive training in digital leadership by 2025, Inner Mongolia's colleges are also implementing regional approaches[43].

In order to meet the specific requirements of a large and diversified region, this regional program clearly connects administrators training to enhanced digital infrastructure deployment and pedagogical innovation[43]. Institutions deliberately use learning management systems (LMS), data analytics platforms, and collaborative technologies to create more dynamic, personalised, and research-informed instruction. The effectiveness of education is clearly strengthened by this kind of technological integration[44,45].

The literature also shows that digital leadership has an impact on teacher development and institutional culture in addition to technology adoption. Given the distinctive and intricate structure of universities, which is defined by academic autonomy and disciplinary variety, the previously described benefits of digital leadership are especially important. According to Jing et al. (2025), this structure emphasises how important it is for principals to practise digital leadership in order to assist and improve teachers' instructional performance[46]. Successful digital leaders aggressively seek to overcome reluctance to adopt innovative teaching practices and make investments in the professional growth of educators. Additionally, they foster professional learning communities that inspire scholars and enable them to flourish in their teaching positions[47].

Enhancing teaching performance requires consistent focus on pedagogical support, intrinsic motivation, and faculty training. To support these procedures, digitally savvy administrators employ a variety of tools[48]. These resources include digital repositories, academic analytics dashboards, virtual collaboration platforms (like Teams and Zoom), and advanced learning management system features.

Digital leadership supports structural and cultural change at the institutional level. University administrators' use of digital leadership techniques sparks a shift in the institutional culture that goes beyond individual teaching effectiveness and is more creative, cooperative, and data-savvy[49]. The creation, evaluation, and tracking of curricula become more flexible and grounded on research. The decision-making processes of administrators are particularly centred on pedagogical initiatives and instructional materials. When administrators use data analytics to guide their decisions, these procedures are greatly improved[50]. Additionally, the university's reputation is strengthened by efficient digital communication channels run under this leadership that enhance interactions with students (such as virtual office hours and feedback mechanisms) and external stakeholders. Results such as increased stakeholder participation and student satisfaction are commonly noted[51]. Principals must, however, aggressively promote and broaden faculty and student acceptance of integrated university administration systems while closely observing digital engagement and educational results[52].

In conclusion, the literature emphasises digital leadership as a pedagogical and managerial driver for institutional modernisation. Universities can benefit much from digital leadership. By improving instructors' digital pedagogies and students' digital literacies, it raises institutional efficiency and prestige[53]. A culture like this actively fosters interdisciplinary cooperation, innovative teaching methods, and a shared goal while upholding an optimistic, forward-looking outlook. Technology integration improves teachers' technical and soft abilities under the direction of administrators. These consist of both soft skills (like online communication and virtual collaboration facilitation) and technical skills (like data literacy and the use of new tools). Students' academic performance and employability are significantly impacted by this kind of skill development[54]. The experience of teaching and learning hence becomes much more important and relevant.

It is crucial to take into account how digital leadership appears in geographically dispersed and resource-rich locations like Inner Mongolia in order to connect these global understandings with the particular context. Digital leadership in higher education functions primarily in virtual and hybrid environments, which sets it apart from traditional academic leadership. Administrators communicate with and manage remote teams using digital platforms. Faculty, departments, and research groups are examples of such teams[55]. This is crucial in physically expansive areas like Inner Mongolia (1.18 million km²). Overcoming distances of more than 1,000 km between campuses, Inner Mongolia University administrators oversee 43% of teacher contacts electronically[56]. The administrators must motivate and assist instructors who are physically separated from one another as a virtual leader, which calls for good self-management and the capacity to encourage it in others[57]. It is crucial to engage with the digital world strategically. Teachers' efficacy and happiness are the responsibility of administrators, regardless of their geographical dispersion. Online learning is a common way for professionals to grow. Administrators use digital tools to track developments and give prompt, helpful feedback. With the help of the accessible digital resources, they also encourage teachers to keep improving their methods[58]. In Inner Mongolia, where universities serve scattered populations, this dependence on virtual leadership is especially noticeable. As a result, the ability of administrators to communicate digitally and create communities is essential to preserving faculty morale and unity[59].

The more general claim that contextual and infrastructure elements influence the implementation of digital leadership is exemplified by this local case. In the current period of rapid technology change and altering educational paradigms, university administrators must execute strong digital leadership[60]. For efficiency, scalability, and data-driven insights, universities are depending more and more on digital operations. In order to preserve educational continuity and quality during disruptions, circumstances such as the COVID-19 pandemic made clear how important it is to have good digital leadership[14]. During epidemic closures, 92% of courses were offered at Inner Mongolian universities with established digital leadership frameworks by administrators, compared to 67% at less equipped institutions[43]. These results highlight the concrete benefits of regional digital leadership programs and imply that localised approaches might support international trends in innovative education.

Implementing digital leadership continues to provide difficulties. The development of teachers is still a significant challenge, especially at schools with little funding or in areas without a sufficient infrastructure for technology. For advanced online teaching and collaboration, some academics are not familiar with digital leadership paradigms or have inadequate digital literacy[61]. Further impeding growth are resource limitations including obsolete hardware, a lack of software licenses, erratic connectivity, or insufficient technical help[62]. Importantly, principals cannot effectively mentor or assist teachers who are encountering difficulties in the digital classroom environment if they themselves lack digital leadership competencies or vision[63].

Therefore, integrating professional development strategies for principals and teachers is necessary to solve these issues. A concentrated effort must be made to improve the capacities of both principals and teachers in order to address these enduring issues. Regional programs like Inner Mongolia's "Grassland Digital Talent Initiative" serve as examples of this dual-focus strategy. The abilities of teachers and principals are crucial to the success of digital leadership. A confident and tech-savvy academic workforce is essential for effective practices[64]. Therefore, university administrators need to create all-encompassing plans for instructors' and leaders' continuous digital upskilling. An example of this is the "Grassland Digital Talent Initiative" in Inner Mongolia, which trains 1,200 teachers each year in bilingual (Mongolian/Chinese) digital pedagogy with an emphasis on integrating ethnic cultural resources into digital teaching and overcoming regional disparities[65]. In order to eliminate obstacles to effective online teaching and leadership, it is imperative to provide sufficient technology resources and ongoing assistance. Clarity, openness, and clearly stated expectations must be given top priority by digital leaders. Crucial leadership behaviours include active listening, figuring out the underlying reasons of issues, and fostering close relationships even in a virtual environment. Ultimately, a competent workforce that is enabled by capable digital leadership propels positive change in higher education by greatly increasing teaching quality and institutional productivity.

2.3. Context of the study

Because of their large geographic area, diverse population, and uneven internet infrastructure, Mongolia and the Inner Mongolia Autonomous Region of China offer a unique setting for studying digital leadership in higher education. The region's higher education sector faces two challenges: pushing institutional modernisation through technology and fostering fair internet access throughout distant steppe regions. Due to these circumstances, digital leadership is now seen as a crucial need for guaranteeing that both urban and rural universities gain from digital change.

The necessity of educators and administrators enhancing their digital skills has been acknowledged by national and provincial governments in recent years. By 2025, 90% of university principals must have had digital leadership training, according to the Inner Mongolia Digital Education Action Plan (2021–2025). The goal of complementary programs like the Grassland Digital Talent Initiative (Inner Mongolia Department of Education, 2023) is to integrate ethnic cultural resources into online learning environments and improve instructors' bilingual (Mongolian–Chinese) digital pedagogy[31]. These programs are in line with national plans for rural revitalisation and educational informatisation, and they represent an increasing policy emphasis on leadership-driven digital change.

However, many institutions continue to apply digital leadership in different ways. While flagship universities in Hohhot and Baotou have steady broadband access and cutting-edge digital platforms, colleges in pastoral or border regions sometimes struggle with issues like inadequate teacher preparation, unstable networks, and a lack of technical staff. Principals and faculty members' perceptions and practices of digital leadership are impacted by these differences. For instance, maintaining administrative data and information systems is frequently given precedence over innovative pedagogy or the creation of creative digital content, indicating practical adaptation to infrastructure constraints.

Additionally, Inner Mongolia's language and cultural variety gives digital leadership an additional dimension. Principals are under added pressure to spearhead digital transformation in ways that are both linguistically inclusive and culturally sensitive as universities that serve ethnic minority communities are increasingly compelled to create digital resources in Inner Mongolian. Therefore, digital leadership entails striking a balance between modernisation, cultural preservation, and educational justice in addition to technological coordination.

In this regard, comprehending the connection between digital leadership, teachers' digital proficiency, and instructional effectiveness offers essential information for institutional growth and educational policy. The current study places its analysis inside this dynamic environment, where cultural factors, infrastructure realities, and regional initiatives all work together to influence how digital leadership supports educational innovation and equity in Inner Mongolian universities.

3. Materials and methods

In order to quantify the association between principals' digital leadership and teachers' teaching performance and investigate the mediating role of teachers' digital competency, this study uses a quantitative research approach. A cross-sectional survey using online questionnaires was used to gather data in China's Inner Mongolia Autonomous Region. The Wenjuanxing software platform was used to distribute the online surveys to the intended audience.

Data were gathered from a sample of Inner Mongolian university instructors in order to carry out this research design. An approach known as proportionate random sampling was used to choose the sample. Using Krejcie & Morgan's (1970) sample size table, which suggests a sample of 375 for a population of 16,092, the sample size of teacher responders was established[66]. This study administered questionnaires to 470 university lecturers in Inner Mongolia, compensating for an expected 20% non-response rate, in order to improve sample representativeness and account for potential non-response. This strategy is in line with Hair et al. (2010)'s guidelines, which state that a minimum sample size of 150 is necessary for structural equation modelling (SEM)[67]. Additionally, it is in line with recommendations made by Babbie (2014)[68], Cohen et al. (2011)[69], Creswell (2009)[70], and Slavin (2007)[71], who stress that in questionnaire-based research, bigger samples aid in lowering sampling error, enhancing reliability, and accounting for non-response. 386 valid questionnaires were gathered, resulting in an 82.1% response rate.

Table 1 provides an overview of the respondents' demographics. Of the 386 legitimate responses, 28.8% (n=111) were male and 71.2% (n=275) were female. 39.9% of respondents were between the ages of 31 and 40, while 30.3% were between the ages of 41 and 50. 69.9% of respondents had postgraduate degrees, such as a master's or doctorate. In terms of teaching experience, 26.9% had less than five years, 31.9% had more than ten years, and 41.2% had between five and ten years. Furthermore, 36.5% of respondents had more than ten years of expertise with digital technologies, 56.5% had five to ten years, and 7% had fewer than five years.

Table 1. Profiles of respondents according to demographic variables (N=386).

Variable		Frequency	Percentage(%)
Gender	Male	111	28.8%
	Female	275	71.2%
Age (At January 2025)	Below 31 years old	78	20.2%
	31 -40 years old	154	39.9%
	41-50 years old	117	30.3%
	Above 50 years old	37	9.6%
Highest Educational Level	Certificate/ Diploma	17	4.4%
	Bachelor's Degree	99	25.6%
	Master's Degree	212	54.9%
	Doctorate's Degree	58	15.1%

Years of Teaching Experience	Under 5 years	104	26.9%
	5-10 years	159	41.2%
	Above 10 years	123	31.9%
Years of Experience in Using Digital Technologies	Under 5 years	27	7%
	5-10 years	218	56.5%
	Above 10 years	141	36.5%

Table 1. (*Continued*)

Since there are three primary variables in this study, three measurement tools were developed for them. These are the subscales for Teachers' Digital Competency (TDC), Teachers' Teaching Performance (TTP), and Principals' Digital Leadership (PDL). A 5-point Likert scale was utilised for all instruments. These measures were modified from tried-and-true tools that had already been created and proven in prior studies. Here are the specifics.

1) The International Society for Technology in Education's Standards for Administrators (2018) served as the model for the scale used to assess principals' digital leadership.It had 22 items in five different dimensions.

2) The Marco de Competencia Digital Docente (INTEF 2017) served as the model for the scale used to assess teachers' digital proficiency. It had 44 objects in five different dimensions.

3) The National Professional Standards for Teachers (Ministry of Education, Ethiopia 2000) served as the model for the scale that was used to assess teachers' performance in the classroom. It had 34 objects in five different dimensions.

Before developing the questionnaire, the researcher carefully reviewed published and validated scales. Two bilingual experts in educational psychology used a forward-backward translation process to convert the original English elements into Chinese. To verify conceptual and semantic equivalency, a different impartial bilingual scholar compared the translated and original versions. The original meaning of each item was preserved but minor linguistic modifications were made to comply with Chinese linguistic rules. To prevent any potential language hurdles among participants, the final instrument was provided in Chinese.

Data analysis was performed using SPSS version 26.0. The mean values, standard deviations, and competence levels of teachers' digital competency, principals' digital leadership, and teaching performance were interpreted using descriptive analysis. The associations between the three primary variables were then investigated using Pearson correlation analysis. Lastly, the mediating role of teachers' digital ability was verified using structural equation modelling (SEM).

4. Results

4.1. Descriptive statistics

Descriptive statistics is a method that uses measures such as mean and standard deviation to summarize and describe data. In this study, the descriptive statistics for the three main variables are presented in **Table 2**. Mean scores were categorised into three levels: low (1.00–2.33), medium (2.34–3.66), and high (3.67–5.00), in accordance with the interpretive framework put forward by Nunnally and Bernstein (1994)[72] and used in related educational leadership research[73]. The relative strength of each construct can be ascertained using these theoretical thresholds as a guide.

The overall level of principals' digital leadership was high (M = 3.50, S.D. = 1.02). Among its dimensions, Visionary Leadership (M = 3.56) and Systemic Improvement (M = 3.55) scored the highest. The mean value (3.50) shows a strong tendency towards effective digital leadership among principals, even though it is slightly below the "high" threshold. This is in line with findings by Soncin and Arnaboldi[73], who observed that digital leadership maturity frequently emerges incrementally within educational institutions.

The overall level of teachers' digital competency was at a medium level (M = 3.44, S.D. = 0.96), with Managing Information (M = 3.52) being the strongest dimension. This is consistent with earlier studies[75,76], which discovered that teachers' digital abilities frequently cluster at a modest level in emerging digital ecosystems, indicating continuous adaptation rather than complete integration.

For teachers' teaching performance, a high level was reported (M = 3.54, S.D. = 1.04). The dimensions of Teacher Leadership (M = 3.71) and Monitoring and Evaluation (M = 3.59) were the most prominent. In line with similar SEM-based studies in higher education[77], which report higher self-evaluations in pedagogical leadership and reflective practice under supportive digital leadership conditions, this suggests that teachers view their leadership and instructional effectiveness favourably.

Table 2. Mean, standard deviation and the level of main variables (N=386).

Variable	Dimension	Mean	Standard Deviation	Interpretations (Level)
Principals' Digital Leadership (PDL)	Visionary Leadership	3.56	1.01	High
	Excellence in Professional Practice	3.48	1.01	Medium
	Digital-age Learning Culture	3.47	1.04	Medium
	Digital Citizenship	3.46	1.03	Medium
	Systematic Improvement	3.55	1.02	High
	Overall	3.50	1.02	High
Teachers' Digital Competency (TDC)	Managing Information	3.52	0.99	High
	Communication and Collaboration	3.41	0.97	Medium
	Creating Digital Content	3.39	0.94	Medium
	Digital Security	3.43	0.95	Medium
	Problem Solving	3.44	0.96	Medium
	Overall	3.44	0.96	Medium
Teachers' Teaching Performance (TTP)	Planning	3.48	1.06	Medium
	Organization	3.46	0.94	Medium
	Monitoring and Evaluation	3.59	1.07	High
	Classroom Atmosphere and Discipline	3.48	1.09	Medium
	Teacher Leadership	3.71	1.04	High
	Overall	3.54	1.04	High

4.2. Pearson correlation analysis

The Pearson product-moment correlation coefficient is a measure of the strength and direction of the linear relationship between two continuous variables. Pearson product-moment correlation analysis revealed

significant positive relationships among all three main variables (see **Table 3**). A moderate positive correlation was found between principals' digital leadership and teachers' digital competency (*r* = .413, *p* < .01). Teachers' digital competency was also moderately correlated with their teaching performance (*r* = .374, *p* < .01). The relationship between principals' digital leadership and teachers' teaching performance was positive but weaker (*r* = .328, *p* < .01).

According to Cohen's (1988) recommendations[78], these correlation strengths imply a minor influence (r = 0.10–0.29), a moderate effect (r = 0.30–0.49), and a high effect (r ≥ 0.50). The findings thus demonstrate that although digital leadership somewhat improves teachers' competency, its direct impact on teaching effectiveness is less significant but still significant.

Table 3. Pearson correlation analysis matrix between variables.

Variable	Principals' Digital Leadership	Teachers' Digital Competency	Teachers' Teaching Performance
Principals' Digital Leadership	1	.413**	.328**
Teachers' Digital Competency	.413**	1	.374**
Teachers' Teaching Performance	.328**	.374**	1

4.3. Mediation analysis via structural equation modeling (SEM)

The Analysis of Moment Structures (AMOS) is a widely used software tool for structural equation modeling (SEM), capable of simultaneously handling measurement models and structural models. It is particularly suitable for validating direct, indirect, and total effects among variables. In this study, AMOS was employed to establish a structural equation model with teachers' digital competency as a mediating variable, aiming to systematically examine the mechanism through which principals' digital leadership influences teachers' teaching performance. The model demonstrated excellent fit, with specific indices as follows: χ^2/df = 1.163, RMSEA = 0.021, CFI = 0.994, TLI = 0.993 (see **Figure 1**). The model fits the data well because these values are higher than the suggested cutoffs (χ^2/df < 3.00, RMSEA < 0.08, CFI > 0.90, TLI > 0.90) proposed by Hair et al. (2010) and Hu and Bentler (1999)[79,80]. The analysis results in **Table 4** demonstrate a significant direct effect of principals' digital leadership on teachers' teaching performance (β = 0.215, *p* < .001). More importantly, the study found that principals' digital leadership exerted a significant indirect effect on teaching performance through teachers' digital competency (β = 0.168, *p* < .001), suggesting that teachers' digital competency plays a partial mediating role in this relationship. The total effect was 0.383 (*p* < .001), indicating that principals' digital leadership and teachers' digital competency collectively have strong explanatory power for teaching performance.
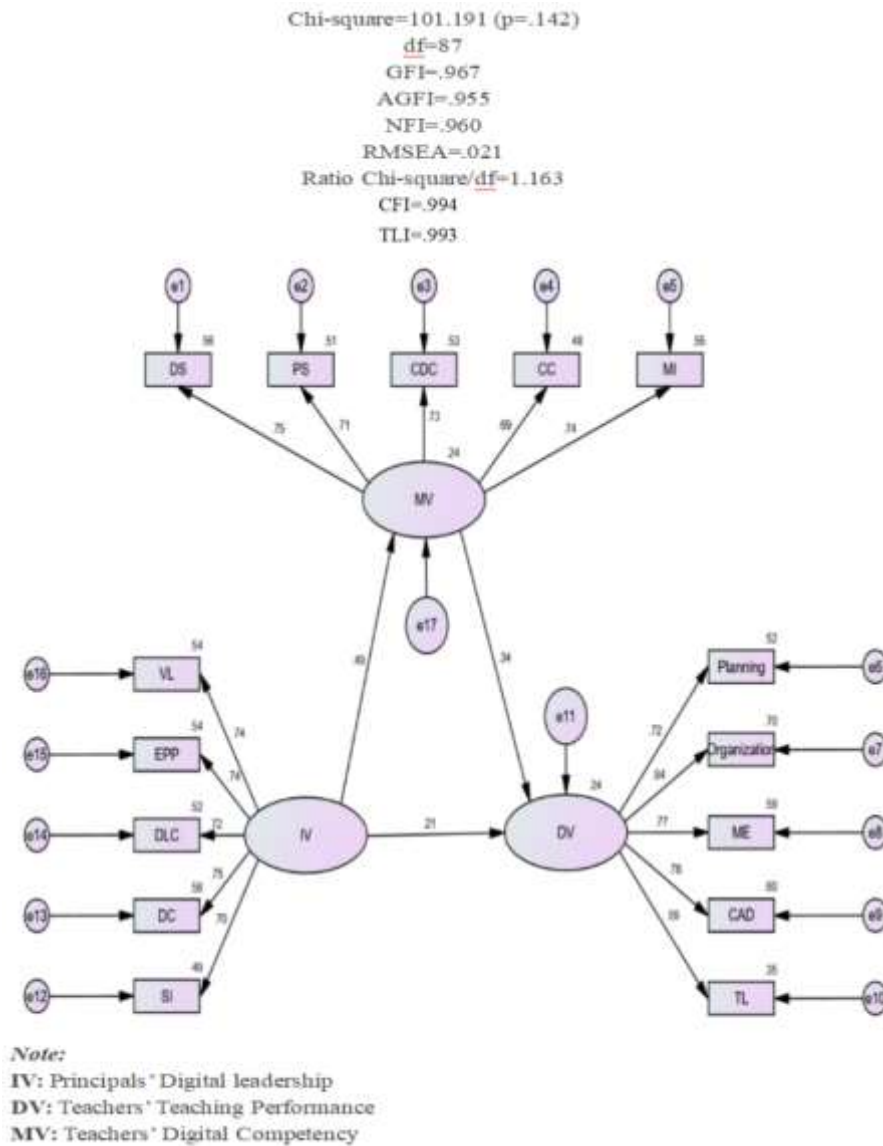
Note:
IV: Principals' Digital leadership
DV: Teachers' Teaching Performance
MV: Teachers' Digital Competency

Figure 1. Mediation model for teachers' digital competency on the relationship between principals' digital leadership and teachers' teaching performance.

Table 4. The standardized regression weights for the specified mediating model.

Path	Estimate	S.E.	C.R.	P	Result	Std. Estimate
PDL --- TDC	.494	.066	7.537	***	Significant	0.488
TTP --- PDL	.231	.071	3.251	***	Significant	0.215
TTP --- TDC	.366	.073	5.040	***	Significant	0.345

Note: Correlation is significant at the 0.001 level

5. Discussions

5.1. Summary of the findings

With an emphasis on the mediating function of teachers' digital competency, this study investigates the impact of principals' digital leadership on the teaching performance of university instructors in Inner Mongolia, China. Guided by the Technology Acceptance Model (TAM) and Transformational Leadership

Theory, the findings show that principals' digital leadership influences teachers' teaching performance directly as well as indirectly by improving their digital proficiency.

Regarding their overall teaching performance, teachers showed a moderate to high level. In particular, they demonstrated excellent proficiency in traditional teaching areas including instructional design and execution. Nonetheless, there is still opportunity for advancement in both the innovative teaching techniques and the thorough incorporation of digital technologies. Although the degree of digital teaching practice still need improvement, this lends credence to the claim that educators are starting to see the advantages of technology-based instruction. According to this distribution, instructors need to improve their ability to teach innovation and technology application in the context of digital transformation, even when they already possess the fundamental teaching competences.

Teachers had the highest ratings in the information management category, indicating a modest level of digital competency. This result reflects the unique regional environment of Inner Mongolia, where programs like the "Grassland Digital Talent Initiative" have prioritised data handling skills and basic ICT literacy above more creative or production-oriented abilities. As a result, educators are typically adept in organising and retrieving digital data but lack confidence when it comes to producing original instructional materials or digital content. Thus, the comparatively low ratings in the "Creating Digital Content" and "Problem Solving" categories reflect the region's universities' uneven access to technical infrastructure and restricted access to advanced digital training programs. This result implies that although teachers are able to use current information systems, they still encounter structural obstacles when trying to create unique digital teaching materials or successfully integrate new technology in the classroom. Reports emphasising discrepancies in training resources and the unequal distribution of digital facilities between urban and rural higher education institutions in Inner Mongolia are consistent with these contextual differences between informational and creative competencies. This outcome is in line with earlier studies conducted in China[81], which discovered that even with the nationwide adoption of the Education Informatisation 2.0 Action Plan, teachers' digital proficiency is still mostly insufficient.

Additionally, the study discovered a strong positive relationship between teachers' digital proficiency and their teaching performance, as well as between principals' digital leadership and teachers' digital competency. These connections provide credence to the idea that by boosting digital competency, digital leadership raises instructional effectiveness. According to Transformational Leadership Theory, principals that exhibit supportive and visionary digital behaviours assist teachers in internalising digital objectives and developing intrinsic motivation. This procedure is similar to the "perceived usefulness" and "perceived ease of use" paths in TAM, where instructors' willingness to use technology into their lessons is increased by leadership support.

However, the institutional and infrastructure limitations in Inner Mongolia should also be taken into consideration when interpreting the very small direct impact of digital leadership on teaching performance. The immediate impact of leadership techniques may be lessened by the region's numerous universities' old infrastructure, insufficient bandwidth, and disjointed administrative support for digital transformation. The development of teacher competency is one way that leadership has a greater indirect impact than a direct one, which may be explained by these contextual barriers.

Furthermore, mediation research verified that teachers' digital competency partially mediates the relationship between teachers' instructional performance and principals' digital leadership. This implies that although teaching effectiveness is immediately impacted by digital leadership, the majority of its impact is felt when teachers' digital abilities are improved. According to this research, principals should create

professional development programs to assist teachers in implementing digital teaching practices. This will give them the assurance and drive to keep using digital teaching techniques, which will improve student learning outcomes[82]. This is in line with global studies, including that of Sheninger[83], which highlights that in order to achieve long-term educational development, effective digital leadership must give priority to teacher capacity building.

These results underscore structural limitations in Inner Mongolia, including regional differences in training opportunities, uneven digital infrastructure, and culturally hierarchical leadership practices. These contextual realities may increase the mediating impact of teacher competence while decreasing the direct effects of digital leadership, indicating that institutional and cultural norms frequently filter leadership influence. In this sense, the results confirm the necessity of region-specific digital leadership strategies that complement current government initiatives such as the "Grassland Digital Talent Initiative," which aims to strike a balance between infrastructure investment and teacher upskilling.

Despite its statistical importance, the direct impact of administrators' digital leadership on teachers' instructional effectiveness is quite minor. This contextual view is consistent with regional data demonstrating that administrative autonomy, ICT resources, and broadband connectivity remain issues for Inner Mongolian universities[31]. These limitations might lessen the direct impact of leadership techniques on learning outcomes, highlighting the necessity of focused assistance and resource distribution. This is also somewhat in line with Yusof et al.[84], who discovered that digital learning functionality might not yet fully satisfy requirements, indicating that principals should fill in management gaps.

In conclusion, the study's findings highlight how crucial it is to improve teachers' digital competency and principals' digital leadership in order to improve teaching effectiveness. The study offers a regionally grounded knowledge of how competency and leadership interact in resource-constrained environments by connecting these findings to Inner Mongolia's ongoing regional development initiatives. This is in line with national education strategies that seek to develop highly qualified and informed teachers by utilising digital technologies in the classroom. The study also emphasises how institutional support and ongoing professional development are necessary to close the gap between digital education policies and practices. These findings are understood as a narrative synthesis of current patterns, emphasising the interaction between leadership behaviours, teacher capability, and local institutional environment, rather than offering prescriptive policy recommendations.

5.2. Implications

By empirically validating a contextually refined conceptual model that links teaching effectiveness, teachers' digital competency, and principals' digital leadership in the context of Chinese higher education, this study adds to the body of knowledge at the theoretical level. It makes clear how digital leadership affects the integration of technology into instruction by confirming that teachers' digital proficiency serves as a crucial mediating variable. By combining the organisational (leadership), individual (competence), and performance (teaching) components found in this study, the refined model—referred to as "improved" in previous drafts—builds upon TAM and Transformational Leadership Theory.

By incorporating organisational and individual elements unique to educational digital transformation, the findings expand on traditional ideas like transformational leadership and the Technology Acceptance Model. By improving teachers' technology skills and confidence, this contextually grounded model advances our knowledge of how digital leadership indirectly enhances teaching performance. The study provides information pertinent to international initiatives in digital education leadership, even outside of the Chinese setting. It emphasises the necessity of flexible leadership frameworks that take into account national

differences in infrastructure, institutions, and culture. The findings in Southeast Asian and European contexts are consistent with the mediating role of teachers' digital competence, indicating that the interaction between competence development and leadership may be a universal mechanism within digital transformation processes[85,86].

The study provides additional practical consequences for educational practice, building on these theoretical discoveries.Practically speaking, it emphasises how important it is to create methodical plans that improve teachers' digital competency and principals' digital leadership. To enhance instructors' technological competence and pedagogical abilities for incorporating digital resources, higher education institutions should set up ongoing, professionally supported training programs. At the same time, principals must support a culture of digital learning, supply adequate resources, and set an example of how to use technology effectively. From a cross-cultural perspective, these tactics are consistent with global best practices that support context-sensitive leadership adaption and capacity-building over one-size-fits-all regulations. Together, these actions will support successful digital transformation and enhanced teaching effectiveness. Rather than being prescriptive policy recommendations, these implications should be seen as research-based insights that encourage more research into the localisation of leadership tactics in areas like Inner Mongolia. Future research could develop comparative models to investigate how digital leadership operates in various educational systems, expanding this framework's global applicability.

5.3. Limitations

It is obvious that there are several problems that require attention. To accomplish a number of aims and objectives, certain procedures must be followed. Some suggestions are offered for further study and consideration in the same field in light of these. The study's limitations serve as the primary foundation for the recommendations for further research, which go outside its purview.

From a methodological standpoint, research on digital leadership necessitates a paradigm change in order to better understand variables that have not received enough attention. Almost every study that has been done so far has used quantitative research techniques, primarily positivist in nature. On the other hand, qualitative approaches with interpretivist roots can be just as enlightening, providing scholars with fresh perspectives on digital leadership techniques and serving as a useful substitute strategy. To further improve teaching performance, instructors must embrace and incorporate digital tools, resources, and technology into their curricula in order to increase their digital competency. As a result, instructors' acceptance behaviour demands that determining elements be periodically reevaluated in order to keep up with the advancement of digital technologies. Emerging technologies frequently include factors that were not taken into account in earlier studies. Potential determinants can be identified inductively by researchers using this methodological lens.

The study employed the survey approach to examine the connections among teachers' instructional performance, principals' digital leadership, and teachers' digital competency. A self-administered questionnaire was utilised to gather data. There are certain drawbacks to this data collection strategy. First, the approach depends on participants answering the researcher's questions as truthfully as feasible. The research next requires analysing the connections between two or more of these self-reported pieces of data, as was the case in this study. Common method variance is a potential source of bias introduced by the use of this kind of research design and analysis, where answers to one question may influence answers to other questions[87]. Therefore, in order to cross-validate the replies provided, it is advised that future study use other data collection methods including interviews and direct observation.

The current study was cross-sectional in nature, gathering information from 17 Inner Mongolian universities at a specific moment in time. Over time, the respondents' opinions on teaching effectiveness, digital leadership, and digital competency may shift. In order to examine changes over time, future study should use a longitudinal research approach.

In order to predict teachers' teaching ability, this study combined two human factors: teachers' digital competency and principals' digital leadership. The results of this study should only be used and interpreted cautiously because this is a relatively new research field in Inner Mongolia. Therefore, additional research of this kind is required to test and validate the findings from regression and correlation analysis. To put it another way, more research is needed in this area so that university administrators, both present and future, would be better equipped to handle digital difficulties and successfully execute digital policies. The ISTE Standards for Administrators (ISTE Standards·A) will also be improved in the future. A research agenda on digital leadership should therefore stay abreast of these developments and track how universities' capabilities in this area are developing.

5.4. Future research directions

In order to further understand how principals' digital leadership affects teachers' teaching effectiveness through the mediating role of digital competency, a number of research pathways are suggested for future studies, building upon the findings, limits, and implications of the current study.

First, in order to capture the dynamic and changing nature of the digital transition in higher education, future research should use mixed-method or longitudinal methods. Although a cross-sectional quantitative approach was used in this study, qualitative investigations like focus groups, interviews, or ethnographic observations could uncover subtle mechanisms underlying how teachers' professional development and pedagogical innovations are influenced by digital leadership practices. It would also be easier to draw conclusions about causality and spot trends of long-lasting change if teachers' performance and digital competency were tracked longitudinally.

Second, universities in various parts of China and comparable overseas environments should be included in future studies, broadening the institutional and geographic scope beyond Inner Mongolia. The association between teaching performance and digital leadership may be moderated by regional differences in training support, digital infrastructure, and resource allocation. A more thorough grasp of how regional socioeconomic circumstances impact digital transformation in higher education could result from comparative studies that reveal contextual elements impacting the application of digital leadership.

Third, multi-level analytical frameworks that incorporate systemic, organisational, and individual aspects may be investigated in future studies. Teachers' digital competency is shaped by institutional digital culture, leadership philosophies, and policy frameworks rather than emerging in a vacuum. Thus, cross-level interactions—like how leadership environment or institutional digital policies affect the relationship between teachers' digital competency and teaching outcomes—could be investigated using multi-level SEM or hierarchical linear modelling (HLM).

Fourth, in addition to teachers' digital ability, it is advised that future research look into other mediating and moderating factors. The suggested relationships may be strengthened or weakened by moderators like institutional support, leadership communication style, and access to professional development resources, while potential mediators include teachers' organisational commitment, innovation willingness, and digital self-efficacy. These investigations will enhance the theoretical framework and provide useful information for leadership tactics in online learning settings.

Fifth, in order to assess the efficacy of leadership and competency development programs, future research should plan and assess focused intervention programs. Before putting training programs into place, principals should be urged to evaluate teachers' baseline levels of digital proficiency to make sure that the delivery and content meet their real needs. The effects of such interventions on teachers' digital proficiency and instructional effectiveness might be evaluated using experimental or quasi-experimental approaches, offering evidence-based suggestions for practice and policy.

Sixth, studies ought to concentrate on principals' own professional growth. Principals need ongoing education to improve their digital leadership skills as the pace of digital transformation quickens. Future research could look at the results of regional or national leadership development programs, like those provided by the China Education Cadre Online Academy or the National Academy of Educational Administration, and how well they match up with global frameworks like the ISTE Standards for Administrators. A localised yet globally informed model of digital leadership that works well for China's higher education system can be developed with the help of such studies.

Lastly, by coordinating institutional digital transformation with China's Education Modernisation 2035 agenda and Education Informatisation 2.0 Action Plan, future research should tackle the macro-level policy dimension. Building a cohesive ecosystem that enables sustainable digital transformation may be made easier with research examining the interactions between leadership implementation, resource allocation, and legislative demands. Achieving the high-quality advancement of Chinese higher education in the digital age would require the convergence of strategic leadership development, resource equity, and teacher empowerment.

In conclusion, future studies should move closer to a multifaceted, contextually aware, and policy-driven understanding of digital leadership. Future research can more clearly show how digital leadership develops teachers' digital competency and improves teaching effectiveness in an increasingly complicated digital educational environment by fusing methodological innovation with cross-level viewpoints.

6. Conclusion

This research advances our knowledge of how educational actors adjust both behaviourally and psychologically to the quickly changing digital learning environment. The results demonstrate that administrators' digital leadership improves teachers' teaching performance both directly and indirectly by bolstering their digital competency. These findings point to a twin mechanism that promotes successful engagement with technology-mediated instruction: instructors' digital competency acts as a personal adaptive ability, while leadership acts as a contextual enabler. This illustrates how people and organisations co-evolve with their evolving technological environment through competence development and adaptive behaviours, according to environmental psychology. In practical terms, the results indicate that the beneficial behavioural consequences of digital leadership can be enhanced by fostering teachers' digital competency through ongoing support and professional development environments. This report offers evidence-based recommendations for administrators and legislators looking to support long-term digital transformation in higher education. Theoretically, it connects behavioural and environmental viewpoints with leadership research, enhancing knowledge of how digital surroundings influence academic achievement, motivation, and adaption.

Author contributions

Conceptualization, Yuexin Xin, Aida Hanim A. Hamid, and Azlin Norhaini Mansor; Methodology, Yuexin Xin; Software, Yuexin Xin; Validation, Yuexin Xin, Aida Hanim A. Hamid, and Azlin Norhaini

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