Development and Validation of a Digital Leadership Instrument for Malaysian Primary School Principals

Lokman Mohd Tahir[1]*, Roslizam Hassan[1], Mohd Shafie Rosli[1], Norazah Abdul Aziz[2], Nur Jannah Abdullah[1]

[1]Faculty of Educational Sciences and Technology, Universiti Teknologi Malaysia, 81310, Skudai, Johor, Malaysia.
p-lokman@utm.my,
roslizam@utm.my,
mohdshafie@utm.my,
njannah42@graduate.utm.my
[2]Faculty of Education, Universiti Teknologi MARA, UiTM Puncak Alam Campus, 42300 Puncak Alam, Selangor, Malaysia
norazahaa@uitm.edu.my
*Corresponding author

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Abstract: The concept of digital leadership is increasingly being recognised as an abstract process, with school leaders playing vital roles in influencing, promoting, and facilitating the integration of Information Communication Technology (ICT) within their school environments. The objective of this study is to develop and validate a scale for assessing and evaluating the digital leadership practices of primary school principals in Malaysia. The items for this Digital Leadership Scale (DLS) were crafted based on the International Society for Technology in Education (ISTE) framework. Three constructs of digital leadership were established to examine its role in primary schools, focusing on providing support, encouragement, and motivation, addressing challenges in the school's digitalisation, and offering ICT support and resources. A survey to evaluate the DLS was conducted with 326 Malaysian primary school teachers and the findings revealed strong correlations among the three dimensions. The results reinforced the three-factor model and confirmed the appropriateness of item fit statistics. The final version of the DLS comprises 20 items designed to assess the digital leadership practices of primary school principals within the ISTE framework. In conclusion, the DLS scale has demonstrated a significant practical benefit in evaluating principals' roles as digital leaders in schools. These findings enhance our understanding of principals' digital leadership practices and recommend the need for further exploration of digital leadership within the context of Malaysian school leadership.

Keywords: Digital Leadership Instrument, Item Development and Validation, Primary School Principals, Scaling Validation

1. Introduction

In the 21st century, information and communication technologies (ICT) have become essential in revolutionizing teaching and learning in schools, enhancing engagement and interaction as part of the ongoing digital transformation in education (Eickelmann, 2018; Karakose et al., 2021). The significance of Information Communication Technology (henceforth referred to as ICT) in educational settings is underscored by its various advantages that support teachers in their instructional practices. In addition to supporting teachers, ICT streamlines administrative operations, making it easier for

school leaders to manage data about students, staff, and educators. Consequently, the role of school leaders is vital in motivating and enabling teachers to effectively incorporate ICT into their school and learning environments (Ruloff & Petko, 2021; Chua & Chua, 2017). Previous research indicates that the support of school leaders has a substantial impact on the successful integration of ICT in schools (Sheninger, 2014; Zhong, 2017). Without such backing, the goals of implementing ICT in educational settings may remain unfulfilled. Thus, it is clear that school leaders are essential in promoting the effective use of ICT in schools and providing teachers with opportunities to enhance their access to and utilisation of digital technologies in the teaching and learning process (Al-Harthi, 2017).

In the realm of 21st-century school leadership research, the pivotal role of principals and school leaders in promoting the effective use of ICT in schools is regarded as essential for maximising its potential (Ruloff & Petko, 2021). Consequently, school leaders are expected to assume the role of digital or technological leaders by integrating ICT into the school culture and encouraging teachers and students to incorporate it into their teaching and learning practices. Since the early 21st century, the role of principals as digital and information leaders in implementing ICT in schools has been a topic of considerable discussion. As school leaders, they are expected to provide motivation, encouragement, and resources to teachers, particularly during the digital transformation process. In this context, school leaders fulfil their responsibilities as digital leaders by practising digital leadership. Digital leadership is defined as an approach that aligns an organisation's digital practices and development to facilitate, support, and motivate the process of digitalisation (Sagbasi & Erdogan, 2022; Okunlola et al., 2024). In the educational context, Sheninger (2014) emphasises the vital role of school leaders in establishing direction, influencing teachers, initiating changes in ICT knowledge and skills, and creating networks to enhance digitalisation for the success of the school. Similarly, Zhong (2017) characterizes digital leadership as the actions taken by school leaders to accept, adopt, and apply ICT to transform schools into environments conducive to digital learning.

During the COVID-19 pandemic, schools were required to close their doors to prevent social interactions and physical contact that could facilitate the spread of the virus. As a result, principals had to step into their roles as digital leaders, guiding online learning initiatives (Harris, 2020), assisting teachers in overcoming challenges during virtual sessions, and providing support to students (Kafa & Pashiardis, 2020). They were also tasked with encouraging teachers to utilise online platforms for their classes (Harris, 2020; Beilstein et al., 2021; Bradley & Sellars, 2020) and offering motivation and assistance to those struggling with technology (Kafa & Pashiardis, 2020). Thus, the pandemic shifted the leadership responsibilities of principals towards managing their schools in a virtual environment and overseeing online learning (Pollock, 2020). This situation highlighted the growing significance of digital leadership in schools, which had previously not been effectively harnessed (Berkovich & Hassan, 2024; Pollock, 2020).

Researchers in the field of school leadership have emphasised the essential role of principals as digital leaders. The role involves encouraging, supporting, and motivating teachers to integrate technology into their teaching practices. Despite the growing interest in this area, a significant gap remains in research regarding digital leadership within specific local contexts. Further studies are necessary to evaluate how digital leadership has facilitated the digitalisation of schools. This highlights the need for the development of a new assessment tool tailored to digital leadership in Malaysian schools, particularly in primary institutions that have been largely overlooked in previous research. A rigorous review of existing literature has revealed a scarcity of items explicitly developed to evaluate digital leadership, which is crucial for assessing school leaders' roles as digital leaders. Consequently, this article proposes an exploration of how digital leadership can be effectively implemented within the context of Malaysian schools as part of 21st-century learning, which emphasises the importance of ICT in modern education. It also advocates for the creation and validation of new items, instruments, and measurement models for digital-based leadership in Malaysian primary schools. The study aims to achieve the following objectives:

(a) to evaluate the digital leadership items for principals to establish their content validity using the Content Validity Index (CVI).
(b) to investigate the reliability and validity of these digital leadership items.
(c) to confirm the factor structure of the measurement model related to principal digital leadership.

2. Literature Review

2.1 Theoretical framework

In evaluating the roles and standards of school leaders in digital leadership, the International Society for Technology in Education (ISTE) (2014) has identified five essential elements of effective digital leadership practice: (a) Visionary leadership: This entails organisational leaders articulating a clear vision for the integration of digital technologies within the organization, driving transformation, and leveraging digitalisation to meet organizational objectives. As such, school leaders are also expected to support staff in the ongoing development, implementation, and communication of technology-enhanced strategic plans. (b) Learning culture in the digital age: School leaders are expected to cultivate and maintain a dynamic learning culture that embraces the digital age, providing an environment that fosters rigorous, relevant, and engaging learning experiences for students of all backgrounds and socioeconomic statuses. As digital leaders, they should advocate for the frequent and effective use of technology in learning while emphasizing the importance of digital literacy, innovation, creativity, and collaboration. (c) Excellence in professional practices: Leaders should empower staff to enhance and promote digital learning by supplying resources and opportunities for continuous professional development in technological proficiency and integration. (d) Systemic Improvement: School leaders are responsible for managing the effective use of information and technology resources to ensure ongoing improvement within the organisation. This includes recruiting staff capable of proficient technology use, establishing strategic partnerships, and providing a robust technological infrastructure. (e) Digital citizenship: organizational leaders must ensure equitable access to appropriate digital tools and resources while addressing various issues and responsibilities associated with digital culture.

2.2. Relevant models in digital leadership

In analysing the various models of digital leadership, several frameworks were studied and evaluated. Munsamy (2022) proposed a digital leadership model that includes five key components: (a) embracing digital: Organisational leaders should maintain a positive attitude toward the significance of digitalisation for their organizations. In this sense, digitalization is considered vital for organisational survival and involves collaboration, fostering a continuous mindset among staff, technology-driven initiatives, and a commitment to leveraging digitalization. (b) Leadership that supports the digital drive: Leaders must facilitate digitalization by demonstrating business acumen, enabling decision-making, adopting a solution-oriented approach, and promoting knowledge sharing through digital means, integrity, and flexible work practices. (c) Digital adaptability and resilience: This component encompasses adaptability, change management, self-awareness, and customer-centric digital initiatives. (d) Cultivating a digital culture: Organizations should foster creativity and innovation, promote fluid communication, strive for continuous improvement, and nurture digitally relationship-based potential. (e) Digital skills: This aspect includes knowledge of systems and tools, understanding digital processes, active listening, and data analytics. Additionally, a sixth component is digital competitive intelligence: This involves systemic thinking, an external focus, comprehending the risks and opportunities in the digital landscape, market and business intelligence, networking, and understanding social dynamics.

Alternatively, Yusof et al. (2019) proposed a digital leadership framework comprising two primary elements designed for practical implementation within the educational context: communication and school climate. In terms of communication, school leaders are encouraged to leverage digitalisation or ICT for various electronic communication purposes, including meetings, file sharing, discussions, information dissemination, and virtual interactions. Regarding school climate, school leaders should embed digitalisation into the school's objectives, foster staff development and professionalism in utilising digital tools, implement virtual teaching and learning strategies, monitor student performance, and establish a conducive digital learning environment.

Damayanti and Mirfani (2020) also introduced a framework for digital leadership from an Indonesian perspective, which examined five key aspects. The leadership and vision dimension includes elements that assess whether leaders are suitable to guide schools, their use of technology in instruction, and their decision-making processes. The teaching and learning component address the integration of ICT and technology platforms such as *Gmail, Google Meet, Zoom, Cloud Meeting*, and *WhatsApp* into

educational practices. The practice and professionalism dimension focuses on the effective implementation of digitalisation within schools. Lastly, the support, management, and operation dimension encompasses planning, organising, leading, and overseeing the utilisation of technology in the school environment.

2.3 The concept of digital leadership in education

The concept of digital-based leadership transcends traditional leadership, which relies on hierarchy and long-term planning. In contrast, digital-based leadership integrates both hardware and software to achieve organisational goals while aligning technological elements for meaningful outcomes (Cortellazzo et al., 2019; Ruloff & Petko, 2021; Yusof et al., 2019). Al-Ajmi (2022) defines digital-based leadership as the implementation of leadership processes that heavily rely on technology platforms. This approach is commonly utilized in business-oriented organisations as a strategic means to ensure success within the business ecosystem (El Sawy et al., 2020). This form of leadership is referred to by various names, including ICT leadership, technology leadership, virtual leadership, digital leadership, and online leadership (Jameson, 2013; Ridho et al., 2023). Narbona (2016) conceptualises digital leadership as the human aspect of leadership that is enhanced through the use of digital tools. Furthermore, Sasmoko et al. (2019) suggest that digital leadership integrates leadership capabilities with digital technology, thereby influencing both leadership and decision-making processes.

Karakose et al. (2021) characterise digital leadership as the integration of transformational leadership with the use of digital technologies. Similarly, Ping et al. (2024) note that digital-based leadership is often referred to by various terms, including "technology leadership," "information leadership," and "e-leadership," especially in the context of leaders influencing, promoting, and supporting the adoption of ICT within their school environments. Effective implementation of digital technologies in schools hinges on leaders who are both passionate and skilled in digitalisation (Christensen et al., 2018; Dexter & Richardson, 2020). Therefore, through digital leadership, school leaders are expected to provide support, facilitate professional development opportunities, and address challenges to foster the meaningful integration of technology into the school culture (Dexter, 2018; McLeod, 2018). Creating a school environment that embraces digitalisation necessitates a positive attitude from school leaders, which in turn serves to engage and motivate teachers (Mingaine, 2013; Hish & Segolsson, 2019; Gupta et al., 2023).

In the 21st century, school leaders are responsible for integrating technology into the educational experience to enhance teaching and prepare educators for the digital landscape (Zhong, 2016). Yusof et al. (2013) previously proposed a model of digital-based leadership in education that emphasises the practical application of various digital tools within schools, including online sessions, blogs, file sharing, and video conferencing, to improve both leadership and learning practices. Research has indicated that digital-based leadership significantly enhances teachers' digital literacy and facilitates the incorporation of technology and ICT in classroom environments. Through effective digital leadership, school leaders are expected to positively influence teachers' acceptance of using ICT, thereby fostering excellence in learning outcomes (Indra et al., 2022).

3. Methodology

3.1 Participants

This study aimed to gather the perspectives of primary school teachers on the digital leadership practices of their school leaders. The goal was to gain insights into how these leaders implemented digital leadership within their schools. The research involved 329 primary teachers from 14 schools, representing both urban and rural backgrounds. Participants were selected using a convenience sampling method based on their experience. The sample size was calculated with a 95% confidence interval and a 6.1% margin of error, establishing a minimum required sample size of 288. The actual participation of 329 teachers exceeded this requirement. Participation in the study was entirely voluntary, and all teachers provided their consent, with those hesitant to participate being excluded from the research.

A total of 329 primary school teachers were selected from 14 different educational institutions for this study. Among the participants, 97 teachers (29.05%) were male, while 232 teachers (70.5%)

were female. Descriptive analysis revealed that 65 teachers (19.8%) had been teaching for less than five years, 82 teachers (24.9%) possessed six to ten years of experience, and 182 teachers (55.30%) had taught for 11 to 20 years. Furthermore, the findings indicated that 238 teachers (72.3%) were from urban schools, while 91 teachers (27.7%) came from rural schools. Table 1 below provides a detailed breakdown of the teachers' demographics, including gender, school type, teaching experience, and their use of online learning platforms.

Table 1

Teachers' demographics

Demographics	N	Percentage
Gender		
Male	97	29.0
Female	232	70.5
School locations		
Rural schools	91	27
Urban schools	238	72.3
Teaching experiences		
Less than five years	65	19.8
Six to 10 years	82	24.9
11 to 20 years of experience	182	55.3

3.2 Instrumentation

The primary method for quantitative data collection is through the distribution of questionnaires. The questionnaire is divided into two main sections. Section A focuses on gathering demographic information about teachers, such as their gender, school locations, and teaching experience, while section B contains 21 items that assess the digital leadership practices of primary school principals, organized around three core constructs: addressing teachers' problems and challenges (7 items), providing support and motivation (7 items), and equipping teachers with essential ICT skills and foundational exposure (7 items). Each item uses a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Higher mean scores indicate a greater level of digital leadership practised by primary school leaders. The items were developed based on previous studies and literature regarding digital leadership, which have thoroughly examined and discussed its constructs.

Prior to the actual data collection, it is crucial to enhance the questionnaires through a pilot study designed to gather respondents' opinions and feedback, ultimately improving the quality of the items. Additionally, establishing a reliability index is necessary before proceeding with data collection. In this pilot study, 30 primary school teachers participated, providing valuable insights and suggestions for refining the questionnaire statements and scaling. The results yielded a Cronbach's alpha value of 0.902, indicating a strong level of reliability. The teachers' feedback was instrumental in revising the items to better align with the respondents' understanding and experiences related to online learning.

3.3 Data collection and analysis procedures

Questionnaires were administered to selected primary schools, resulting in 345 teachers returning their responses. However, only 329 of these were utilized for data analysis. Following careful review, 16 questionnaires were discarded because they did not meet the required criteria, namely for (a) selecting or providing more than one response and (b) failing to respond to all items on the questionnaire. Teachers were randomly chosen from lists of names supplied by their respective schools. Before distributing the questionnaires, permission to conduct the data collection was obtained from the principal of each school. Each questionnaire was accompanied by a consent form to ensure voluntary participation, and teachers were given one week to complete and return the questionnaires to the administrative staff. They were encouraged to read the instructions carefully and to provide honest answers to all items in the questionnaire.

Two primary tests were utilized to assess the consistency and alignment of items within constructs: exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). Additionally, the average variance extracted (AVE) and composite reliability index (CRI) values were computed. According to Fornell and Larcker (1981), the standard cut-off value for the CRI should exceed 0.70. Meanwhile, for the AVE assessment, Hair et al. (2018) and Bagozzi (1981) recommended that the value should meet a benchmark of 0.50 to establish construct and convergent validity.

The descriptive statistics included percentages for items related to the demographic variables of the teachers. Mean scores and standard deviations were calculated for all items based on the feedback from the teachers' survey. The confirmatory factor analysis (CFA) took into consideration the recommendations from Anderson and Gerbing (1988), who suggested examining the construct validity of the variables under study. Thus, the AMOS software runs a series of CFA models to inspect the significance and distinctiveness of chi-square statistics and fit indices, such as the Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI). Several recommended fit indices were utilised to assess the measurement and hypothesized models. To evaluate the model's quality, various indices were inspected, including the Chi-square statistic ($\chi 2$), the goodness-of-fit index (GFI $\geq .90$), the normed fit index (NFI $\geq .90$), the minimum discrepancy function by degrees of freedom (CMIN/DF $\chi 2$ /df ≤ 3), and the root mean square error of approximation (RMSEA between 0.05 to 0.08). In inspecting the values, Hu and Bentler's (1995; 1999) recommendations were followed: good and accepted fit statistics must exceed the values of 0.90 based on CFI, TLI, and NFI values, whereas the RMSEA value must be less than 0.08.

4. Results

4.1 Content validity

The focus of the first research question was on evaluating the content validity, specifically the Content Validity Index (CVI) values of the digital leadership items. The assessment began with an inter-rater approach to determine whether the content experts reached a consensus on the constructed items related to digital leadership. This method is effective in supporting the validity of the assessment tool (Yusoff, 2019; Davis, 1992). Subsequently, the experts' agreement was quantified using the Kappa Cohen/Modified Kappa approach. To determine the content validity and CVI values, we followed the methodology outlined by Mohd Yusof and Tengku Ariffin (2023) for contextual leadership among Malaysian principals. A similar approach was also employed by Salokivi et al. (2024) to draw the CVI values in their study.

For the inter-rater reliability assessment, we appointed two groups: one consisting of school leaders (n=2 primary principals) and the other comprising teachers from primary schools (n=2). This selection was based on their expertise in the practice and implementation (Salokivi et al., 2024) of digital leadership within schools during and after the pandemic. The selected teachers and principals were asked to review and rate all 21 items, providing feedback on the relevance of the items and their agreement with them (Polit & Beck, 2006; Polit et al., 2007).

Table 2

Assessments of I-CVIs from the agreements of the experts.

	Item statements **My principal…**	1	2	3	4	Number of approvals	CVR* values
1	provides training or workshops for teachers who are not proficient in ICT	√	√	√	√	4	1.00
2	exposure to relevant courses to do the online teaching	√	√	√	√	4	1.00
3	given reinforcement training through an online course provided	√	√	√	√	4	1.00
4	provide expert or technical assistance if teachers face technical problems in teaching and learning	√	√	√	√	4	1.00
5	I am asked to inform my school leader if there is a problem when teaching and learning using the online mode.	√	√	√	√	4	1.00

	Item statements **My principal…**	1	2	3	4	Number of approvals	CVR* values
6	loaned ICT equipment to teachers for online learning	√	√	√	√	4	1.00
7	asks other teachers if there are teachers who have problems learning online.	√	√	√	X	3	0.80
8	asks if there are students who have problems learning online	√	√	√	X	3	0.80
9	motivates teachers for teaching and learning purposes.	√	√	√	√	4	1.00
10	tells us about online learning problems related to the students' attendance.	√	√	√	√	4	1.00
11	strongly encouraged us to implement online learning even after the pandemic is over.	√	X	√	√	3	0.80
12	ensure that all teachers conduct teaching and learning classes even after the pandemic session	√	√	√	√	4	1.00
13	ensure that students feel comfortable and conducive to online learning sessions	√	√	√	√	4	1.00
14	Discussions with teachers are held regularly to ensure online learning sessions take place.	√	√	√	√	4	1.00
15	give feedback immediately when I face problems in online learning	√	√	√	√	4	1.00
16	immediately provide problem-solving suggestions when teachers face problems	√	X	√	√	3	0.80
17	asked to contact him/her if there is a problem while implementing online learning	√	√	√	X	3	0.80
18	provide teachers with technical staff who can help me if I face technical problems.	√	√	√	√	4	1.00
19	contact teachers immediately if they find out that I have problems with my online learning	√	√	√	√	4	1.00
20	provides resources to help teachers who face problems in online learning	√	√	√	√	4	1.00
21	Discuss with teachers often to solve problems during online learning sessions.	√	√	√	√	4	1.00
	Content Validity Ratio						**0.955**

*Content validity ratio (CVR) = (Ne−N/2)/(N/2) involves four expert panels (N = 4); items with CVR values of 0.8 and above were retained as instrument-forming items.

All teachers and principals were asked to give their agreement based on the items' ratings. The ratings are based on two-point ordinal ratings, which are: 1 - agreed and 2– disagreed (Lynn, 1986). The expert panellists, comprising primary principals and teachers were given the opportunity to write their comments on each item that they found difficult to understand and needed modifications or rewording (Salokivi et al., 2024). Table 2 also displays the calculation of the Modified Kappa or Kappa Cohen based on the study's findings from four assessors: two primary principals and two teachers who have evaluated the 21 items related to digital leadership. Each item was assessed separately. Items that scored 0.80 or higher were retained, while those scoring below 0.80 were either dropped or replaced (Polit & Beck, 2006; Polit et al., 2007). The scores for each item were then combined to obtain the inter-rater Modified Kappa or Kappa Cohen value. In this study, the scores given by the assessors were: Assessor 1 = 1.00, Assessor 2 = 0.964, Assessor 3 = 1.00, and Assessor 4 = 0.854. The combined score was 0.955 for the Content Validity Ratio (CVR).

4.2. Reliability analysis

The reliability of the items were determined by analysing all 21 items based on the responses of 369 primary teachers. The analysis answers research question 2, which focused on the reliability of the developed items.** In checking the reliability values, all 21 items were inspected based on Cronbach's alpha values. Results are presented in Table 3 below.

Table 3

Reliability values and mean scores

	Item statements My principal…	Cronbach's values	Mean scores	Standard Deviations
1	provides training or workshops for teachers who are not proficient in ICT	0.92	3.40	0.91
2	exposure to relevant courses to do the online teaching	0.94	3.33	0.81
3	given reinforcement training through an online course provided	0.92	3.40	0.92
4	provide expert or technical assistance if teachers face technical problems in teaching and learning	0.92	3.39	0.98
5	I am asked to inform my school leader if there is a problem when teaching and learning using the online mode.	0.92	3.53	0.93
6	loaned ICT equipment to teachers for online learning	0.92	3.24	0.93
7	asks other teachers if there are teachers who have problems learning online.	0.92	3.55	0.92
8	asks if there are students who have problems learning online	0.92	3.70	0.92
9	motivates teachers for teaching and learning purposes.	0.92	3.57	0.93
10	tells us about online learning problems related to the students' attendance.	0.92	3.79	0.94
11	strongly encouraged us to implement online learning even after the pandemic is over.	0.92	3.28	0.97
12	ensure that all teachers conduct teaching and learning classes even after the pandemic session	0.93	4.08	0.98
13	ensure that students feel comfortable and conducive to online learning sessions	0.93	3.66	0.97
14	Discussions with teachers are held regularly to ensure online learning sessions take place.	0.93	3.60	0.82
15	give feedback immediately when I face problems in online learning	0.94	3.53	0.66
16	immediately provide problem-solving suggestions when teachers face problems	0.94	3.60	0.73
17	asked to contact him/her if there is a problem while implementing online learning	0.94	3.60	0.83
18	provide teachers with technical staff who can help me if I face technical problems.	0.94	3.45	0.89
19	contact teachers immediately if they find out that I have problems with my online learning	0.94	3.48	0.88
20	provides resources to help teachers who face problems in online learning	0.94	3,36	0.78
21	Discuss with teachers often to solve problems during online learning sessions.	0.94	3.51	0.93
	Overall mean score and alpha value	0.94	3.72	0.89

In Table 3, In general, the reliability analysis indicated that all 24 items had acceptable values. The analysis of Cronbach's alpha values showed a range from 0.92 to 0.94, signifying good reliability and internal consistency. This meant that all 21 items achieved the accepted criteria of exceeding 0.70 as suggested by Hair et al. (2019). Additionally, their mean scores and standard deviations were analysed. The average mean score of 3.72 indicates a high level of digital leadership practice. Thus, this has illustrated that the primary principals have effectively fulfilled their duties, roles, and responsibilities as digital leaders in schools.

4.4. Exploratory factor analysis

In the realm of digital leadership, the KMO-MSA analysis revealed a value of 0.943, which is considered acceptable for EFA implementation (Morgan et al., 2013; Kaiser, 1974; Ho, 2006). Additionally, Bartlett's Test of Sphericity produced accepted values (Appro. $\chi 2 = 4884.0379$; df = 190;

Sig. = 0.00). The EFA analysis results showed that digital-based leadership is comprised of three-factor component matrices after the *Varimax* rotation procedure: solving teachers' problems and issues (7 items), providing support and motivation (7 items), and equipping teachers with basic ICT skills and initial exposure (7 items). The initial eigenvalues were greater than 1, and the total variance explained was 65.816% for the digital leadership construct (see Table 4). As illustrated in Table 1, the constructed items about digital leadership displayed factor loadings exceeding 0.40. Factor 1 consisted of 7 items on a 5-point Likert scale, explaining 52% of the variance, with factor loadings ranging from 0.567 to 0.818. This factor represents the aspects of giving motivation, encouragement, and support.

Table 4

Factorial loading, internal consistency, and mean scores for digital leadership

	Item statements **My principal…**	Factor loadings **Factor 1** Giving support and motivation	**Factor 2** Solving problems	**Factor 3** Prepare ICT skills and support	**AVE**	**CRI**
1	provides training or workshops for teachers who are not proficient in ICT			**.783**		
2	expose to relevant courses to do the online teaching			**.768**		
3	given reinforcement training through an online course provided			**.518**		
4	provide expert or technical assistance if teachers face technical problems in teaching and learning			**.617**	0.616	0.81
5	I am asked to inform my school leader if there is a problem when teaching and learning using the online mode.			**.480**		
6	loaned with ICT equipment to teachers for online learning			**.592**		
7	asks other teachers if there are teachers who have problems learning online.			**.559**		
8	asks if there are students who have problems learning online		**.631**			
9	motivates teachers for teaching and learning purposes		**.668**			
10	tells us about online learning problems related to the students' attendance.		**.806**			
11	strongly encouraged us to implement online learning even after the pandemic is over.		**.484**			
12	ensure that all teachers conduct teaching and learning classes even after the pandemic session		**.819**			
13	ensure that students feel comfortable and conducive to online learning sessions		**.641**			
14	Discussions are held regularly to ensure online learning sessions take place.		**.348**		0.671	0.88
15	give feedback immediately when I face problems in online learning	**.688**				
16	immediately provide problem-solving suggestions when teachers face problems	**.720**			0.730	0.851
17	asked to contact him/her if there is a problem while implementing online learning	**.740**				
18	provide teachers with technical staff who can help me if I face technical problems.	**.837**				
19	contact teachers immediately if they find out that I have problems with my online learning	**.656**				
20	provides resources to help teachers who face problems in online learning	**.690**				
21	discuss with teachers often to solve problems during online learning sessions.	**.783**				
	Percent of variance	52.410	8.114	5.292		
	Overall mean score and alpha value					

Note: Loadings less than 0.4 are omitted.

Factor 2 included 7 items that explained 8.1% of the variance, with factor loadings from 0.585 to 0.803. However, item 14 was discarded due to its low factor loading of 0.348, which did not meet the 0.5 cut-off threshold for item acceptance. According to Chin (1998), items should have loading values of at least 0.5 to be considered valid. As a result, Factor 2 was labeled as solving problems while teachers use ICT for teaching and learning in classes. Thus, only 6 items remained in this factor instead of the initial 7 items, focusing on school leaders' digital leadership practices related to problem-solving. Finally, Factor 3 comprised 7 items, explaining 5.2% of the variance with factor loadings ranging from 0.574 to 0.793. Although 21 items were evaluated, only 20 items were retained to measure the practice of digital leadership. The calculated average variance extracted (AVE) values were 0.616 for ICT skills and exposure, 0.671 for problem-solving, and 0.730 for support and motivation. The composite reliability index (CRI) was 0.81 for ICT skills and exposure, 0.88 for problem-solving, and 0.85 for support and motivation.

4.5. Confirmatory factor analysis

To conduct confirmatory factor analysis (CFA), we constructed measurement models based on the main variable of digital leadership. We evaluated the measurement model using various fit indexes such as the Comparative Fit Index (CFI), Incremental Fit Index (IFI), Normalized Fit Index (NFI), and Root Mean Square Error of Approximation (RMSEA). As suggested by Hair et al. (2013), the recommended values for these fit indexes are CFI > 0.90, RMSEA < 0.08, and Ratio $\chi 2/df < 5.0$. After completing the exploratory factor analysis (EFA), we developed the measurement model using the CFA method. The CFA analysis began with constructing the measurement model for digital leadership. In the process, we developed four phases of measurement models to assess the fit statistics of the CFA for digital leadership. We also utilised the modification indices procedure to improve the fit statistics values and reduce the RMSEA value. The latest fit statistics for the confirmatory factor analysis for digital leadership exceed the recommended values by Hair et al. (2019). The calculated average variance extracted (AVE) is 0.710 for ICT skills and exposure, 0.732 for problem-solving, and 0.653 for providing support and motivation. The composite reliability index (CRI) values are 0.76 for ICT skills and exposure, 0.81 for problem-solving, and 0.84 for providing support and motivation.

Figure 1

The hypothesized model of confirmatory factor analysis for digital leadership

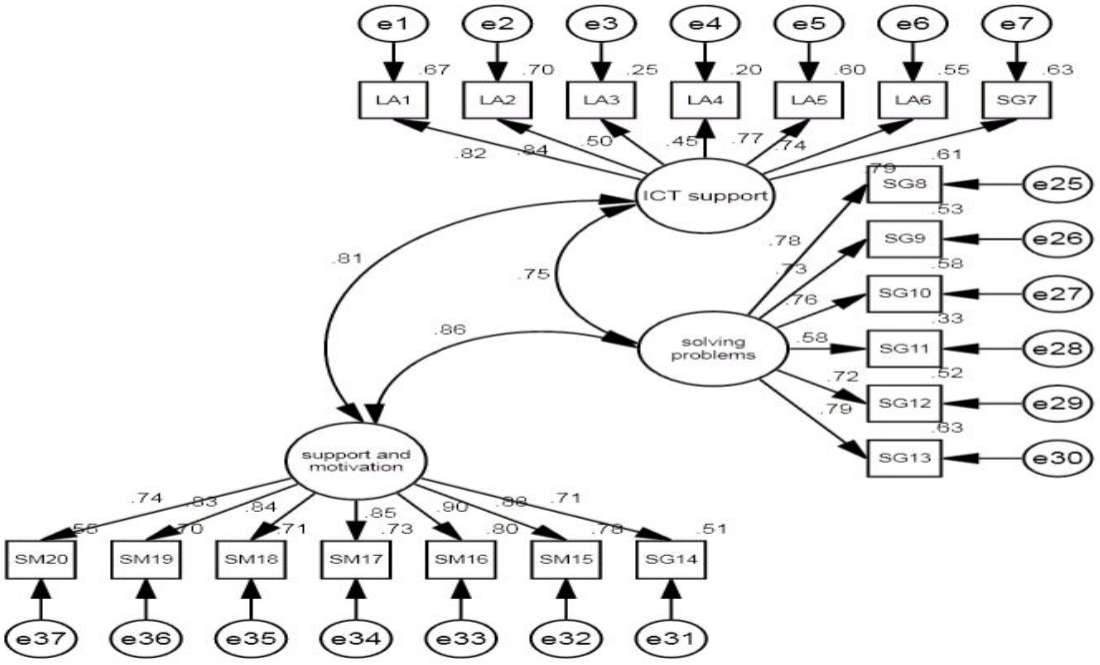

Table 5

Improvement of the fit statistics for digital leadership

Model	χ^2/df	IFI	CFI	NFI	RMSEA
Model 1	5.548	.875	.874	.851	.118
Model 2	4.242	.912	.912	.889	.100

Table 5 displays the fit statistics for hypothesised digital leadership models. In the first model, the χ2/df value was 5.548, df = 74, IFI = 0.875, CFI = 0.874, NFI = 0.851, and the RMSEA was 0.118. The second model exhibited improved fit statistics with a lower RMSEA value. Specifically, in the second model, the χ2/df was 4.242; NFI = 0.947, IFI = 0.968, CFI = 0.968, and RMSEA was 0.100, indicating an improvement compared to the first model. Moreover, there were also strong relationship values that validate the connection between the three major constructs of digital leadership. The associations between ICT skills support to problem-solving (r = 0.79; p 0.00), ICT skills support and motivation (r = 0.65; p= 0.00), and support and motivation with problem-solving (r = 0.86; p= 0.00).

4.6. Second-order confirmatory factor analysis

The final analysis involves establishing a second-order measurement model for confirmatory factor analysis of digital leadership from the perspective of primary Malaysian teachers. The analysis shows the measurement model fits well based on fit statistics values. The latest fit statistics for the fourth model of CFA for digital leadership are as follows: χ2/df = 1.644, NFI = 0.968, CFI = 0.987, IFI = 0.987, and RMSEA = 0.44, which exceeds the recommended values by Hair et al. (2013). The calculated average variance extracted (AVE) is 0.725 for ICT skills and exposure, 0.741 for problem-solving, and 0.659 for providing support and motivation. The composite reliability index (CRI) values are 0.81 for ICT skills and exposure, 0.88 for problem-solving, and 0.85 for providing support and motivation.

Figure 2

The second-order measurement model for digital leadership

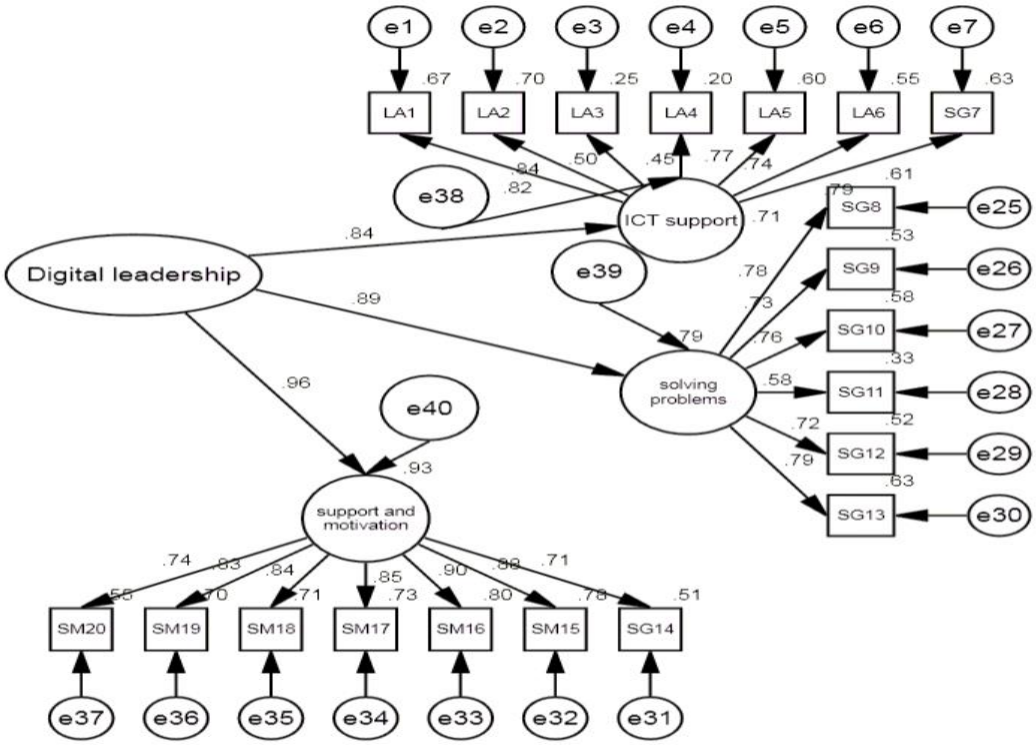

Table 6 displays the fit statistics for four hypothesised models. The first model had a χ2/df value of 5.548, IFI = 0.875, CFI = 0.874, NFI = 0.851, and an RMSEA of 0.118. In comparison, the second model exhibited improved-fit statistics with a lower RMSEA value. Specifically, the second model had a χ2/df = 2.345, NFI = 0.947, IFI = 0.968, CFI = 0.968, and RMSEA = 0.066. This demonstrates an enhancement relative to the first model. Upon analysing the third model, the fit statistics continued to increase, and the RMSEA values were noticeably lower. Model 3 reported a χ2/df = 2.087, IFI = 0.977, CFI = 0.977, NFI = 0.957, and RMSEA = 0.058.

Table 6

Improvement of the fit statistics for digital leadership

Model	χ^2/df	IFI	CFI	NFI	RMSEA
Model 1	5.548	.875	.874	.851	.118
Model 2	2.435	.968	.968	.947	.066
Model 3	2.087	.977	.977	.957	.058
Model 4	1.644	.987	.987	.968	.044

Table 6 displays the fit statistics for four hypothesised models. The first model had a χ2/df value of 5.548, IFI = 0.875, CFI = 0.874, NFI = 0.851, and an RMSEA of 0.118. In comparison, the second model exhibited improved-fit statistics with a lower RMSEA value. Specifically, the second model had a χ2/df = 2.345, NFI = 0.947, IFI = 0.968, CFI = 0.968, and RMSEA = 0.066. This demonstrates an enhancement relative to the first model. Upon analysing the third model, the fit statistics continued to increase, and the RMSEA values were noticeably lower. Model 3 reported a χ2/df = 2.087, IFI = 0.977, CFI = 0.977, NFI = 0.957, and RMSEA = 0.058. Lastly, Model 4 reported better and accepted values: χ2/df = 1.644, IFI = 0.987, CFI = 0.987, NFI = 0.968, and RMSEA = 0.044. Furthermore, Table 5 and Figure 2 display the results for the second-order CFA for digital leadership. Figure 2 illustrates the second-order measurement model, or CFA model, which was constructed from the analysis. Additionally, the factor loadings ranged from 0.79 to 0.90. The average variance extracted (AVE) and composite reliability (CR) were also checked to ensure the convergent validity of the model (Kline, 2011).

5. Discussion

Digital leadership is defined as an abstract process that empowers, supports, and motivates teachers to integrate digital technologies or ICT in educational settings (Sagbasi & Erdogan, 2022; Okunlola et al., 2024). Therefore, this study focuses on the factor structure necessary for constructing and developing items related to digital leadership, which was evaluated through multivariate statistics to ensure consistency and reliability. Furthermore, the items pertaining to digital leadership were analyzed using Kappa Cohen or Modified Kappa agreements to assess high levels of inter-rater reliability.

In this study, all 21 items were developed by the researchers and underwent psychometric tests and assessments to ensure their validity in evaluating the practice of digital leadership among primary principals. After assessments and content validity procedures, the items were grouped into three dimensions: (1) providing support, encouragement, and motivation for digitalization (7 items); (2) problem-solving in digitalization (7 items); and (3) providing ICT support and resources (7 items). One item was discarded due to low factor loading during the exploratory factor analysis (EFA).

To obtain the content validity ratio (CVR) values, two principals and two teachers were appointed to evaluate the relevance of the items. All 21 items received strong CVR values, leading to a scale content validity index (S-CVI) of 0.955, indicating that the self-developed items on digital leadership possess high and acceptable content validity. These results support the measurement and consistency of the digital leadership scale. The study assessed the reliability and factor structure of the 21 items, finding an overall Cronbach's alpha value of 0.94, which indicates good reliability. Each of the 21 items demonstrated strong reliability and internal consistency, with Cronbach's alpha values exceeding 0.90,

surpassing the accepted criterion of 0.70. Mean scores and standard deviations were also analyzed. The average mean score for the digital leadership items reflects a high level of digital leadership practice, indicating that primary principals are effectively fulfilling their duties and responsibilities.

The exploratory factor analysis (EFA) confirmed three major factors related to digital leadership: (1) providing support, encouragement, and motivation for digitalization; (2) problem-solving in digitalization; and (3) providing ICT support and resources. The accounted variance for all 21 items related to digital leadership was noted at 65.8 percent, indicating that the items can be grouped into these three primary constructs. Following the EFA, item 14 was discarded due to its low loading value, which fell below the cut-off threshold of 0.5, as suggested by Chin (1998). Consequently, only 20 items reported factor loadings exceeding the recommended value of 0.5. Additionally, the calculated average variance extracted (AVE) exceeded the accepted value of 0.60 for all three constructs. The composite reliability index (CRI) also indicated values that surpassed the accepted standard of 0.80 for each of the constructs.

The next phase of the analysis involves developing a measurement model through Confirmatory Factor Analysis (CFA) for digital leadership. The purpose of this model is to evaluate the factor structure and internal consistency of items related to three constructs: (1) providing support, encouragement, and motivation for digitalization; (2) problem-solving in digitalization; and (3) providing ICT support and resources. The CFA results supported a three-factor structure for digital leadership. The analysis revealed strong correlations between the three constructs, with values exceeding r=0.65, indicating a high degree of correlation. The fit statistics were also within an acceptable range, with $\chi 2/df = 4.242$, NFI = 0.947, IFI = 0.968, CFI = 0.968, and RMSEA = 0.100. A second-order CFA for all three constructs of digital leadership was subsequently developed; this modification yielded even better and acceptable values: $\chi 2/df = 1.644$, IFI = 0.987, CFI = 0.987, NFI = 0.968, and RMSEA = 0.044.

The first construct of digital leadership pertains to the role of principals in providing support, encouragement, and motivation. This includes principals offering teachers advice, support, and motivation to effectively use digital platforms for instructional purposes. Principals are expected to provide prompt solutions to teachers who encounter challenges during their online learning sessions (Beilstein et al., 2021; Bradley & Sellars, 2020). Additionally, principals should ensure that teachers communicate any issues they face while using the online platform. It is also essential for school leaders to provide technical assistance to teachers dealing with problems during online learning sessions (Dexter, 2018; McLeod, 2018). If the principal is unable to assist directly, they must coordinate with technical staff to help resolve any technical issues that teachers may encounter (Antonopoulou et al., 2020; Aksal, 2015). Principals, as digital leaders, need to address the online learning challenges faced by teachers by frequently offering help and guidance on technical matters, as well as providing suggestions for overcoming problems that arise during online instruction (Awidi & Cooper, 2015; Chua & Chua, 2017).

The second construct pertains to the role of school leaders in supporting teachers with ICT-related knowledge through the provision of courses or workshops aimed at enabling effective and efficient implementation of ICT-assisted teaching. Consequently, principals are expected to organize relevant training sessions for teachers who may lack the necessary knowledge and skills in ICT (Dexter, 2018; McLeod, 2018). In their capacity as digital leaders, principals must ensure that teachers are adequately exposed to strategies for implementing ICT-assisted instruction. Furthermore, they are tasked with providing technical skills and expertise to those teachers who encounter challenges, proactively identifying any issues that may arise. This may even extend to providing teachers with access to the school's computer or ICT equipment when they face technological difficulties during online teaching.

The problem-solving construct highlights the principal's essential role in addressing challenges that teachers encounter while implementing online instruction. Within this framework, principals must pay close attention to the students' readiness and ability to participate in online learning sessions. Additionally, as digital leaders, principals are required to motivate teachers, particularly those who have never engaged in online teaching (Raman & Thannamalai, 2019). Many teachers have expressed feelings of pressure when asked to adopt online teaching methods, especially if they lack prior experience. Thus, the principal's role is to offer encouragement and expert assistance to these teachers. It is equally important for principals to ensure that both teachers and students feel comfortable and

unburdened during online learning sessions, even in the aftermath of the COVID-19 pandemic (Al-Ajmi, 2022).

5.1. Study's limitation

The study on digital leadership revealed that certain psychometric indicators fell within accepted ranges. However, several limitations should be acknowledged. Firstly, the research focused solely on principals and teachers from primary schools, excluding participants from secondary schools, religious institutions, high-performing institutions, or technical schools. To yield more meaningful insights, future studies should aim to include samples from these other educational types to provide a comprehensive overview and contrast within the Malaysian educational landscape. Secondly, the items assessing digital leadership were originally designed to measure the support provided by school leaders or principals to teachers in their utilization of digital and ICT platforms in their teaching roles. These items were initially formulated in Malay to ensure clarity for locally based educators; however, this approach restricts the applicability for cross-cultural research. Thus, it is recommended that future research translate these items into English and validate them using a more diverse sample to achieve a broader range of findings, as suggested by Mei et al. (2023), rather than relying exclusively on the Malay language.

5.2. Practical implications

Despite the acknowledged limitations, the items related to digital leadership are regarded as reliable and valid measures within the context of education, particularly in primary schools, which have been less explored in this area. Consequently, these digital leadership items can serve as a validated instrument comprising 20 items. Utilizing these items facilitates a deeper understanding of principals' roles in supporting teachers with the digitalization process in schools, especially in instructional activities such as teaching and learning. Additionally, the digital leadership items enable education authorities to evaluate whether school leaders are effectively implementing or supporting digital initiatives. If the results are unfavorable, officials at the national or district level can offer assistance to principals and school leaders. This support may include providing ICT or computer courses tailored specifically for school leaders, particularly principals.

In terms of personal growth and self-assessment, principals can gather comprehensive feedback from teachers regarding their effectiveness as digital leaders. Should teachers perceive the principal's role as ineffective, the principal has the opportunity to enhance their digital leadership skills. Furthermore, Mohd Yusof and Tengku Ariffin (2023) noted that developing criteria for digital leadership can be instrumental in assessing the training of future school leaders for their roles as digital leaders. These criteria can also be applied to evaluate the digital leadership roles of principals within the educational system beyond Malaysian schools.

6. Conclusion

The concept of digital leadership in schools highlights the critical role of school leaders in supporting, motivating, and equipping teachers throughout the digital transformation process. By fostering digital leadership, educators are encouraged to leverage ICT and digital platforms to enhance their teaching effectiveness. This study developed the Digital Leadership Scale (DLS), offering a user-friendly questionnaire to assess the role of principals as digital leaders within their schools. The scale's reliability and validity, demonstrated through Content Validity Index (CVI), Exploratory Factor Analysis (EFA), and Confirmatory Factor Analysis (CFA), underscore its effectiveness as a tool for measuring the leadership roles of principals in the digital age.

7. Co-Author Contributions

The authors affirmed that there is no conflict of interest in this article. The first, second, and third co-authors were responsible for the theoretical and conceptual framework of the study, data, and data

collection. The first and fourth co-authors were responsible for proofreading and editing the manuscript, and the second and third co-authors were responsible for the data analysis.

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