education sciences

MDPI

Article

Principals' Digital Leadership Competencies in the Fourth Industrial Revolution: Teachers' Perspectives

John Olayemi Okunlola * and Suraiya Rathankoomar Naicker

Department of Education Leadership and Management, Faculty of Education, University of Johannesburg, P.O. Box 524, Auckland Park 2006, South Africa; snaicker@uj.ac.za

* Correspondence: jokunlola@uj.ac.za or jookunlola2@gmail.com

Abstract: As the Fourth Industrial Revolution (4IR) reshapes society, digital leadership in education becomes crucial. This study explores teachers' perspectives on high school principals' digital leadership competencies in Oyo State, Nigeria, a region grappling with the digital divide. This offers a counterpoint to research in high-income countries. Using a quantitative, descriptive research design, 381 teachers across three senatorial districts were selected via multi-stage sampling. The study addressed one research question and tested two hypotheses. Data were collected using the High Schools' Digital Leadership Standards Questionnaire (HSDLSQ). The reliability coefficients ranged from $\alpha = 0.85$ to 0.91 across five domains: visionary leadership, digital learning culture, professional development, systemic improvement, and digital citizenship. Descriptive statistics (percentages, mean, and standard deviation) and inferential statistics (independent *t*-test) were used for analysis at a 0.05 significance level. The findings revealed that high school leaders possess the skills to meet the ISTE-A digital leadership standards set by the International Society for Technology in Education (ISTE). Female leaders exhibited slightly higher digital skills than males, though gender was insignificant in meeting the ISTE-A standards overall. The study underscores the importance of digital leadership in school management, offering practical implications for leadership practices, policy decisions, and future research. Although the ISTE-A standards are met, the emphasis on systemic improvement highlights how Nigerian principals adapt strategies to local resource constraints, differing from high-tech education systems. Recommendations include promoting the ISTE-A standards among school leaders, investing in digital leadership training, fostering digital literacy, and supporting adaptability to technological changes to advance digital transformation in education.

Keywords: digital leadership; Fourth Industrial Revolution; high school leaders; ISTE-A standards

check for updates

Academic Editor: Doris L. Watson

Received: 22 March 2025
Revised: 25 April 2025
Accepted: 22 May 2025
Published: 26 May 2025

Citation: Okunlola, J. O., & Naicker, S. R. (2025). Principals' Digital Leadership Competencies in the Fourth Industrial Revolution: Teachers' Perspectives. *Education Sciences*, *15*(6), 656. https://doi.org/10.3390/educsci15060656

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

The Fourth Industrial Revolution (4IR) is taking its toll on several human endeavours by adding digital values and virtues to the societal ecosystem. The vast impacts of digitization are not limited to communication, aviation, health, the public sector, the economy, defence, and education (Okunlola et al., 2024). The 4IR signifies the era of digital technologies' convergence involving physical, biological, and social systems, fundamentally altering how we live, work, and learn (Datta, 2023). The 4IR has changed pedagogical modes across the globe. However, traditional teaching–learning may still exist in rural and remote communities disadvantaged by the digital divide. Digital transformation, birthed by the 4IR, has also crept into the realm of educational leadership.

Traditional leadership styles are believed to be incapable of effectively addressing the opportunities and challenges brought about by the 4IR. As a result, digital leadership evolves (Mo et al., 2023). Therefore, a new dimension of digital leadership emerges with the 4IR (Avwokeni, 2024; Rogers, 2016). It is safe to state that digital leadership is an offspring of the 4IR, as this emerging leadership style is flying on the wings of technological innovations and advancement.

Hence, leading schools in the 4IR are changing rapidly from traditional face-to-face leadership to digital leadership. The emergence of digital technologies in the 4IR calls for principals' technology integration to support teaching–learning processes (Zhong, 2016). Moreover, the phenomenon of globalization is putting leadership ideologies to the test; as a result, high school leaders must adapt to this digital change to have a competitive edge in an ever-evolving future (Brooks & Ezzani, 2022; Hariri et al., 2016; Riski et al., 2023). In digital leadership, school leaders are required to act as digital leaders who, in turn, lead innovative and technological ideas to formulate and reformulate the vision and mission of their organizations. In other words, organizational leaders must adopt and imitate digital leadership as a new paradigm shift to lead successfully and efficiently (Avwokeni, 2024; Guzman et al., 2020; Herder-Wynne et al., 2017; Oberer & Erkollar, 2018; Rogers, 2016). Digital leadership is characterized by strategically using technology and data to achieve organizational objectives, vision, effective communication, influence, and technological proficiency (Ismarsanto et al., 2023; Khan, 2016). Considering its developmental evolution and velocity, digital leadership gradually assumes a global phenomenon.

However, the International Society for Technology in Education (ISTE) published the ISTE Standards for Administrators (ISTE-A) in 2009; there is still a research gap because there are not enough studies on the indicators of digital leadership (Zhong, 2017). The ISTE-A standards require leaders to exhibit five dimensions of skills and knowledge: visionary leadership, digital age learning culture, excellence in professional practice, systemic improvement, and digital citizenship to qualify as digital leaders (Zhong, 2016). It is noteworthy that the overall ISTE Standards for Administrators demonstrate how strong standards are provided by the ISTE-A to aid and support principals in their roles as digital leaders (Hamzah et al., 2021). Meanwhile, Veithzal and Rony (2024) affirmed a surge in research interest in digital leadership, but few studies have investigated digital leadership indicators or competencies required of a digital leader (Karakose et al., 2021, 2022; Zhong, 2017). Scholars' recent interest in investigating digital leadership seems to underscore its significance in organizational governance and school administration. Further study on digital leadership is necessary, according to Indrio and Herachwati (2024), who also claimed that digital leadership is becoming more and more critical in the age of digital transformation. Still, studies on it are few compared to other leadership styles. Hence, school administration cannot ignore the speed of technological innovations being born daily in the 4IR era. Wu et al. (2020) cautioned school leaders to adapt to change and resist reluctance to embrace digital and information communication technology (ICT) skills. School administrators are expected to take the lead in spearheading and maintaining the integrated use of technology in education by incorporating it into their regular management practices (Aslam et al., 2020). Technological advancements will continue to evolve in the 4IR, so school administrators must adapt to change (Aslam et al., 2020; Pribadi et al., 2024).

The 4IR era has brought about transformative changes that have reshaped teaching and learning processes and school administrative functions. Thus, principals must become proficient in digital technology, including leadership qualities specific to digital technology (Wu et al., 2020). However, embracing new tools alone will not be enough to realize digital technology's educational potential fully; this requires demonstrating specific skills and competencies by high school leaders. Leadership becomes crucial in high schools,

where students prepare to navigate a rapidly evolving digital landscape. In addition to influencing how digital technologies are incorporated into instruction, high school leaders also significantly impact the ethos and attitude of the school community around technology use. Yet, there is a gap in understanding the digital leadership skills or competencies required in high school settings within the 4IR by high school leaders. As a result, Veithzal and Rony (2024) posit that companies and academia are developing a keen interest in digital leadership due to the transformative benefits of digitalization.

Meanwhile, this study primarily focuses on teachers' perspectives in presenting a critical lens through which to evaluate digital leadership competencies, because they reveal how the ISTE-A standards are operationalized daily. Teachers are frontline implementers who directly experience how leadership decisions translate into classroom activities. As a result, their feedback can expose gaps between policy propositions (e.g., the ISTE-A standards) and practical execution, especially in resource-constrained settings like Nigeria, where infrastructure and training disparities exist. Prior studies (Hamzah et al., 2021; Zhong, 2017) contend that teacher buy-in is a prerequisite for sustainable digital transformation, indicating a school's digital readiness. Hence, this study investigated the gap by examining the skills and competencies of high school leaders in meeting the ISTE-A digital leadership standards in school management in the context of the 4IR. In achieving this research objective, one research question was raised, and two hypotheses were formulated and tested at the 0.05 level of significance.

Purpose of the Study

The main purpose of this study is to investigate how high school leaders meet the ISTE-A digital leadership standards in school management.

1.1. Literature Review

Digital Leadership

The emergence of digital leadership remains elusive, but some extant literature credits its evolution to certain authors. The word "e-leadership" is credited to Avolio et al. (2000), whereas Fisk (2002) is credited as the first author to use the term "digital leadership" in scholarly writing and states as follows: "The digital leaders must possess a visionary mindset and are adept at driving change. They have the ability to integrate ideas within the organization to execute projects and facilitate partnerships, joint ventures, outsourcing, and other collaborative endeavours." (Veithzal & Rony, 2024). The idea of digital leadership has since been described in a variety of ways by different scholars. Digital leadership refers to the social influencer's use of technology to modify an individual's or an organization's emotions, actions, attitudes, and outcomes (Stana et al., 2018). Digital leadership, according to Antonopoulou et al. (2021), is the ability to effectively manage human resources and technology usage while utilizing information and communication technologies to achieve specific project goals. Some scholars, too, have termed this leadership phenomenon heralded by digital emergences and innovations with different phrases such as remote leadership, electronic leadership, virtual leadership, and e-leadership (Avolio et al., 2000; Prahmana et al., 2021; Riski et al., 2023; Waruwu et al., 2023).

In addition, Zhong (2017) describes digital leadership as: the "application of instructional technology such as digital device, service, and resources to inspire and lead school digital transformation, create and sustain digital learning culture, support and enhance technology-based professional development, provide and maintain digital organization management, and facilitate and manage digital citizenship" p. 28. Another similar definition is that of Magesa and Jonathan (2019), who also emphasized that digital leadership leverages information technology to leadership styles (Ismarsanto et al., 2023). This implies that the core objective of digital leadership is never to obliterate existing leadership styles

that have been established for ages but rather to play supportive, innovative, and transformative roles demanded by the 4IR. In other words, digital leadership only seeks to enhance leadership in the 4IR by applying digital tools. To these researchers, digital leadership influences those being led toward realizing organizational goals through the operation of digital technologies by leveraging existing leadership styles, philosophies, or ideologies.

Today, more than ever, digital leaders' roles in driving digital transition are urgently needed if tangible results are achieved across the globe, as witnessed in higher education institutions such as those in Greece. Hence, those leading digitalization efforts in educational institutions must acquire digital skills and competencies that are urgently demanded (Antonopoulou et al., 2021). Additionally, digital leaders should function in these capacities: they should encourage staff members to apply knowledge gained from their personal experiences; they should disseminate knowledge among team members to foster a more profound comprehension; they should enable internal knowledge sharing; and they should bring in outside insight (Veithzal & Rony, 2024; Zupancic et al., 2018).

Meaning of the International Society for Technology in Education (ISTE) Standards

The International Society for Technology in Education (ISTE) is a non-governmental organization that partners with the global education community to promote and accelerate the use of technology in education for innovation and problem-solving (Affan, 2024). The ISTE has established standards for school leaders, guiding their technological professional practice and focusing on teaching, learning, and digital leadership (Al-Matri & Al-Rasebeah, 2021). The ISTE standards were recently revised to reflect the evolving nature of learning. The revised standards have four components that offer a thorough framework for coaches, educators, educational leaders, and students. The ISTE Standards are research-based and can be adopted in various ways by schools, districts, or states. They guide system-wide planning, professional development, curriculum mapping, lesson design, learning management systems, teacher preparation, job descriptions, and hiring decisions (ISTE, 2018).

Moreover, the ISTE released the ISTE Standards for Administrators (ISTE-A), a digital leadership standard for administrators. The ISTE-A Standards provide a guideline for school administrators to foster leadership. It outlines five dimensions of digital leadership: visionary leadership, digital age learning culture, excellence in professional practice, systemic improvement, and digital citizenship (Hamzah et al., 2021). The ISTE-A Standards are graphically represented below in Figure 1.



Figure 1. ISTE Standards A 2009 International Society for Technology in Education.

Visionary Leadership: Educational administrators lead the development and implementation of a shared vision for technology integration, promoting excellence and transformation. They inspire stakeholders, facilitate change, develop and communicate technology-infused strategic plans, and advocate for policies, programs, and funding to

support this vision and strategic plan (ISTE-A, 2009). Educational administrators lead the development and implementation of a shared vision for technology integration. They advocate for policies, programs, and funds to support this vision and strategic plan. They also motivate stakeholders, promote change, and create and convey technology-infused strategic plans.

Digital Age Learning Culture: Educational administrators foster a dynamic digital-age learning culture by promoting continuous improvement, frequent use of technology, learner-centred environments, effective technology study, and participation in local, national, and global learning communities to stimulate innovation, creativity, and collaboration among students (ISTE-A, 2009).

Excellence in Professional Practice: Educational administrators foster a learning environment that empowers educators to enhance student learning by integrating modern technologies and digital resources. They allocate resources for continuous professional growth, facilitate learning communities, promote effective communication, and stay updated on educational research trends (ISTE-A, 2009).

Systemic Improvement: Educational administrators use digital age leadership to continuously improve organizations by effectively using information and technology resources. They lead change, collaborate on data collection and analysis, recruit competent personnel, establish strategic partnerships, and maintain a robust technology infrastructure for management, operations, teaching, and learning (ISTE-A, 2009).

Digital Citizenship: Educational administrators play a crucial role in promoting digital citizenship by ensuring equitable access to digital tools, promoting safe, ethical, and legal use of technology, promoting responsible social interactions, and fostering a shared cultural understanding of global issues using contemporary communication tools (ISTE-A, 2009).

1.2. Research Question and Hypotheses

This investigation was guided by the following research question:

1. What are teachers' perceptions of high school leaders in meeting the ISTE-A digital leadership standards in school management in terms of visionary leadership, digital learning culture, professional development, systemic improvement, and digital citizenship?

The hypotheses used in this study are:

1. There is no significant difference between male and female high school leaders in meeting ISTE-A digital leadership standards.
2. There is no significant difference between the digital skills possessed by male and female high school leaders.

2. Materials and Methods

2.1. Research Design

The study adopted the descriptive research design. This is so because the phenomena under study already exist, resulting in no manipulation of variables. The researcher does not control or influence changes; variables are only seen, observed, and measured (Ansari et al., 2022).

2.2. Sampling and Sampling Procedure

A multi-stage sampling technique was used to select teachers across the three senatorial districts of Oyo State. In the first stage, cluster sampling was used to select seven secondary schools from each of the three senatorial districts. Then, simple random sampling was used to choose 20 teachers from each of the 21 secondary schools. Three hundred and eighty-one teacher-respondents completed and returned the questionnaire.

2.3. Instrumentation

A structured questionnaire titled High Schools' Digital Leadership Standards Questionnaire (HSDLSQ), containing sections A and B, was used for data collection. Section A was used to collect the respondents' demographic data. In contrast, section B comprises 33 items grouped into five sections used in obtaining data on five dimensions of the ISTE-A digital leadership standards for the study. Educational leadership, management, and test measurement experts were consulted to determine the instrument's content validity. Their recommendations were incorporated into the final instrument administered to the respondents. The instrument's reliability was ascertained through Cronbach's Alpha (α) to measure the internal consistency among the items (Cohen et al., 2018). The reliability index is as follows: visionary leadership ($\alpha = 0.86$), digital learning culture ($\alpha = 0.90$), professional development ($\alpha = 0.90$), systemic improvement ($\alpha = 0.91$), and digital citizenship ($\alpha = 0.85$) at a 0.05 significance level.

2.4. Ethical Consideration

This study complied with all ethical standards and was approved by the University of Johannesburg's Faculty of Education Research Ethics Committee, with ethical clearance number: SEM 2-2023-003. The principals of every school the researchers sampled in Oyo State, Nigeria, were also asked for and granted permission by the researchers.

2.5. Data Analysis

Descriptive statistics, which include simple percentages and the mean and standard deviation, were used to analyse the respondents' research questions and demographic data. In contrast, inferential statistics (independent *t*-test) were used to test the hypotheses formulated at the 0.05 significance level.

3. Results

3.1. Socio-Demographic Characteristics of Participants

Table 1 and Figure 2 reveal that 59.1% of the teachers are female, while 40.9% are male. This highlights a significant gender disparity, with females being the majority. This trend aligns with broader societal norms associating teaching with nurturing roles often linked to women. Such gender distribution has implications for diversity in educational leadership and emphasizes the need for strategies to encourage balanced representation within the teaching profession.

Table 1. Gender Representation in the Teaching Workforce.

Gender	Frequency	Percentage
Male	156	40.9
Female	225	59.1
Total	381	100.0

Table 2 and Figure 3 indicate a balanced representation across different age groups, with the majority (31.2%) aged 41–50 years. Teachers aged 31–40 account for 30.4%, those aged 21–30 make up 21.3%, and 17.1% are aged 51–60. This spread reflects a healthy mix of early-career, mid-career, and experienced educators, which is crucial for knowledge transfer and mentorship within the profession. The diversity in age groups also ensures a dynamic teaching environment that combines fresh perspectives with seasoned expertise.

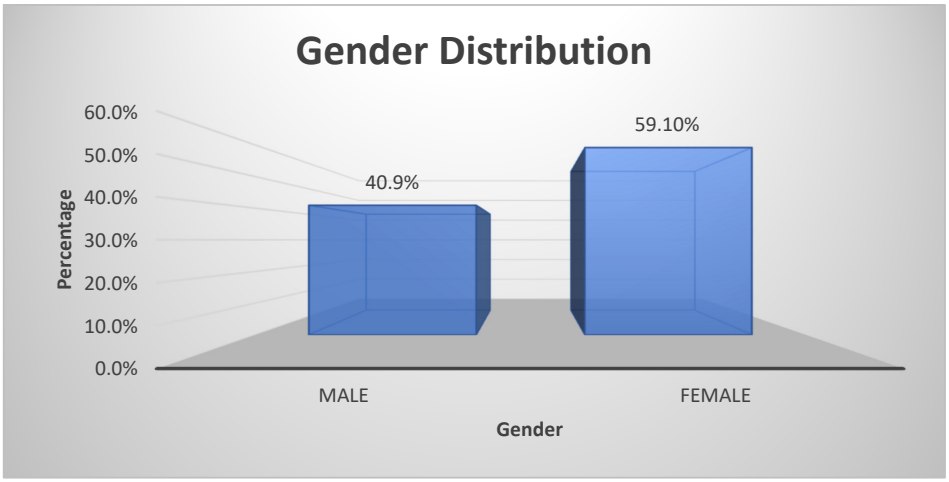

Figure 2. Gender Representation in the Teaching Workforce.

Table 2. Age Distribution in the Teaching Workforce.

Age Range	Frequency	Percentage
21–30	81	21.3
31–40	116	30.4
41–50	119	31.2
51–60	65	17.1
Total	381	100.0

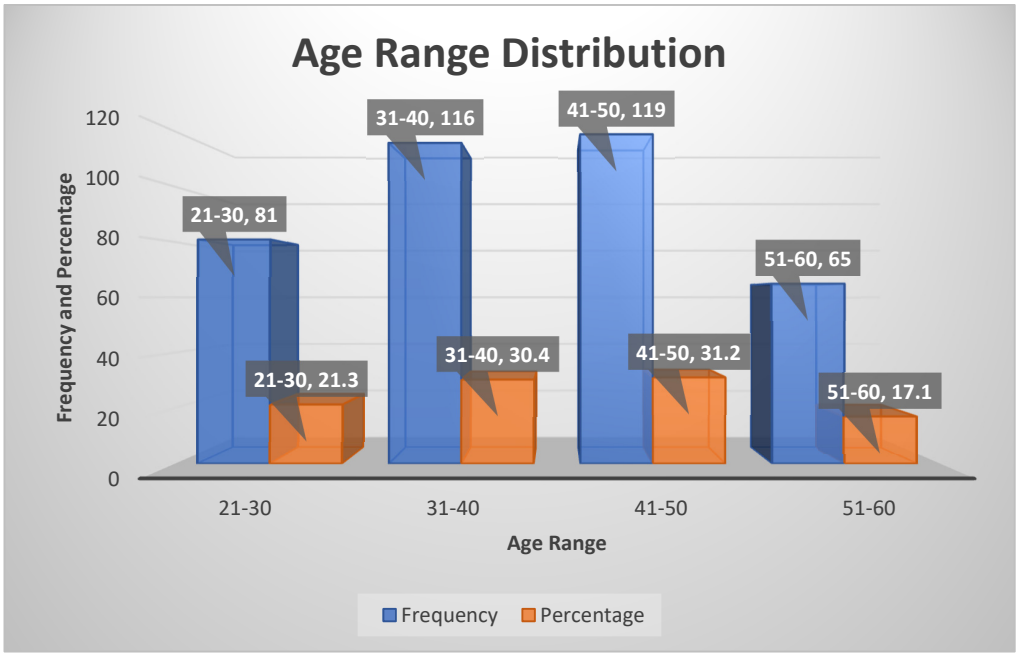

Figure 3. Age Distribution in the Teaching Workforce.

Table 3 and Figure 4 reveal that the majority (71.7%) hold a bachelor's degree (B.Ed./B.A./B.Sc.), reflecting the standard entry-level requirement for teaching roles. Additionally, 15.7% possess a Nigerian Certificate in Education (NCE), while 10.2% hold a master's degree (M.Ed./M.A./M.Sc.), and 2.4% have other qualifications. This distribution highlights a well-educated workforce, with most teachers meeting or exceeding basic professional qualifications. The presence of advanced degree holders underscores

opportunities for specialization and leadership within the profession, enhancing the quality of education delivery.

Table 3. Qualification Distribution in the Teaching Workforce.

Qualification	Frequency	Percent
NCE	60	15.7
B.ED./B.A/B.SC	273	71.7
M.ED./MA/MSC	39	10.2
OTHERS	9	2.4
Total	381	100.0

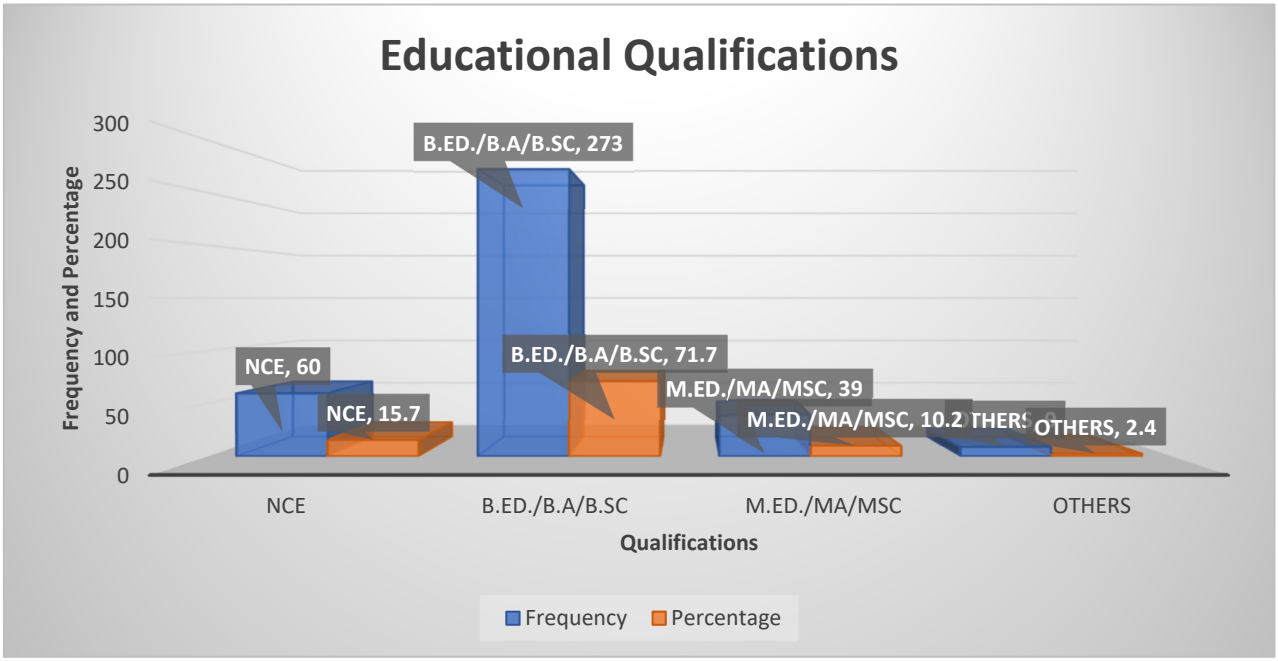

Figure 4. Qualification Distribution in the Teaching Workforce.

Table 4 and Figure 5 demonstrate a diverse range of professional experience. Teachers with 0–5 years of experience constitute the largest group at 26.0%, followed closely by those with 11–15 years (24.7%). Educators with 16–20 years of experience account for 20.2%, while 15.0% have 6–10 years of experience. Those with 21 years or more in service make up 14.2%. This distribution reflects a balanced mix of new and seasoned professionals, fostering an environment where innovation meets experience. Such diversity is critical for mentorship, continuity, and the sustained development of the teaching profession.

Table 4. Experience Distribution in the Teaching Workforce.

Experience	Frequency	Percentage
0–5	99	26.0
6–10	57	15.0
11–15	94	24.7
16–20	77	20.2
21 and above	54	14.2
Total	381	100.0

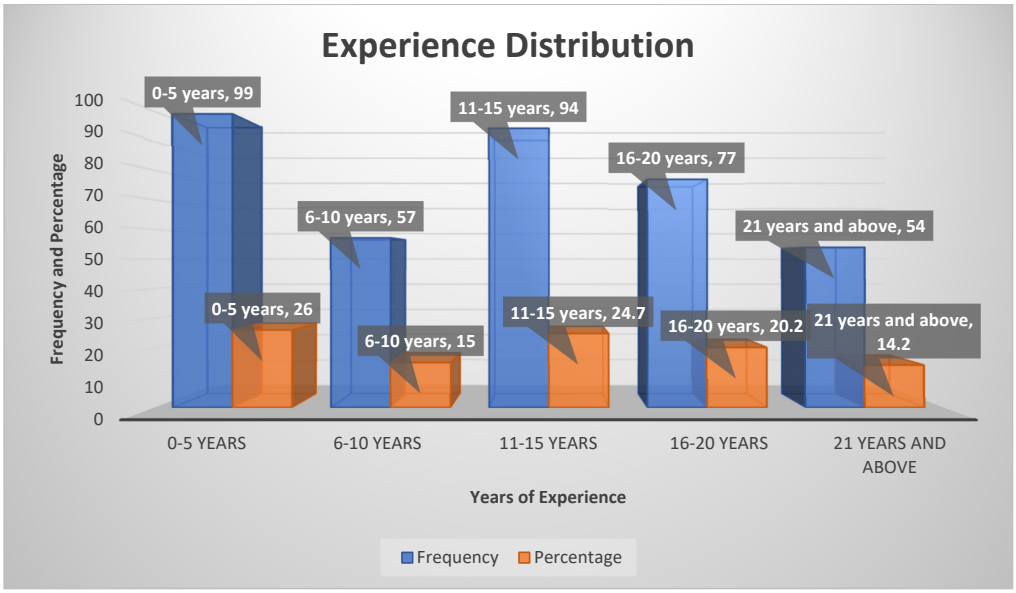

Figure 5. Experience Distribution in the Teaching Workforce.

3.2. Research Question 1

What are teachers' perceptions of high school leaders in meeting the ISTE-A digital leadership standards in school management in terms of visionary leadership, digital learning culture, professional development, systemic improvement, and digital citizenship?

The participants' responses were subjected to item-by-item analysis using descriptive statistics of the mean. Since the questionnaire items were structured in a four-response-type of SA, A, D, and SD with coding scores of 4, 3, 2, and 1, respectively, a cut-off mean value of 2.50 was used as the baseline for decision. Given that perception could be positive or negative, a weighted mean score equal to or above 2.50 signified positive perception, while one below 2.50 was remarked otherwise.

As depicted in Table 5, teachers had a positive perception of high school leaders in meeting the ISTE-A digital leadership standards in school management. Hence, teachers have positive views of visionary leadership, digital learning culture, professional development, systemic improvement, and digital citizenship. However, the lower digital learning culture score (Mean = 2.83) signals key implementation challenges, which may likely include infrastructural gaps, unreliable technology access, inadequate teacher training, and resistance to pedagogical change. Although principals meet other ISTE-A standards, the digital learning culture score reveals a critical disconnect. Hence, achieving a transformative digital culture would require sustained investment and stakeholder engagement beyond policy compliance, as evidenced in similar resource-constrained contexts (Yusof et al., 2019).

Table 5. Teachers' Perceptions of High School Leaders in Meeting ISTE-A Digital Leadership Standards.

S/N	ISTE-A Digital Leadership Standards	Mean	Std. Dev.
1	Visionary Leadership	3.39	0.905
2	Digital Learning Culture	2.83	0.874
3	Professional Development	2.93	0.862
4	Systemic Improvement	3.12	0.845
5	Digital Citizenship	3.17	0.837
	Weighted Mean	3.08	
	Remark	Positive Perception	

Mean value decision below 2.50 (negative perception), above 2.50 (positive perception).

3.3. Hypothesis Testing

The hypotheses formulated were tested using an independent *t*-test at a 0.05 alpha level.

Hypothesis 1. *There is no significant difference between the digital skills possessed by male and female high school leaders.*

Table 6 shows that the t-value 9.265 is obtained with a *p*-value of 0.002 when computed at the 0.05 alpha level. The null hypothesis is not retained since the *p*-value of 0.002 is less than the 0.05 alpha level. Therefore, there was a statistically significant difference between the digital skills possessed by male and female high school leaders ($t_{\{379\}} = 9.265$, $p < 0.05$).

Table 6. Test statistics showing the Difference between Digital Skills possessed by Male and Female High School Leaders.

Gender	No.	Mean	S. D.	Df	t-Value	Sig	Remark
Male	156	1.25	0.434	379	9.265	0.002 *	sig
Female	225	1.32	0.468				

* Significant at $p < 0.05$.

Hypothesis 2. *There is no significant difference between male and female high school leaders in meeting ISTE-A digital leadership standards.*

As revealed in Table 7, the t-value 2.503 is obtained with a *p*-value of 0.114 when computed at the 0.05 alpha level. The null hypothesis is retained since the *p*-value of 0.114 is greater than the 0.05 alpha level. Therefore, there was no statistically significant difference between male and female high school leaders in meeting the ISTE-A digital leadership standards ($t_{\{379\}} = 2.503$, $p > 0.05$).

Table 7. *t*-Test statistics showing the Difference between Male and Female High School Leaders in meeting ISTE-A Digital Leadership Standards.

Gender	No.	Mean	S. D.	df	t-Value	Sig	Remark
Male	156	76.97	17.758	379	2.503	0.114 *	Not sig
Female	225	75.08	16.243				

* Insignificant at $p > 0.05$.

4. Discussion

The only research question in this study examined teachers' perceptions of high school leaders in meeting the ISTE-A digital leadership standards in school management in terms of visionary leadership, digital learning culture, professional development, systemic improvement, and digital citizenship. The findings indicate that teachers generally hold positive perceptions of high school leaders regarding their adherence to ISTE-A digital leadership standards in school management. The mean scores for each dimension of the ISTE-A standards suggest that teachers view high school leaders favourably across all aspects examined: visionary leadership, digital learning culture, professional development, systemic improvement, and digital citizenship. These scores indicate that, on average, teachers perceive high school leaders as effectively demonstrating qualities related to each standard. Moreover, the weighted mean score for all the dimensions combined is 3.08, indicating an overall positive perception of high school leaders' adherence to digital leadership standards. These positive perceptions highlight the effectiveness of

high school leaders in meeting ISTE-A digital leadership standards, which are crucial for facilitating meaningful educational experiences in the digital age. This aligns with the findings of Hamzah et al. (2021) that teachers concur that principals play a crucial role in strategic planning, particularly regarding the application of digital technologies in teaching–learning processes. This shows the pivotal role of principals as digital leaders in school administration and management. They serve as a driving force in leading digital innovation and revolution among teachers. This study supports the findings of Banoğlu et al. (2023), who discovered that technology leadership practices, such as a principal's data-driven decision-making and technology-focused personnel recruitment, have been shown to be a strong predictor of successful school administration. This further bolsters the cardinal importance of integrating digital tools into school administration in this digital age. Thus, leading in the 4IR does not make adopting and using digital technologies an option. However, according to Yusof et al. (2019), the digital learning environment's functions do not yet meet the minimal requirements, indicating that school principals in Malaysia have not optimally operationalized the digital leadership concept as required.

Similarly, Hamzah et al. (2021) posited that principals must engage in professional development programs that empower teachers to upskill their digital teaching practices. This has also shown that a gap exists in digital leadership practices. As a result, Zhong (2016) added that principals should use hybrid approaches by implementing teacher standards, including digital teaching, online instruction, professional development, conferences, cooperative groups, and social media usage for administrative functions. In summary, the findings suggest that teachers perceive high school leaders as successfully embodying visionary leadership, fostering a digital learning culture, promoting professional development, implementing systemic improvements, and cultivating digital citizenship within the school environment.

The first hypothesis examined the significant difference between digital skills possessed by male and female high school leaders. Table 2 presents the outcomes of the *t*-test statistics comparing the mean scores of digital skills between the two genders. The result indicates a statistically significant difference between the digital skills possessed by male and female high school leaders. There is a notable divergence in digital skills between male and female high school leaders. The mean score for female high school leaders was slightly higher than that for male high school leaders. The gender difference in digital skills tends to favour female high school leaders in this study. This study agrees with the research conducted to determine digital literacy among teachers from a gender perspective by Wigati et al. (2022), which revealed that male teachers demonstrated lower levels of digital literacy skills than female teachers. However, this study contradicts the research by Gupta et al. (2023) on gender gaps in internet literacy in India, whose findings indicated that males used the internet more than females. This study also contradicts the findings of Rizal et al. (2020), who found a difference in digital literacy between male and female prospective physics teachers in a study on gender differences in digital literacy among prospective physics teachers. It was confirmed that male prospective physics teachers had higher digital literacy than female ones.

The second hypothesis on the significant difference between male and female high school leaders in meeting ISTE-A digital leadership standards revealed no statistically significant difference between male and female high school leaders in meeting ISTE-A digital leadership standards. These findings suggest that, based on the data analysed, gender does not play a significant role in determining the extent to which high school leaders meet the ISTE-A digital leadership standards. Therefore, it can be inferred that both

male and female high school leaders demonstrate similar levels of proficiency in digital leadership as assessed by the ISTE-A standards.

5. Conclusions

This study investigated how high school leaders meet the ISTE-A digital leadership standards in school management in terms of visionary leadership, digital learning culture, professional development, systemic improvement, and digital citizenship. It found that teachers perceived principals as meeting the ISTE-A standards. However, it should be acknowledged that there is a potential gap between perception and practice. Teacher assessments may be influenced by personal biases or a partial view of leadership actions rather than actual implementation realities. Hence, future research should combine these perceptual measures with objective indicators to validate whether reported compliance translates to tangible digital transformation in schools. Meanwhile, this research has shown that high school leaders possess the skills and competencies required to meet the ISTE-A digital leadership standards set by the ISTE. This study also concluded that there is a slightly higher gender difference in digital skills between female high school leaders and male high school leaders. This study also extends digital leadership theory by demonstrating how the ISTE-A standards are operationalized in low-resource settings, offering a model for adaptive implementation that can refine global policy frameworks. However, the study concluded that gender was insignificant in meeting ISTE-A digital leadership standards in school management. Conclusively, this research contributes to a deeper understanding of digital leadership among high school leaders and provides practical implications for improving leadership practices, informing policy decisions, and guiding future research. However, it should be noted that the study has limitations that should be acknowledged. Firstly, relying on teachers' perspectives may not fully capture the implementation of digital leadership practices, as responses could be influenced by personal biases or limited visibility into administrative decisions. In addition, the focus on Oyo State, Nigeria, limits the generalizability of findings to other regions with different socio-economic or infrastructural contexts. Lastly, using a quantitative design alone restricts deeper exploration of the "how" and "why" behind the observed trends. Future research could address these gaps by:

- Employing mixed methods research (MMR) to triangulate/validate data from both quantitative and qualitative sources,
- Expanding the geographic scope to compare digital leadership challenges across diverse Nigerian states or other emerging economies,
- Investigating the long-term impact of digital leadership on student performance and school-wide digital transformation.

5.1. Recommendations

- Authorities in charge of government and private schools should invest in digital leadership skills, fostering digital literacy, adaptability to technology changes, and digital transformation leadership.
- High school leaders should also create a culture that supports digital innovation and prioritize training in digital skills like artificial intelligence, data analytics, and other emerging digital innovations.
- School leaders should promote and ensure the implementation of and compliance with the ISTE-A standards among other school leaders and teachers.
- Further investigation may be needed to understand the factors contributing to the discrepancy in gender digital skills among high school leaders and identify strategies to promote equitable development of such skills.

5.2. Implications of the Study

The study highlights that high school principals possess the necessary digital leadership competencies to meet the ISTE-A standards, which are crucial for fostering a digital learning culture, systemic improvement, and digital citizenship in schools. This implies that school leaders should continue to prioritize visionary leadership, professional development, and the integration of digital tools into their practices to enhance educational outcomes in the digital age. Teachers perceive their leaders positively regarding digital leadership, indicating that principals effectively support digital learning and professional growth. Therefore, ongoing professional development programs should be encouraged to further enhance teachers' digital skills and adaptability to technological changes. The study also underscores the importance of principals fostering a continuous learning and innovation culture, which can lead to improved teaching practices and better student engagement in digital learning environments. Additionally, policymakers should consider incorporating the ISTE-A standards into national educational frameworks to ensure that school leaders are adequately prepared to lead in a digital age.

The study also found a slight gender difference in digital skills, with female leaders demonstrating slightly higher proficiency, implying that efforts should be made to ensure equitable access to digital skill development for both male and female leaders, promoting gender balance in digital leadership roles. Further research is recommended to explore the factors contributing to this gender disparity and to develop strategies that support the digital skills development of all school leaders, regardless of gender. The study opens avenues for further research into the factors that influence digital leadership effectiveness, particularly in diverse cultural and socioeconomic contexts. Future studies could explore how digital leadership impacts student outcomes, teacher performance, and overall school success in the 4IR era. In summary, the study provides valuable insights into the digital leadership competencies of high school principals and offers practical recommendations for improving leadership practices, informing policy decisions, and guiding future research in the field of digital education.

Author Contributions: Conceptualization, J.O.O. and S.R.N.; methodology, J.O.O. and S.R.N.; software, J.O.O.; validation, J.O.O. and S.R.N.; formal J.O.O.; investigation, J.O.O. and S.R.N.; resources, J.O.O. and S.R.N.; writing—original draft preparation, J.O.O. and S.R.N.; writing—review and editing, J.O.O. and S.R.N.; visualization, J.O.O. and S.R.N.; supervision, S.R.N.; project administration, J.O.O. and S.R.N.; funding acquisition, J.O.O. and S.R.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Faculty of Education Research Ethics Committee of the University of Johannesburg with ethical clearance Number: SEM2-2023-003 on 21 July 2023.

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

Data Availability Statement: The raw data supporting the conclusions of this article will be made available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

Affan, M. (2024). Requirements for digital leadership implementation in Indonesian embassy's schools in Saudi Arabia in accordance with ISTE standards. *Journal of Educational and Human Sciences*, *33*, 165–186.

Al-Matri, A. S., & Al-Rasebeah, A. R. (2021). The degree of availability of the standards of the International Society for Technology in Education (ISTE-2018) among principals of the second cycle of basic education in the Governorate of South Al Sharqiyah in the Sultanate of Oman. *International Journal of Educational & Psychological Studies (EPS)*, *10*(3), 592–613.

Ansari, M. R., Rahim, K., Bhoje, R., & Bhosale, S. (2022). A study on research design and its types. *International Research Journal of Engineering and Technology (IRJET)*, *9*(7), 1132–1135. Available online: www.irjet.net (accessed on 21 August 2024).

Antonopoulou, H., Halkiopoulos, C., Barlou, O., & Beligiannis, G. N. (2021). Transformational leadership and digital skills in higher education institutes: During the COVID-19 pandemic hera. *Emerging Science Journal*, *5*(1), 1–15. [CrossRef]

Aslam, R., Khan, N., & Ahmed, U. (2020). Technology integration and teachers' professional knowledge with reference to international society for technology in education (ISTE)-standard: A causal study. *Journal of Education and Educational Development*, *7*(2), 307–327. [CrossRef]

Avolio, B. J., Kahai, S., & Dodge, G. E. (2000). E-leadership: Implications for theory, research, and practice. *The Leadership Quarterly*, *11*, 615–668. [CrossRef]

Avwokeni, A. J. (2024). Strategic leadership and transactional leadership: The mediating effect of digital leadership in the world of Industry 4.0. *Journal of Economic and Administrative Sciences*. [CrossRef]

Banoğlu, K., Vanderlinde, R., Çetin, M., & Aesaert, K. (2023). Role of school principals' technology leadership practices in building a learning organization culture in public K-12 schools. *Journal of School Leadership*, *33*(1), 66–91. [CrossRef]

Brooks, M. C., & Ezzani, M. D. (2022). Islamic school leadership: Advancing a framework for critical spirituality. *International Journal of Qualitative Studies in Education*, *35*(3), 319–336. [CrossRef]

Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education* (8th ed.). Routledge.

Datta, P. (2023). The promise and challenges of the fourth industrial revolution (4IR). *Journal of Information Technology Teaching Cases*, *13*(1), 2–15. [CrossRef]

Fisk, P. (2002). The making of a digital Leader. *Business Strategy Review*, *13*(1), 43–50. [CrossRef]

Gupta, T., Jana, A., Maiti, S., & Meenakshi, Y. (2023). Gender-gap in internet literacy in India: A state-level analysis. *Scholars Journal of Economics, Business and Management*, *10*(09), 209–213. [CrossRef]

Guzman, V., Muschard, B., Gerolamo, M., Kohl, H., & Rozenfeld, H. (2020). Characteristics and skills of leadership in the context of industry 4.0. *Procedia Manufacturing*, *43*, 543–550. [CrossRef]

Hamzah, N. H., Nasir, N. K. M., & Wahab, J. A. (2021). The effects of principals' digital leadership on teachers' digital teaching during the COVID-19 pandemic in Malaysia. *Journal of Education and E-Learning Research*, *8*(2), 216–221. [CrossRef]

Hariri, H., Monypenny, R., & Prideaux, M. (2016). Teacher-perceived principal leadership styles, decision-making styles and job satisfaction: How congruent are data from Indonesia with the Anglophile and Western literature? *School Leadership & Management*, *36*, 41–62.

Herder-Wynne, F., Amato, R., & De Weerd, F. U. (2017). *Leadership 4.0: A review of the thinking*. Research Report. Available online: https://www.oxfordleadership.com/leadership-4-0-a-review-of-the-thinking/ (accessed on 21 August 2024).

Indrio, L. W., & Herachwati, N. (2024). Digital leadership in organization: Systematic literature review. *Al-Kharaj: Jurnal Ekonomi, Keuangan & Bisnis Syariah*, *6*(2), 2547–2562. [CrossRef]

International Society for Technology in Education Standards for Administrators (ISTE-A). (2009). *ISTE standards for administrators*. Available online: https://cdn.iste.org/www-root/Libraries/Images/Standards/Download/ISTE%20Standards%20for%20Administrators,%202009%20(Permitted%20Educational%20Use).pdf (accessed on 21 August 2024).

Ismarsanto, F. I., Kirana, K. C., & Kusuma, N. T. (2023). The influence of digital leadership style, work motivation on employee performance: A mediation of work discipline. *International Conference on Humanity Education and Sosial*, *2*(1), 11.

ISTE. (2018). *International society for technology in education*. Available online: https://iste.org/standards (accessed on 21 August 2024).

Karakose, T., Kocabas, I., Yirci, R., Papadakis, S., Ozdemir, T. Y., & Demirkol, M. (2022). The development and evolution of digital leadership: A bibliometric mapping approach-based study. *Sustainability*, *14*(23), 16171. [CrossRef]

Karakose, T., Polat, H., & Papadakis, S. (2021). Exploring teachers' perspectives on the role of digital leadership in the COVID-19 pandemic and tech skills of school leaders. *Sustainability*, *13*(23), 13448. [CrossRef]

Khan, S. (2016). *Leadership in the digital age: A study on the effects of digitalisation on top management leadership* [Master's Thesis, Stockholm Business School]. Available online: https://www.diva-portal.org/smash/get/diva2:971518/FULLTEXT02 (accessed on 22 August 2024).

Magesa, M., & Jonathan, J. (2019). Digital leadership for digital transformation. *Electronic Scientific Journal*, *10*(4), 2082–2677.

Mo, Z., Liu, Y., Lu, C., & Yu, J. (2023). Influences of industrial internet platform firms' ESG performance and digital leadership on user firms' innovation performance: The mediating role of inter-firm trust. *Journal of Digital Economy*, *2*, 204–220. [CrossRef]

Oberer, B., & Erkollar, A. (2018). Leadership 4.0: Digital leaders in the age of industry 4.0. *International Journal of Organizational Leadership*, *7*(4), 404–412. [CrossRef]

Okunlola, J. O., Naicker, S. R., & Uleanya, C. (2024). Digital leadership in the fourth industrial revolution enacted during the COVID-19 pandemic: A systematic review. *Cogent Education*, *11*(1), 2317258. [CrossRef]

Prahmana, R. C. I., Hartanto, D., Kusumaningtyas, D. A., Ali, R. M., & Muchlas. (2021). Community radio-based blended learning model: A promising learning model in remote area during pandemic era. *Heliyon*, *7*(7), e07511. [CrossRef] [PubMed]

Pribadi, L. A., Nurdin, D., & Edy, S. (2024). Digital leadership in improving teacher performance during the COVID-19 pandemic. *International Journal Of Humanities Education And Social Sciences (IJHESS)*, *3*(4), 2159–2168. Available online: https://ijhess.com/index.php/ijhess/ (accessed on 15 January 2025). [CrossRef]

Riski, A., Tambunan, R., Anggraeni, N., & Alam, F. (2023). Implementation of the spiritual leadership model in improving the quality of education in Islamic boarding schools. *JOELS: Journal of Election and Leadership*, *4*(2), 159–167. [CrossRef]

Rizal, R., Rusdiana, D., Setiawan, W., & Ridwan, P. S. (2020, July 14–15). *Gender differences in digital literacy among prospective physics teachers Gender differences in digital literacy among prospective physics teachers*. International Conference on Mathematics and Science Education (ICMScE), Jawa Barat, Indonesia. [CrossRef]

Rogers, D. L. (2016). *The digital transformation play book: Rethink your business for the digital age*. Columbia University Press.

Stana, R., Fischer, L. H., & Nicolajsen, H. W. (2018). Review for future research in digital leadership. *arXiv*, arXiv:2409.01056.

Veithzal, A. P., & Rony, Z. T. (2024). Analysis of implementing digital leadership within organizations. *Journal of Digital Business Management (DIJDBM)*, *5*(2), 303–316.

Waruwu, N., Arifin, F., & Hady, Y. (2023). The implementation of post-pandemic blended learning in elementary schools. Tafkir: Interdisciplinary. *Journal of Islamic Education*, *4*(3), 446–457. [CrossRef]

Wigati, I., Faisal, F., & Astuti, R. T. (2022). Determining digital literacy among teacher from gender perspective through the Rasch model. *Journal of Education and Learning (EduLearn)*, *16*(3), 330–335. [CrossRef]

Wu, H., Gao, X., & Shen, J. (2020). Principal leadership effects on student achievement: A multilevel analysis using programme FOR International student assessment 2015 data. *Educational Studies*, *46*(3), 316–336. [CrossRef]

Yusof, M. R., Yaakob, M. F. M., & Ibrahim, M. Y. (2019). Digital leadership among school leaders in Malaysia. *International Journal of Innovative Technology and Exploring Engineering*, *8*(9), 1481–1485. [CrossRef]

Zhong, L. (2016). *The effectiveness of digital leadership at K-12 schools in Mississippi regarding communication and collaboration during CCRS implementation* [Ph.D. Dissertations, Graduate School of The University of Southern Mississippi]. Available online: https://aquila.usm.edu/dissertations/328 (accessed on 23 November 2023).

Zhong, L. (2017). Indicators of digital leadership in the context of K-12 education. *Journal of Educational Technology Development and Exchange*, *10*(1), 27–40. [CrossRef]

Zupancic, T., Herneoja, A., Schoonjans, Y., & Achten, H. (2018). A research framework of digital leadership. *Computing for a Better Tomorrow*, *2*, 641–646.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.