

Enhancing Leadership for Sustainable Digital Transformation: Insights from Secondary Schools

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ABSTRACT

Digital transformation in secondary education presents opportunities for innovation but also poses sustainability challenges that extend beyond technological implementation. This study explores the critical role of leadership in ensuring the sustainable integration of digital technologies in private secondary schools. A mixed-methods design was employed, involving a survey of 284 teachers from private high schools in West Java and Jakarta, alongside in-depth interviews with school leaders. Quantitative data were analyzed using Structural Equation Modeling (SEM) to examine the relationships between leadership, institutional culture, digital maturity, and transformation outcomes. Findings indicate that leadership has a significant direct and indirect impact on digital transformation. Specifically, effective leadership fosters a supportive institutional culture and enhances digital maturity, both of which are essential for schools to successfully adapt to digital change. Schools with strong leadership demonstrated higher levels of readiness and adaptability in navigating technological shifts. The study underscores leadership as a key driver in aligning institutional culture with digital infrastructure to sustain transformation efforts. A robust digital ecosystem—characterized by well-developed infrastructure, collaborative practices, and effective governance—was found to be essential for long-term success. Strategic leadership is vital for the sustainable digital transformation of educational institutions. Strengthening leadership capabilities is crucial for cultivating digital maturity and achieving enduring institutional resilience in the face of evolving technological demands.

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1. INTRODUCTION

Digital transformation (DT) in education marks a significant shift in institutional practices, extending beyond the integration of digital tools to include changes in governance, pedagogy, and organizational culture. While DT enhances adaptability and fosters innovation, it is neither linear nor purely technical.

Rather, it is a socially embedded and strategically complex process that requires coordinated alignment across multiple institutional dimensions (Ziyadin et al., 2020; Hanelt et al., 2021). Despite its potential, DT also introduces challenges such as declining student literacy, weakened teacher-student relationships, and increased digital fatigue (Alhumaid, 2019). These issues are particularly pronounced in countries still in the early stages of digital integration.

Indonesia offers a pertinent case study due to its disparities in digital infrastructure, socio-economic diversity, and policy limitations within secondary education. Many Indonesian schools lack a coherent strategy for digital transformation, underscoring the critical role of leadership in fostering sustainable change. Leadership shapes the vision and strategy for digital integration and directly influences digital maturity and institutional readiness (Weber et al., 2022; Konopik et al., 2022). However, there is limited understanding of how leadership operates as a dynamic resource during digital change.

This study addresses that gap by examining how leadership interacts with organizational culture and digital maturity to influence the sustainability of digital transformation in Indonesian secondary schools. Digital leadership—defined as the capacity to guide institutions through technological change while fostering a supportive culture—emerges as an essential leadership model in the digital age (Anwar & Saraih, 2024; Connolly et al., 2023; Gledson et al., 2024). Though rooted in the concept of e-leadership, digital leadership is a relatively new interdisciplinary field that requires deeper exploration across all levels of the educational system (Jameson et al., 2022; Tigre et al., 2023; Zahra & Wirawan, 2024; Gilli et al., 2024).

Leadership influences culture (Alabdali et al., 2024; Gilli et al., 2024), a crucial capability in the transformation process. Leaders must recognize the impact of their decisions on subcultures within the institution, and effective leadership fosters collaboration and cultural awareness, ensuring that diverse subcultures can work together positively (Normore et al., 2016). Leadership inspires innovation, culture development, and sustainable digital transformation (Shin et al., 2023; Timotheou et al., 2023). Digital culture refers to the values, practices, and expectations concerning how people behave and interact within the connected, networked society (Deuze, 2006; Shin et al., 2023). In the context of digital transformation, the influence of leadership on culture requires further study. From a contingency perspective, leadership is highly dynamic. Contingency and functional leadership theories suggest that any leadership style can be effective if it aligns with the goals and disposition of the organization (Eva et al., 2018; Kumar et al., 2023).

In addition to culture, organizational capability includes digital maturity, which is the ability to respond to the rapidly evolving digital business environment (Fernández et al., 2023; Thordsen & Bick, 2023), including in education (Marks & Al-Ali, 2022). (P. Senna et al., 2023) indicate that digital maturity helps assess readiness to adopt digital technologies. Farias-Gaytan et al. (2023) highlight that developing digital skills is crucial. Konopik et al. (2022) emphasize that sustaining the transformation process involves introducing various digital technologies into activities, such as IoT, cloud computing, advanced algorithms, artificial intelligence, hyper-connectivity, self-learning systems, automation, big data, and analytics (Imran et al., 2021). Digital leadership influences digital maturity (Abbu et al., 2020; Kaufmann, 2022; Shin et al., 2023; Zhan et al., 2024). Digital maturity positively impacts performance through enhanced digital capabilities (Shin et al., 2023). Despite the importance of digital maturity, digital skill levels remain uneven in countries like Indonesia (Indonesian Internet Service Providers Association, 2023).

Leadership plays a central role in the dynamic development of organizational capabilities such as culture and digital maturity, ensuring the sustainability of the digital transformation process. The role of leaders is strategic in the transformation process. Leadership influences culture, which reflects an organization's capability to transform (Al Nuaimi et al., 2024; Arham et al., 2024; Schein, 1992; Zhan et al., 2024). Leadership determines the sustainability of the transformation process (Khaw et al., 2022). The interaction between resources and the environment cannot be ignored in this process.

The digital educational ecosystem influences organizational capabilities and functions. Suleimankadieva et al., (2021) describe the "digital educational ecosystem" as aligned with the term

"ecological system," which is built based on global trends in educational space development and considers the characteristics of modern intellectual economies. The digital educational ecosystem can be divided into two main structural entities: the educational ecosystem and the digital ecosystem, which coexist specifically (Chigbu et al., 2023; Markoska, 2017). Despite its importance, the digital ecosystem has yet to receive the research attention it deserves, even though its significance is increasing in the educational world (Rojas & Chiappe, 2024). The role of the environmental theme in adopting and enhancing digital technology has yet to be a focus (P. Senna et al., 2023). In Indonesia, the digital ecosystem is still in the growth stage, with infrastructure and digital ecosystem scoring 57.06 (Indonesia Digital Society Index/IMDI, 2023).

This research has contributions. First, it highlights the importance of understanding digital transformation as a process of social change at the organizational level. Second is the need to understand the support of organizational capabilities as a function of the digital transformation process in a highly dynamic digital environment. Strong organizational capabilities in the context of digital transformation enable organizations to manage change better, create new value, and maintain their competitiveness in the digital era. Third, it provides a clear and detailed view of the leadership model needed to ensure the success of the digital transformation process.

The research objective is derived from the formulation of the research question, which is as follows:

RQ1 : How effective is Digital Leadership in influencing the process of sustainable digital transformation, both directly and indirectly, through digital culture and digital maturity?

RQ2 : How does the role of the Digital educational ecosystem moderate the influence of digital leadership and digital culture on digital maturity?

RQ3 : How does digital maturity affect the sustainable digital transformation process?

The structure of this journal consists of four sections. The first section is the Introduction, which outlines the theoretical gaps in leadership and its relationship with other dynamic organizational capabilities in digital transformation processes. The second section is the Research Method, which details the chosen methods and data collection techniques following the selected sample. The third section presents the research results, followed by the fourth section, which discusses the findings. This section analyzes the results based on field findings, compares them with previous studies, and discusses the contribution of the research to addressing knowledge gaps regarding leadership in the context of digital transformation. The Conclusion is presented, followed by the limitations and theoretical implications of the research, including the contribution to knowledge and practical implications for educational institutions..

2. METHODS

This study employed a mixed-methods sequential exploratory design (Leso et al., 2023; Venkatesh et al., 2016) to investigate leadership as an organizational capability in the context of digital transformation (DT) in Indonesian secondary schools. The integration of qualitative and quantitative methods enabled the development and empirical testing of a conceptual model grounded in real-world insights, offering both interpretive depth and statistical validation.

2.1 Qualitative Phase: Exploration and Theory Development

The initial qualitative phase involved semi-structured interviews and focus group discussions (FGDs) with key stakeholders—teachers, principals, and digital transformation experts—selected through purposive and snowball sampling. Selection criteria included active involvement in DT initiatives and demonstrable digital maturity. Interviews were conducted via video conferencing, recorded with informed consent, transcribed, and returned to participants for validation to ensure accuracy.

Data were analyzed using Grounded Theory methodology. The process began with Open Coding, where interview transcripts were segmented and labeled to extract key concepts. This was followed by Axial Coding, which organized related codes into broader categories to identify recurring patterns and relationships. These emergent themes served as the foundation for the development of a conceptual model, representing the interplay among leadership, organizational culture, and digital maturity.

2.2 Quantitative Phase: Model Testing

Insights from the qualitative phase directly informed the design of the quantitative instrument, particularly constructs such as adaptive leadership, digital readiness, and collaborative culture. A structured online questionnaire using a five-point Likert scale was distributed to a sample of 284 respondents, including teachers, school leaders, and parents from private high schools in West Java and Jakarta. Participants were selected via simple random sampling, ensuring representation and meeting the recommended sample size for Structural Equation Modelling (SEM), which requires at least 200 observations for robust statistical analysis (Hair et al., 2019).

2.3 Data Analysis

The data analysis followed a sequential approach. First, qualitative themes were transformed into quantifiable variables. Next, SEM was used to evaluate the relationships among leadership, institutional culture, digital maturity, and DT outcomes. Statistical tests included assessments of reliability (Cronbach's alpha), construct validity (confirmatory factor analysis), and multicollinearity (Variance Inflation Factors – VIFs) to ensure the robustness of the model.

2.4 Ethical Considerations

All participants provided informed consent prior to data collection. Anonymity and confidentiality were maintained throughout, and data were used exclusively for research purposes. Ethical approval was granted by the Institutional Review Board (IRB) of the affiliated university.

2.5 Limitations

Potential biases stemmed from snowball sampling during the qualitative phase and self-reported survey data in the quantitative phase. These were mitigated through triangulation—cross-validating data via FGDs and integrating multiple sources—and member-checking, where participants reviewed and confirmed the accuracy of transcripts.

2.6 Research Flow

A visual summary of the research process is provided in Figure 1, illustrating the interplay between the qualitative and quantitative phases. The diagram highlights how qualitative findings informed the survey design and how the resulting conceptual model was tested empirically using SEM.

Figure 1. The research flows.

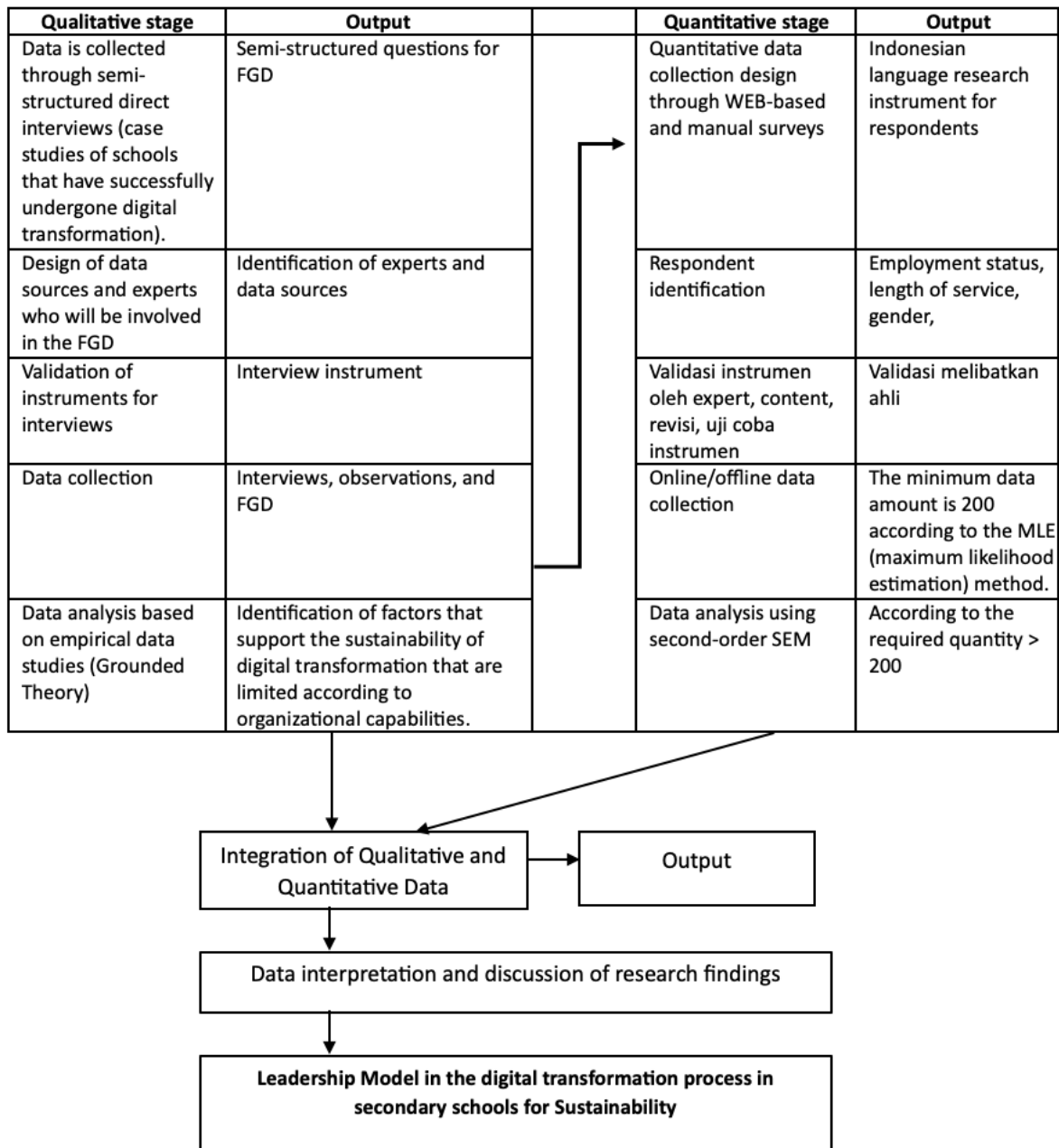


Figure 1. Research Flow

3. FINDINGS AND DISCUSSION

3.1 Qualitative Research Results

A qualitative study based on interviews with various competent stakeholders, including education practitioners, ICT professionals, and teachers, reveals that the digital transformation process in education encompasses deep technology integration, strong understanding and support from the entire school community, management of digital challenges and risks, and continuous updates in technology

and knowledge. The success of digital transformation depends on how these elements are applied and managed together. Technology use should not be merely an additional tool but an integral part of the educational process. All members of the school community—including students and educators—must understand and support the use of technology to ensure that it enhances the quality of learning. Digital transformation is demonstrated by the availability and use of adequate equipment, and training for both educators and students is crucial to ensure effective technology utilization. Readiness to use technology and adequate devices are key factors in the success of digital transformation. Education on handling and managing digital risks is important to protect students and ensure they use technology safely. Educators must provide an understanding of digital risks and how to avoid them as part of the curriculum. It is acknowledged that technology has negative impacts. Technology evolves rapidly, so it is essential to update devices and knowledge about technology continuously. Ongoing updates in technology and understanding of digital innovations help ensure that the learning process remains relevant and effective. Continuous training for teachers and updates to technological devices are integral parts of this process.

The interviews provided significant insights into the importance of leadership in digital transformation in education and the challenges faced. According to a senior teacher/assistant principal (ADS):

“Strong and highly hierarchical leadership within educational institutions plays a crucial role in making decisions and policies that support the implementation of digital technology. Leaders face challenges in digital transformation, such as human resources readiness and device adequacy. Digital transformation requires time and a phased process to be fully implemented within educational units. Leadership must ensure that the technology applied aligns with the school’s vision and mission and supports long-term graduate quality. (Source: Semi-structured interview with the assistant principal/senior teacher, 2024)”

The leader's character is crucial for ensuring the success of the digitization process. Assertive and straightforward leadership is essential in the digital transformation process. Leaders must ensure that human resource preparation and educational device provisioning are well-managed. In digitization, it is important to integrate ethics and religious norms into learning to prevent students from accessing inappropriate content and ensure that technology use benefits the learning process. Leaders must address challenges related to varying ages and digital competencies among teachers. All young and old teachers must be trained to ensure adequate digital competencies. This point of the interview highlights the importance of strong leadership models and ethics in supporting digital transformation in schools.

Several teachers and school staff have acknowledged that providing devices and human resources (HR) is a major concern. Schools face various limitations, particularly budget constraints. They must prepare hardware such as projectors, laptops, and web-based platforms to support the learning process. On the other hand, not all teachers and instructors possess the digital competencies to integrate technology into teaching effectively. For some teachers, making the learning process more engaging and effective through digital technology has yet to become a primary focus, unlike younger teachers. This challenge requires support from the government and associations in training and developing digital competencies for educators. Schools must also collaborate in preparing various devices and resources, including digital libraries and laboratories. This preparation must be done progressively but consistently to ensure the sustainability of education.

In interviews with education practitioners, IT experts, and teachers, several important points regarding digital transformation in education were discussed in depth. Education practitioners emphasized that technology must be integrated into all school learning aspects. According to them, the entire school community, including students and educators, needs to understand and support digital transformation. IT experts added that comprehensive technology implementation is crucial for

enhancing educational effectiveness. They highlighted that all aspects of learning should involve technology to prepare students for the digital world. The teachers' perspective stresses the importance of understanding technology among all school members. Support in the form of adequate equipment and devices is also considered crucial for effective technology use. Teachers expressed that they often feel unprepared to use technology in teaching, so training and technical support are highly needed.

Regarding digital challenges, education practitioners noted the importance of educating students about risks such as online scams. Education on handling digital challenges should be part of the curriculum to protect students. IT experts agreed that a proactive approach is needed to address digital risks, including training on digital security. Knowledge and technology updates must be noticed. Education practitioners emphasized the importance of regularly updating devices and technology knowledge. According to IT experts, outdated technology can hinder learning, so updates should be made periodically. Teachers added that they must continually update their knowledge about the latest technology to teach effectively and support student learning. This interview demonstrates that digital transformation in education requires understanding, support, and ongoing updates from the entire school community.

3.2 Quantitative Research Results

The development of the research hypothesis is as follows:

3.2.1 The Influence of Digital Leadership on Digital Culture

The influence of digital leadership on digital culture can be observed through the leader's role in guiding, inspiring, and supporting the organization to exhibit norms, beliefs, artifacts, and assumptions in the use of technology. Organizational culture is a pattern of assumptions a group develops as they solve external problems and internal integration (Normore et al., 2016; Schein, 1992; Shin et al., 2023). Leaders introduce and utilize technology, transforming the organization's way of working, values, and assumptions underlying the use of digital technology (Ghamrawi & M. Tamim, 2023). Technology adoption becomes an integral part of organizational values (innovation, efficiency) and eventually permeates into the basic assumptions of culture (belief in technology as a factor supporting organizational success). Digital leadership plays a crucial role in shaping and reinforcing digital culture within the organization, influencing how work is done, values, and attitudes towards technology throughout the organization. A strong digital culture facilitates easier technology adoption and ensures the entire organization aligns with its digital goals (P. McCarthy et al., 2022). Digital leadership is an organizational agility that promotes an agile organizational culture capable of rapidly adapting to technological and market changes. Digital leadership communicates the digital vision, optimizes business processes, and promotes understanding and acceptance of digital transformation across various organizational levels. Digital leadership drives changes in digital culture to adapt to an increasingly competitive and barrier-free environment (Shin et al., 2023). Leaders make decisions about the digital transformation process based on available data and facilitate strategic convergence in digital culture (Anwar & Saraih, 2024). Digital leadership integrates technology into organizational processes and values, creating a culture prepared to face uncertainty and rapid changes in the digital era (Arham et al., 2024). The proposed hypothesis is:

H1: Digital Leadership has a positive influence on Digital Culture

3.2.2 The Influence of Digital Leadership on Digital Maturity

Digital leadership plays a central role in influencing digital maturity through appropriate leadership characteristics and consistent actions to drive sustainability in digital transformation (Malik et al., 2024). Leaders with the right characteristics, such as digital strategists, can lead digital transformation effectively, enhancing digital maturity (P. McCarthy et al., 2022). Digital leaders formulate and communicate a clear digital vision and usage to the organization (Ghamrawi & M.

Tamim, 2023). Digital leadership ensures that digital transformation becomes a strategic priority, which requires support for digital maturity. As strategy designers, leaders enable the organization to understand the goals of digital transformation and the steps taken to achieve them by enhancing dynamic capabilities in digital contexts (Albannai et al., 2024). Digital leadership fosters digital maturity through interactive processes, creating an environment that supports the development of digital capabilities and organizational processes (Shin et al., 2023); (Anwar & Saraih, 2024). The proposed hypothesis is:

H2: Digital Leadership has a positive influence on digital maturity

3.2.3 The Influence of Digital Leadership on Sustainable Digital Transformation Processes

Digital leadership plays a critical role in maintaining the momentum of digital transformation and ensuring that the organization responds to current technological changes and sustainability (Karakose et al., 2021; Shin et al., 2023). Sustainable digital transformation requires a combination of strategic vision, technological capabilities, supportive culture, and optimized processes under the guidance of effective digital leaders (Albannai et al., 2024). Digital leaders continuously optimize business processes through digitalization using various strategies (Khaw et al., 2022; Türk, 2023; Yao et al., 2024). Digital leadership focuses on efficiency, innovation, and continuous improvement, ensuring that digital transformation delivers both short-term benefits and sustainable value (Lin, 2024; Magesa & Jonathan, 2022; P. McCarthy et al., 2022). Digital leadership enables technology-driven approaches in educational supervision, ensuring accurate evaluations and timely feedback on educational digitalization (Anwar & Saraih, 2024; Carvalho et al., 2022). Effective digital leadership is key to standardizing IT systems and driving sustainable performance by leveraging technology (Chen et al., 2024). The proposed hypothesis is:

H3: Digital Leadership positively influences the sustainable digital transformation process.

3.2.4 Digital Educational Ecosystem Moderates the Influence of Digital Leadership on Digital Maturity

The interaction between Digital Leadership (DL) and the Digital Educational Ecosystem (DEE) enables the design and creation of a responsive and dynamic work environment. DL ensures that the organization is prepared to face new challenges and continuously evolve digitally. DEE facilitates DL efforts to make various decisions supporting success in digital transformation. DEE acts as a catalyst in accelerating digital transformation and optimizing the digital maturity of educational organizations under the vision of digital leaders. DEE provides access to information and data analysis processes that aid in effective decision-making. This process encourages schools to continually improve digital processes while enhancing digital maturity to keep pace with these processes. DEE plays a role in expanding the scope of various skills required for continuous improvement. Effective digital leadership will leverage this platform to enhance engagement and interaction across the educational community, ultimately improving institutions' digital maturity. The digital ecosystem comprises interconnected elements that create a seamless and integrated digital experience (Rojas & Chiappe, 2024). The Digital Ecosystem (DE) provides a collaborative platform that enables technology integration, inter-organizational collaboration, and sustainable adaptation (Oberländer et al., 2024). The proposed hypothesis is:

H4: Digital educational ecosystem moderates the influence of Digital Leadership on Digital maturity

3.2.5 The digital educational ecosystem moderates the influence of digital culture on digital maturity

Digital education ecosystem (DEE) functions as a critical tool for Digital Leadership (DL) to moderate and enhance the influence of digital culture on digital maturity. DEE helps create an organizational culture that supports the assumption that digital maturity is integral to digital transformation. With the support of DEE, leaders as digital culturalists can ensure that digital culture is well-integrated into the organization, fostering sustainable digital growth and maturity (P. McCarthy et al., 2022). DEE provides experiences that form the foundation of digital maturity. Digital maturity is closely related to knowledge management, particularly in sharing tacit knowledge (Bhatti et al., 2024). DEE helps enhance experiences that support work visibility and improve workflows through digital platforms. DEE facilitates communication and collaboration for explicit and tacit knowledge, contributing to digital maturity. DL adopts a digital mindset that involves iterative learning from DEE sources, which promotes the development of digital skills essential for navigating digital transformation (Arham et al., 2024). The proposed hypothesis is:

Ha5: Digital Educational Ecosystem Moderates the Influence of Digital Culture on Digital Maturity

3.2.6 Digital educational ecosystem moderates the influence of Digital Leadership on Digital maturity

Digital education ecosystem (DEE) provides resources and tools that support Digital Leadership (DL) in achieving digital maturity as part of realizing the vision and mission for sustainable digitalization. DEE enhances leaders' ability to direct necessary changes to support sustainable digital transformation. DEE plays a crucial role in moderating the influence of Digital Leadership on Digital Maturity. Developing an adequate digital ecosystem enables effective digital implementation (Rojas & Chiappe, 2024). The design of the Digital Educational Ecosystem (DEE) ensures the establishment of essential conditions for digital survival and growth (Markoska, 2017). DEE focuses on assessing potential economic, social, and technological benefits and the ability to design, evaluate outcomes, and adequately assess capabilities to support the digital transformation process (Suleimankadieva et al., 2021).

3.2.7 The influence of digital maturity on the continuous digital transformation process

Digital maturity plays a crucial role in the success of sustainable digital transformation (Feroz et al., 2023). Digital maturity is necessary to address various pressures of change, innovation demands, adaptation, and process optimization. A high level of digital maturity enables organizations to acquire the various needs required for a sustainable transformation process. High digital maturity allows organizations to optimize processes through automation, data analytics, and integrating digital technology into every operational aspect. These more efficient processes enhance productivity and support sustainable digital transformation by reducing costs, improving quality, and enabling more sustainable decision-making. Adopting digital technologies that promote sustainability (Irimiás & Mitev, 2020) facilitates effective and efficient transformation processes with low risk based on data-driven calculations and real-time feedback. Digital maturity fosters sustainable practices and success in a digitally connected world (Awdziej et al., 2023). Digital maturity is an integral part of the digital transformation process (Aras & Büyüközkan, 2023; Kargas et al., 2023). The current level of digital maturity is crucial for planning digital transformation activities to focus on the institution's target image (Ilin et al., 2022). The proposed hypothesis is:

Ha6: Digital educational ecosystem moderates the influence of digital culture on digital maturity

In general, sustainable digital transformation is a complex social process (Roth et al., 2019), and its success depends on supporting the organization's dynamic resources (Konopik et al., 2022). Integrating digital culture and adopting digital leadership enhance digital capabilities that drive the long-term effectiveness of educational institutions (Arham et al., 2024; Retnowati & Santosa, 2023). The proposed model in this study is as follows (see Figure 2).

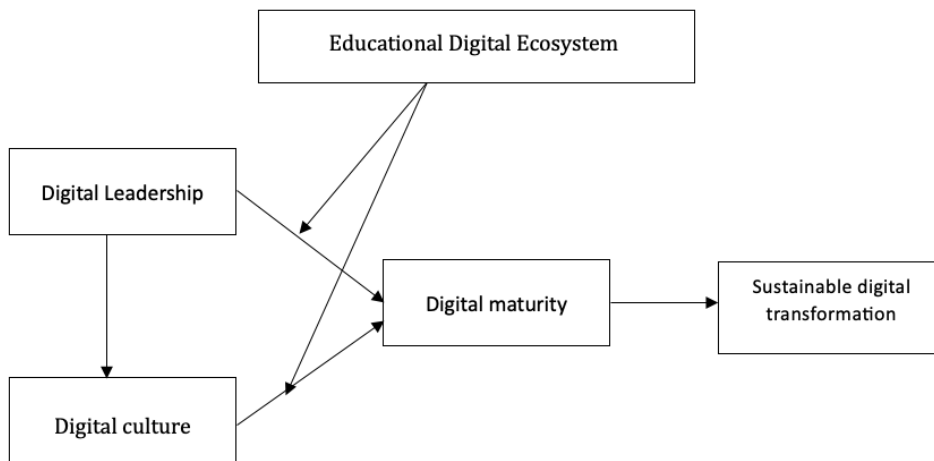


Figure 2. Proposed model

The results of individual model testing show that the designed indicators are acceptable. The results of the convergent validity test, the significance test of the indicators (Regression Weight Measurement Model), and the factor loading value > 0.5 are in accordance with (Hair et al., 2019), as shown in Table 1.

Table 1. Observed Variable Factor Weight Test Results

Variable	Mean	Kode Indikator	Unstandardized Regression weight	Standardized regression weight	CR	p-value
Digital leadership	2.84	DL1-DL10	1.000-2.145	0.522-0.977	6.80-9.358	0.000
Digital culture	3.19	DC1-DC11	1.000-1.759	0.547-0.868	14.1113-18.247	0.000
Digital maturity	3.52	DM1-DM11	0.97-1.338	0.635-0.981	10.882-21.202	0.000
Educational digital ecosystem	3.52	EDE1-EDE6	0.658-1.039	0.585-0.855	10.882-21.202	0.000
Sustainable digital transformation	3.60	STD1-STD6	0.726-1.00	0.63-0.978	14.569-56.505	0.000

Source: own research (2024)

According to the test results of the factor weights, it is observed that all variables in the table show significant regression weights and high CR values, with a p-value of 0.000, indicating that the variables play an important role in the digital transformation model being studied. Significant observed variables explain changes in the latent variables. This can be seen from the values where C.R > 2.004 and the p-value < 0.05. The Unstandardized Regression Weights indicate that the factor weights adequately explain the latent variables within the research context, and these values can be generalized to different

contexts as indicated by the Standardized Regression Weights, which are sufficiently above the minimum of 0.5 (Fornell & Larcker, 1981).

Next, the tests for average variance extracted (AVE), composite reliability, and discriminant validity are to be conducted, as shown in Table 2.

Table 2. AVE Test Results, Composite Reliability Discriminant Validity

Variables	AVE	Composite Reliability	1	2	3	4	5
Digital Leadership	0.477	0.894					
Digital Maturity	0.534	0.905	0.052				
Digital Culture	0.655	0.960	0.089	0.053			
Sustainable Digital Transformation	0.653	0.924	0.132	0.087	0.194		
Digital Educational Ecosystem (M)	0.666	0.963	0.11	0.05	0.09	0.14	

Source: own research (2024)

According to the results of the AVE test, to ensure convergent validity, the AVE value for each construct should be greater than 0.50. The study results show that both AVE and Composite Reliability (minimum of 0.7) are met, indicating consistency in conceptualizing the indicator variables and the model. The discriminant validity test results demonstrate that each observed variable can effectively distinguish between latent variables. Discriminant validity is, therefore, acceptable. Next, the data quality is tested according to the Selected Maximum

Likelihood for Model Estimation (MLE). The author conducts tests for normality and linearity, evaluates outliers, and assesses multicollinearity and singularity. These evaluations confirm that the assumptions for SEM covariance are met. The next step is to evaluate and improve the model by modifying the relationships between constructs according to the modification indices or by changing the indicators used to represent the constructs as follows (see Table 3).

Table 3. Goodness of Fit Test Result

Types of Measurement	Measurement	First test results	Results of the improvements	Conclusion
Absolute fit measures	p-value-	0.000	0.001	Moderate
	RMSEA	0.076	0.035	Fit
	GFI	0.760	0.942	Fit
	NFI	0.863	0.952	Fit
	TLI	0.987	0.977	Fit
Incremental fit measure	RFI	0.843	0.965	Fit
	CFI	0.910	0.978	Fit
	AGFI	0.713	0.915	Fit
Parsimonious fit measure	PNFI	0.756	0.82	Fit
	PGFI	0.636	0.717	Moderate

Source: own research (2024)

The Goodness of Fit (GOF) test results indicate that the model meets the criteria for a good fit for the data. The model is well-suited to the data or sample at hand. These results suggest that the conclusions drawn regarding the model are accurate based on the GOF criteria. Next, the causality test

results and regression weights are based on the research data analysis, with the following results (see Table 4).

Table 4. Causality Test Results Regression Weight

	Path		Unstandardized regression weight	Standardized regression weight	S.E.	C.R.	P-Value
Culture	<---	Leadership	0.73	0.733	0.105	6,962	***
Maturity	<---	Leadership	0.178	0.144	0.109	1,634	0.102
Maturity	<---	Culture	0.5	0.403	0.113	4,411	***
Maturity	<---	Ecosystem	0.415	0.419	0.096	4,301	***
Process	<---	Maturity	0.623	0.467	0.077	8,034	***
Process	<---	Leadership	0.139	0.084	0.108	1,284	0.199
Process	<---	Culture	0.572	0.347	0.128	4,479	***
Culture	<---	Leadership	0.73	0.733	0.105	6,962	***

Source: Regression weight Data processing (2024)

The test results show that the relationships between variables are varied. Two relationships are not significant, specifically concerning the role of leadership based on the C.R value (<2.004) and the p-value (> 0.05). This highlights the importance of mediating variables. The next step is to test the mediating variables, as can be seen in Table 5.

Table 5. Mediation Test Results

	Path			Estimate	Z-Score	
Process	<---	Maturity	<---	Leadership	0.184	2.600
Process	<---	Culture	<---	Leadership	0.274	3.732
Process	<---	Maturity	<---	Culture	0.189	3.888

Source: Results of data processing using SEM

The test results indicate that digital maturity mediates the effect of digital culture on sustainable digital transformation. The estimation value and Z-score show a positive and significant direction. Next, the moderation test is as follows (see Table 6).

Table 6. Moderation Test Results

	Path		Estimate	P-Value
Maturity	<---	interaction EDE & DL	0.196	0.000
Maturity	<---	interactionn EDE & DC	0.339	0.000

Source: Results of data processing using SEM

The next step is to conduct a hypothesis test with the following results (see Table 7):

Table 7. Results of Hypothesis Testing of Research Based on Standardized Regression Weight

Hypothesis	Correlation coefficient	P-Value	Conclusion
H1: Digital Leadership positively influences the digital transformation process directly and through digital culture.	0.374	0.00	Supported
H2: Digital Leadership has a positive influence on the ongoing digital transformation process both directly and through Digital maturity.	0.184	0.00	Supported
H3: Digital education ecosystem moderates the influence of Digital Leadership on Digital maturity	0.196	0.00	Supported
H4: The digital education ecosystem moderates the influence of digital culture on digital maturity	0.339	0.00	Supported
H5: Digital maturity has a positive influence on the digital transformation process.	0.467	0.00	Supported

The research results indicate that all hypotheses are accepted. The development of leadership mechanisms in sustainable digital transformation is based on the role of leadership as a driver of culture, digital maturity, and the synergy of the Educational Digital Ecosystem (EDE) functions to support the digital transformation process.

Discussion

The discussion on organizational capability in the digital process at Senior High Schools (SMA) is essential, involving four main dimensions: leadership, digital culture, and digital maturity (Konopik et al., 2022), which determine the sustainability of the transformation process. Effective leadership in digital transformation involves formulating a clear vision related to digital transformation, motivating staff and students to participate actively, and managing change with supportive policies and strategies. Digital leadership in transformation is developed based on characteristics necessary for change (A. M. McCarthy et al., 2023). Digital leadership in the transformation process includes having a vision goal, understanding culture and subcultures, strategic planning, and the ability to communicate vision and mission to attract talent and resources. Leadership is seen as the central figure of change (Abbu et al., 2020; Imran et al., 2021; Kaufmann, 2022; Shin et al., 2023; Zhan et al., 2024). The study also highlights the importance of digital culture in line with (Deuze, 2006) and (Shin et al., 2023). The study also establishes that digital maturity is crucial and constructed according to previous theoretical foundations, such as (Fernández et al., 2023) and (Thordsen & Bick, 2023), including in education (Marks & Al-Ali, 2022). The output of interactions between variables is the sustainability of the transformation process, which is a key focus. Sustainability pertains not only to the process itself but also to the impact of the process on the environment. Technology adoption requires a balance between internal and external quality management, vital for stability and adaptability to change (Kemenade, 2017) and better working methods and teaching methods (Valdés et al., 2021). Digitalization drives readiness to meet new demands across various opportunity areas (van der Vlies, 2020). Dynamic organizational capabilities will form the basis for developing functional strategies to realize change processes, including managing environments such as the digital ecosystem in education.

Aligning with qualitative insights that emphasize leaders' roles in creating vision, promoting collaboration, and building trust in digital initiatives. However, the absence of a statistically significant direct relationship between leadership and DT outcomes suggests that leadership alone is insufficient without supportive cultural and institutional conditions. Challenges identified include disparities in digital infrastructure, especially in rural areas, and varied levels of staff digital literacy, which hinder consistent implementation. Moreover, ethical concerns surrounding AI integration—such as data

privacy and algorithmic bias—highlight the need for robust governance frameworks. Qualitative data also revealed successful practices in Jakarta-based schools where collaborative leadership involving IT, pedagogy, and administration enhanced digital adaptation. These findings suggest that leadership must be accompanied by institutional support, adequate funding, and clear policies. While the study offers a conceptual model relevant to Indonesia's current digital education context, limitations include the exclusive focus on private schools and the reliance on self-reported data. Future research should explore longitudinal impacts and the applicability of the model across varied educational settings.

Digital leadership focuses on developing and cultivating a digital culture in Senior High Schools (SMA). The culture focuses on digital maturity by changing mindsets, norms, and values that drive innovation, collaboration, and acceptance of digital technologies in the learning context. Digital leadership and culture drive digital maturity, including adopting the latest technologies, secure data management, and a deep understanding of security and privacy. This is connected to SMA as a formal educational institution with various inherent functions and obligations. SMA must progress towards adequate digital maturity to support modern teaching and learning processes. The digital transformation leadership framework should be seen as a more familiar, comprehensive approach with some overlap with existing leadership concepts (Weber et al., 2022).

Furthermore, several key roles have been identified to guide digital transformation within organizations. Firstly, the role of the digital pioneer reflects a focus on strategic orientation, where the leader develops a creative and imaginative digital vision as a guide for transformation. Digital leaders are expected to have a strategic vision to leverage technology to achieve organizational goals, flexibility in the rapidly changing digital landscape, and the ability to shape digital culture within the organization. On the other hand, the role of the innovator emphasizes the operational level, with readiness to allocate resources and implement innovative working methods to achieve the vision. The roles of enabler and mentor highlight relationship-oriented leadership behaviors, with the enabler creating a flexible work environment and empowering the entire team.

In contrast to traditional managerial roles, mentors provide personalized support and feedback to individual team members, while networkers focus on fostering relationships both within and beyond the organization—highlighting the importance of connectivity in digital leadership. Although often associated with Chief Information Officers (CIOs) or Chief Technology Officers (CTOs), digital leadership is not confined to these roles. It requires engagement from leaders at all organizational levels, with digitally competent leadership teams playing a critical role in managing digital complexity.

According to Contingency Theory (Eva et al., 2018; Kumar et al., 2023), the effectiveness of digital leadership depends on alignment with contextual variables, such as the digital education ecosystem. When leadership style corresponds with situational factors—like technological capacity, social dynamics, and institutional culture—it enhances the likelihood of successful and sustainable digital transformation. This alignment reflects both contingency and functional leadership perspectives.

Moreover, digital transformation is not solely a technical shift but a socially embedded process influenced by organizational context (Hanelt et al., 2021; Roth et al., 2019). Leaders who understand these social dynamics are better equipped to apply context-sensitive leadership approaches that support long-term change. In essence, effective digital leadership thrives when matched to the right situational conditions, reinforcing the importance of adaptability in navigating transformation.

As discussed by Weber et al., (2022) and Henderikx & Stoffers, (2022), leadership challenges in the digital transformation process can be addressed by understanding the social context. In line with (Connolly et al., (2023) and Yaraş & Ozturk, (2022), changes in leadership functions are needed in digital transformation processes to promote digital culture and digital maturity and, at the same time, continue to drive sustainable digital transformation with a vision and mission related to sustainable digital education. Digital leadership, as a key driver of change, creates a culture and maturity that support digital growth and development, providing long-term positive impacts on the sustainable digital transformation process.

Digital leadership in the transformation process remains focused on the primary educational goals. Interaction with the digital ecosystem encourages leaders to explore and exploit digital functions for educational purposes. According to (Rojas & Chiappe, 2024), the digital environment provides various informational facilities. In the context of digital transformation at Senior High Schools (SMA), leaders continue to optimize the functions of the digital ecosystem to provide informal learning by integrating digital platforms such as AI-based chatbots and virtual assistants. These technologies enable teachers, staff, and students to engage in self-directed and personalized learning, supporting sustainable digital transformation. Adopting AI tutoring systems allows for real-time feedback as needed, enhancing teaching quality educational services and promoting an adaptive digital culture among educators. Leaders can assess teaching performance and effectiveness, leading to more accurate decision-making and supporting efforts to achieve digital maturity. Leaders support an open community that fosters collaboration among students, teachers, and other educational stakeholders. The digital ecosystem can enhance these interactions, creating an inclusive learning environment that accelerates digital transformation within educational institutions.

The digital ecosystem (DE) plays a moderating role in the relationship between digital leadership and digital maturity by enabling technology integration, fostering collaboration, and supporting continuous organizational adaptation. As a dynamic platform, the DE enhances leaders' capacity to promote digital maturity and sustainable transformation within educational institutions (Rojas & Chiappe, 2024). Effective digital leadership leverages this ecosystem to build organizational capabilities, optimize digital tools, and align technological strategies with institutional goals.

According to McCarthy et al. (2023), sustainable digital transformation requires leadership models that combine technological innovation with shifts in organizational mindset and culture. This transformation begins with a clear understanding of stakeholder expectations and the development of measurable strategies tailored to school contexts. In Indonesia's secondary schools, digital leadership must not only facilitate technology integration but also drive cultural change and collaboration (Mohamed Hashim et al., 2022; Sá & Serpa, 2020).

Leaders must also address the social dimensions of change, including fears of job displacement and resistance to new technologies (Alhumaid, 2019). Developing digital skills and empowering staff are essential for successful transformation. As noted by Henderikx and Stoffers (2022) and Yaraş and Ozturk (2022), leadership must adapt to the specific educational context and respond to the complexities of the digital ecosystem. A contingency-based perspective (Eva et al., 2018; Kumar et al., 2023) highlights the importance of setting strategic goals aligned with the evolving digital landscape in shaping effective digital leadership frameworks for Indonesian senior high schools.

The leadership model developed for the digital transformation process in education includes 1) School Leaders who can maximize the potential of the digital education ecosystem and enhance effectiveness in alignment with educational goals. Their capability lies in guiding and ensuring the organization can integrate technology into educational objectives. An effective digital leadership framework assumes that leaders play a central role in shaping digital culture, enhancing digital maturity, and integrating elements of the digital education ecosystem (DEE) to ensure that digital transformation is executed effectively and sustainably.

4. CONCLUSION

This study concludes that digital leadership plays a critical role in driving sustainable digital transformation in secondary schools by shaping digital culture and enhancing institutional digital maturity. Effective digital leaders not only influence the direct implementation of digital initiatives but also foster a supportive organizational environment that aligns leadership practices, school culture, and the broader digital education ecosystem. When these elements work cohesively, schools are better positioned to adopt and sustain meaningful digital change. The findings highlight that successful

digital transformation extends beyond technology adoption—it involves strategic leadership, cultural alignment, and the development of digital capabilities. However, the study is limited by its focus on private secondary schools in specific regions of Indonesia and by the self-reported nature of data, which may introduce response bias. Future research should explore a broader sample, including public schools and diverse geographic areas, and adopt longitudinal or mixed-method approaches to assess the long-term impact of digital leadership on institutional change. Additionally, further investigation into how different leadership styles interact with policy frameworks and technological infrastructure would deepen understanding of effective strategies for digital transformation across various educational contexts.

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