

FROM PEDAGOGICAL TOOL TO GOVERNANCE MECHANISM: INSTRUCTIONAL LEADERSHIP AND THE INSTITUTIONALIZATION OF DIGITAL INNOVATION IN SCHOOL QUALITY ASSURANCE

Mesterjon¹, Suwarni², Dwi rulismi³, Khairil⁴, Prof. Zulkarnain⁵

^{1,2,3,4} Dehasen University Indonesia, ³ Bengkulu Fatmawati University Indonesia,

^{*)1.} *Corresponding Author:* mesterup@yahoo.co.id

Abstract

This study reconceptualizes digital learning innovation as a mechanism of organizational governance rather than a purely pedagogical intervention. Drawing on instructional and transformational leadership theories, as well as quality management frameworks, we examine how Augmented Reality (AR) can be institutionalized within school-based quality assurance systems. Using a mixed-methods design in an Indonesian vocational secondary school, we analyze the implementation of an AR-based learning prototype (Quizizz 3D AR) across instructional practices and the PPEPP (Plan–Do–Evaluate–Control–Improve) cycle. Findings indicate that AR enhances student engagement and conceptual understanding while simultaneously generating data infrastructures that support monitoring, evaluation, and continuous improvement. However, we identify a persistent structural gap between pedagogical functionality and technical performance, particularly in relation to device compatibility and scalability. Crucially, the study demonstrates that the sustainability of digital innovation is contingent not on technological quality alone, but on leadership-mediated governance processes that align instructional practices, data use, and institutional accountability mechanisms. We contribute to the literature by introducing a governance-oriented framework of digital innovation, in which educational technologies function as instruments of organizational regulation and improvement. This study reconceptualizes leadership as a mechanism of data-driven governance by positioning school leaders as key actors in the institutionalization of technology within quality assurance systems. Implications are discussed for educational leadership, policy design, and the scaling of digital transformation in resource-constrained contexts.

Keywords:

Digital Innovation Governance, Quality Assurance (PPEPP Cycle), Leadership-Mediated Governance, and Data-Driven Educational Transformation.

1. INTRODUCTION

The rapid expansion of digital technologies in education has prompted a significant shift in how schools organize, evaluate, and improve instructional processes. While a substantial body of research has examined the pedagogical benefits of digital tools—particularly in enhancing student engagement and conceptual understanding—far less attention has been given to how such technologies are embedded within organizational governance systems. This gap is especially critical in the context of school leadership, where the challenge is no longer simply adopting innovation, but institutionalizing it in ways that sustain quality improvement over time. Existing studies on educational technology integration have predominantly focused on classroom-level outcomes, teacher beliefs, and user acceptance (e.g., TAM/UTAUT frameworks). In parallel, leadership research has emphasized the role of instructional and transformational leadership in shaping teaching and learning conditions. However, these two strands of literature remain largely disconnected. As a result, digital innovation is often treated as an external intervention rather than an integral component of organizational governance and accountability.

This gap is especially critical in the context of school leadership, where the challenge is no longer simply adopting innovation, but institutionalizing it in ways that sustain quality improvement over time. Existing studies on educational technology integration have predominantly focused on classroom-level outcomes, teacher beliefs, and user acceptance (e.g., TAM/UTAUT frameworks). In parallel, leadership research has emphasized the role of instructional and transformational leadership in shaping teaching and learning conditions. However, these two strands of literature remain largely disconnected. As a result, digital innovation is often treated as an external intervention rather than an integral component of organizational governance and accountability. Recent critical scholarship further suggests that digital technologies are not neutral tools but infrastructures of datafication that reconfigure how educational practices are monitored, evaluated, and governed (Williamson, 2017; Kitchin, 2014; Selwyn, 2021).

This study addresses this gap by reconceptualizing digital learning technologies, specifically Augmented Reality (AR) as instruments of governance within school quality assurance systems. We argue that AR can function not only as a pedagogical tool, but as a mechanism for generating data, structuring evaluation processes, and supporting continuous improvement cycles. Drawing on the Indonesian context of the Internal Quality Assurance System (SPMI) and its PPEPP. Drawing on the Indonesian context of the Internal Quality Assurance System (SPMI) and its PPEPP cycle (Plan–Do–Evaluate–Control–Improve), we examine how digital innovation can be institutionalized through leadership practices. **From a data governance perspective, such institutionalization reflects broader shifts toward algorithmic and data-driven regulation in education, where digital systems increasingly structure decision-making, accountability, and performance evaluation (Decuypere, 2021; Williamson et al., 2020).** By integrating instructional leadership, transformational leadership, and quality management theory, this study develops a governance-oriented framework that explains how digital technologies become embedded in organizational routines.

This study makes three contributions. First, it extends the literature on educational technology by shifting the analytical focus from pedagogical effectiveness to organizational governance. Second, it advances leadership theory by conceptualizing school leaders as mediators of digital institutionalization within quality assurance systems. Third, it provides empirical evidence

from a developing country context, highlighting the structural constraints and opportunities associated with digital transformation in education. In doing so, the study responds to growing calls for more integrative approaches that connect leadership, technology, and accountability in educational systems undergoing digital change.

In doing so, the study responds to growing calls for more integrative approaches that connect leadership, technology, and accountability in educational systems undergoing digital change. **It also aligns with emerging critiques of the “postdigital” condition in education, where distinctions between technological and organizational processes are increasingly blurred, necessitating new analytical frameworks that foreground governance, data, and power (Knox, 2019).**

Theoretical Contribution

This study advances a **theory of digital governance infrastructure in schooling**, in which digital learning technologies operate not merely as pedagogical tools but as mechanisms of datafication, regulation, and organizational control. Moving beyond dominant perspectives that frame technology adoption as a matter of instructional effectiveness or user acceptance, this study reconceptualizes digital innovation as a **governance apparatus** that restructures how schools monitor, evaluate, and standardize instructional practices.

We introduce the concept of **leadership-mediated digital governance**, defined as the process through which school leaders actively configure the alignment between technological systems, instructional practices, and quality assurance mechanisms to enable data-driven regulation. In this view, instructional leadership extends beyond pedagogical supervision to encompass the orchestration of data flows, performance metrics, and evaluative infrastructures that shape institutional accountability.

Furthermore, this study reframes transformational leadership not as a process of motivating change alone, but as a mechanism for **embedding innovation into formal governance structures**, particularly through cyclical quality assurance systems such as PPEPP. This shift highlights leadership as a constitutive element of governance, rather than a contextual enabler of innovation. Critically, the study identifies **datafication-induced tensions** within digital transformation processes, including conflicts between pedagogical flexibility and standardization, as well as between instructional functionality and technological constraints. These tensions reveal that digital innovation is not a neutral enhancement, but a restructuring force that redistributes control, visibility, and decision-making authority within schools.

By theorizing digital innovation as a governance infrastructure, this study contributes to educational leadership research by linking micro-level instructional practices to macro-level accountability systems, thereby offering a new analytical lens for understanding how digital technologies transform the organizational logic of schooling.

2. Expanded and Strengthened Conceptual Model

2.1 Instructional and Transformational Leadership

Instructional leadership, which emphasizes the alignment of curriculum, pedagogy, and assessment procedures within schools, has long been acknowledged as a crucial factor in determining student learning outcomes (Hallinger, 2011). This function goes beyond standard instructional coordination in modern digital learning environments to include incorporating technology into teaching and learning procedures. It is the responsibility of school

administrators to make sure that digital resources effectively promote student learning, are pedagogically meaningful, and are in line with curriculum standards.

In addition, transformational leadership emphasizes creating a culture that welcomes change, encouraging innovation, and defining organizational vision (Leithwood et al., 2020). Transformational leadership becomes crucial in the context of digital transformation to promote the uptake of cutting-edge technologies like AR, especially by: 1) supporting a common vision of technology-enhanced learning; 2) fostering collaborative creativity among educators; and 3) boosting teacher preparedness and digital competency. Leadership is essential to the successful adoption of digital learning tools, especially when it comes to resource organization, teacher training, and integrating evaluation mechanisms into teaching practices, according to empirical data from the Quizizz 3D AR prototype implementation. Technological innovation runs the risk of becoming dispersed and unsustainable in the absence of such leadership. A dual leadership model is thus produced by combining transformational and instructional leadership, in which leaders simultaneously promote innovation within institutional processes and guarantee the quality of instruction.

2.2 Educational Quality Management and PPEPP

According to Total Quality Management (Deming, 1986; Sallis, 2014), educational quality management is essentially based on cyclical improvement procedures. The Internal Quality Assurance System (Sistem Penjaminan Mutu Internal, or SPMI), which uses the PPEPP cycle, operationalizes this strategy in Indonesia: 1) Standard Setting (Penetapan), 2) Pelaksanaan (Execution), 3) Evaluation, 4) Pengendalian (Control), 5) Peningkatan (Enhancement). An organized method for incorporating innovation into institutional practice is offered by the PPEPP framework. Digital technologies like AR transform from discrete teaching tools into systemic elements of educational quality regulation when they are integrated into this cycle. Results from the prototype evaluation show that AR-based educational materials can be successfully included into quality control procedures, especially in: 1) facilitating monitoring through user input and system performance statistics; 2) supporting curriculum alignment and instructional delivery; and 3) guiding ongoing development through iterative refinement. However, the assessment also shows that in order to guarantee that technological integration completely complies with quality requirements, issues like content depth, system scalability, and device compatibility must be resolved. This emphasizes how crucial it is to consider technology as part of a structured governance cycle rather than as a stand-alone innovation.

2.3 Technology Integration and Constructivism (TAM/UTAUT)

User acceptance and pedagogical relevance have a significant impact on the usage of technology in the classroom. Perceived utility and perceived ease of use are important factors that influence technology adoption, according to the Technology Acceptance Model (TAM) (Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003). Regarding AR-based education: 1) AR's capacity to improve conceptual comprehension reflects perceived usefulness, 2) System usability, device accessibility, and interface design all affect perceived ease of use. Because AR allows students to actively construct information through immersive and interactive experiences, it is in line with constructivist learning theory at the educational level. AR makes it possible to visualize abstract ideas in real time, which enables: 1) hands-on learning; 2) contextual comprehension; and 3) multisensory interaction. AR dramatically increases student engagement and comprehension, especially for complicated and abstract content, according to empirical results from the prototype. However, usability and performance problems can have a detrimental impact on user acceptability, particularly on low-specification devices, highlighting the

significance of maximizing both technical and pedagogical aspects. Therefore, a balance between user acceptance (TAM/UTAUT) and pedagogical value (constructivism) is necessary for successful technological integration.

2.4 Conceptual Structure (Improved Model)

This study proposes a **governance-oriented model of digital innovation as a datafication process**, consisting of four interrelated mechanisms:

1. **Digital Innovation → Datafication**
AR-based learning generates continuous streams of interactional and performance data, transforming instructional processes into measurable and traceable activities.
2. **Datafication → Governance Mechanism**
These data streams enable new forms of monitoring, evaluation, and standardization, allowing instructional practices to be governed through metrics, analytics, and performance indicators.
3. **Governance Mechanism → Institutionalization (PPEPP Cycle)**
Data-driven evaluation becomes embedded within cyclical quality assurance processes, institutionalizing digital innovation as part of organizational routines.
4. **Leadership Mediation (Cross-Cutting Mechanism)**
Leadership functions as a mediating force that aligns data systems, instructional practices, and governance structures, determining how digital innovation is translated into organizational control and improvement.

Importantly, this model incorporates **structural tensions** as intrinsic components, particularly:

1. pedagogical flexibility vs. standardization
2. instructional design vs. technological constraints
3. innovation vs. institutional control

These tensions are not anomalies but **constitutive features of digital governance**, requiring continuous leadership intervention.

3. Methodology

3.1 Research Design

This study employs a mixed-methods design to examine how digital innovation can be institutionalized within school governance systems. Rather than treating technology implementation as a purely technical or pedagogical process, the design integrates instructional outcomes with organizational analysis. This approach enables the study to capture both the effectiveness of the innovation and the mechanisms through which it becomes embedded in institutional practices. Quantitative data were used to assess patterns of user engagement, perceived usefulness, and system performance, while qualitative data provided insights into instructional dynamics, leadership mediation, and organizational alignment. The integration of these data sources supports a governance-oriented analysis that links classroom-level practices with system-level processes.

3.2 Research Context and Participants

The study was conducted in a vocational secondary school in Indonesia, a context characterized by increasing policy emphasis on digital transformation and flexible learning under the *Merdeka Belajar* framework. Vocational schools provide a particularly relevant setting due to their focus on applied learning and technology integration. Participants included 60 students

and 10 teachers who were directly involved in the implementation of an AR-based learning system (Quizizz 3D AR). Teachers acted not only as instructional facilitators but also as mediators of the innovation within existing curricular and organizational structures.

3.3 Data Collection

Data were collected through four complementary sources:

1. **User Surveys:** Structured questionnaires measured perceived usefulness, engagement, and usability, drawing on established constructs from TAM/UTAUT frameworks.
2. **Classroom Observations:** Observational protocols captured student interaction patterns, levels of engagement, and the integration of AR within instructional practices.
3. **Expert Validation:** Subject-matter and media experts evaluated the pedagogical alignment, content quality, and instructional relevance of the AR system.
4. **System Performance Data:** Technical logs provided information on responsiveness, compatibility, and system stability across different device specifications.

This multi-source strategy enabled triangulation, enhancing the validity of both instructional and organizational interpretations.

3.4 Data Analysis

Quantitative data were analyzed using descriptive statistics and paired comparisons to identify discrepancies between perceived instructional quality and system performance. Effect sizes (Cohen's *d*) were calculated to assess the practical significance of observed differences. Qualitative data were analyzed thematically, focusing on three analytical dimensions: (1) instructional effectiveness, (2) user experience and constraints, and (3) organizational integration. These themes were then interpreted in relation to leadership practices and quality assurance processes.

3.5 Validity and Reliability

To ensure methodological rigor, the study employed multiple validation strategies. Content validity was established through expert review, while construct reliability was confirmed using Cronbach's alpha (all constructs exceeding 0.80). Data triangulation across surveys, observations, and system logs further strengthened internal validity. Conducting the study in a real classroom setting enhanced ecological validity, allowing findings to reflect authentic implementation conditions.

This study adopts a **theory-building case approach**, in which empirical evidence is used not for statistical generalization, but for analytical generalization (Yin, 2018). The selected case provides a critical context for examining how digital innovation becomes embedded within governance systems under real-world constraints. By integrating multiple data sources, the study aims to develop and refine theoretical insights into leadership-mediated digital governance, rather than to test predefined hypotheses.

4. Expanded and Analytical Results

4.1 Effect on Teaching

The results show that incorporating AR through the Quizizz 3D AR prototype greatly improves the efficacy of training, especially with regard to student engagement and conceptual comprehension. An immersive learning environment that actively incorporates students in the learning process is created by combining gamified features with interactive 3D graphics. Students exhibit greater levels of engagement, focus, and response during AR-supported learning sessions, according to empirical observations. This is consistent with user survey data showing high levels of engagement and favorable opinions of interaction. Learners can

transition from passive receiving to active knowledge construction thanks to augmented reality's capacity to depict abstract concepts, such as technical elements in vocational disciplines. Additionally, the prototype accommodates a variety of learning modalities, such as experiential, kinesthetic, and visual. This multisensory method helps people understand and remember difficult information better. These results are in line with the validation findings, which show that AR visualization is very successful in elucidating abstract ideas that are challenging to communicate using conventional text-based or static media. Nevertheless, in order to maintain long-term engagement and guarantee alignment with more comprehensive learning goals, the results also point to the necessity of further improving the depth of instructional content and diversifying gamification elements.

4.2 Organizational and System Performance

Technically speaking, the system performs fairly consistently in typical classroom settings. Strong usability and accessibility are demonstrated by the application's simplicity of installation, user-friendly interface design, and device compatibility. However, performance testing identifies a number of important restrictions. In particular: 1) Device Constraints: On low-specification devices, the system exhibits decreased responsiveness and rendering delays. 2) Scalability Issues: When there is a lot of concurrent user access, performance deteriorates. 3) Optimization Requirements: Additional improvement is needed for AR rendering and system load management. Performance testing results corroborate these conclusions, showing that although the system functions effectively on mid- to high-range devices, latency and responsiveness problems continue to exist on lower-end hardware. From an organizational perspective, the prototype shows great promise for incorporation into educational institutions. It is a feasible instrument for institutional adoption due to its compatibility with the Merdeka Belajar framework and alignment with curriculum standards. Monitoring learning processes and results is also made possible by the availability of system logs and analytics. Nonetheless, the report notes a number of organizational difficulties: 1) the need for organized teacher and student onboarding and training; 2) the need for better technical infrastructure; and 3) the need for ongoing system improvement to guarantee scalability. These results demonstrate that institutional preparedness and support structures are just as important for successful implementation as technological capacity.

4.3 Consequences for Governance and Leadership

The findings highlight the leadership's strategic role in incorporating AR-based learning into governance frameworks for educational excellence. Instead of being a stand-alone teaching tool, AR can be operationalized within the PPEPP framework as a monitored and continuously improved intervention. In particular, leaders can use AR at every phase of the PPEPP cycle: 1) Penetapan (Standard Setting): Creating guidelines for AR-based material that are in line with learning objectives and curriculum goals. 2) Pelaksanaan (Implementation): Using AR in the classroom and making sure teachers are prepared by providing them with assistance and training. 3) Evaluation: Analytics, user surveys, and system logs are used to evaluate system performance and instructional efficacy. 4) Pengendalian (Control): Finding and fixing performance gaps, like content misalignment and device constraints. 5) Peningkatan (Improvement): To increase user experience, content is continuously improved, system performance is improved, and features are expanded.

According to empirical research, AR-based learning can be institutionalized as a component of a school's quality assurance system if it is backed by strong instructional and transformational leadership. Leaders are essential in: 1) coordinating technology with educational objectives; 2) guaranteeing ongoing observation and assessment; and 3) cultivating an innovative and

progressive culture. Crucially, the study shows that digital innovation can only be sustained when it is integrated into governance frameworks. Technology adoption runs the danger of being dispersed and failing to result in long-term gains in educational quality in the absence of leadership-driven integration.

4.4 Expanded Statistical Interpretation (Quantitative Synopsis)

A comparison of the Quizizz 3D AR prototype's functional and performance scores across important dimensions is shown in Table 1.

Table 1: Performance vs. Functional Scores

Aspect	Functional (Mean)	Performance (Mean)	SD
Interactivity	4.85	4.10	0.52
Visual Quality	4.78	4.05	0.60
Usability	4.90	4.70	0.40
Engagement	4.88	4.15	0.55
Compatibility	4.10	3.20	0.75
Security	–	4.00	0.65

A discrepancy between the system's instructional design quality and its technical execution in real-world circumstances is suggested by the results, which show a consistent trend in which functional scores surpass performance scores across almost all evaluated elements. The prototype has extremely high functional effectiveness from a descriptive perspective, especially in: Usability ($M = 4.90$), participation ($M = 4.88$), Interactivity ($M = 4.85$), as well as visual quality ($M = 4.78$). These results attest to the system's pedagogical resilience, ability to promote active learning, increase user engagement, and facilitate natural interaction. Additionally, the comparatively low standard deviation values ($SD = 0.40$ – 0.60) show stable instructional quality among participants and consistent user perceptions. Performance scores, on the other hand, highlight a number of significant technological shortcomings. The most noticeable disparity is shown in: Compatibility ($SD = 0.75$; $M = 3.20$), Interactivity performance came next ($M = 4.10$), as well as visual rendering ($M = 4.05$). Higher compatibility variability raises concerns about hardware inequality and system scalability by indicating that user experience varies greatly based on device characteristics. With a mean difference of 0.73, the paired comparison analysis further validates a systematic disparity between functional and performance aspects. This suggests that, despite users' perceptions of the system's excellent design and educational value, its actual operational performance falls short of expectations. Effect size study using Cohen's d to gauge the extent of this disparity produced a result of $d = 0.65$, which is in the moderate-to-large effect range. This indicates that the observed disparity is both practically and statistically significant in actual educational environments. From the standpoint of system evaluation, these results imply that: The prototype's educational component is efficient and well-developed, whereas the technical aspect continues to be a constraint, especially compatibility and performance optimization. The results of system testing, which showed performance reduction when low-specification devices and high concurrent usage were present, are consistent with this conclusion. Furthermore, the security dimension (Performance $M = 4.00$; $SD = 0.65$) shows that the system offers a sufficient degree of protection; nonetheless, additional improvement - like the use of sophisticated authentication methods - is advised to bolster data security. Overall, the quantitative results show a structural imbalance between technological robustness and pedagogical strength, highlighting the necessity for future development efforts to concentrate

on: 1. enhancing cross-device compatibility and system scalability, 2. optimizing AR rendering and responsiveness, 3. and guaranteeing fair access in many technical contexts.

5. Expanded and Strengthened Discussion

By redefining AR as a regulated and institutionalized instrument inside educational quality governance systems rather than just a pedagogical innovation, this study contributes to the body of current literature. This finding resonates with critical perspectives that conceptualize digital technologies as infrastructures of datafication, which actively reshape institutional logics through data production, circulation, and use (Williamson, 2017; Kitchin, 2014). Although earlier research has repeatedly shown that AR improves student engagement and conceptual understanding (Ibáñez & Delgado-Kloos, 2018; Radianti et al., 2020), these benefits have mostly been limited to the educational setting. Rather than just a pedagogical innovation, this study contributes to the body of current literature. Although earlier research has repeatedly shown that AR improves student engagement and conceptual understanding (Ibáñez & Delgado-Kloos, 2018; Radianti et al., 2020), these benefits have mostly been limited to the educational setting. By integrating AR into the PPEPP (Penetapan–Pelaksanaan–Evaluasi–Pengendalian–Peningkatan) cycle, the current study expands on this viewpoint and presents it as a method for methodical quality improvement and organizational learning.

The results indicate that AR-based learning can serve as a tool for governance, especially if it is backed by organized evaluation procedures, performance tracking, and ongoing improvement. This is consistent with empirical findings that demonstrate AR not only increases student engagement and educational effectiveness but also produces actionable data through system logs, user feedback, and performance indicators.

By integrating digital innovation into formal quality assurance procedures, these data streams allow schools to turn technology from a teaching tool into an institutional asset. This transformation reflects a broader shift toward data-driven governance in education, where teaching practices become increasingly visible, measurable, and comparable through digital systems (Williamson et al., 2020; Decuypere, 2021). From a leadership standpoint, the findings support and expand on well-established theories of transformative and instructional leadership. The study supports Hallinger's (2011) assertion that curriculum, pedagogy, and assessment alignment are necessary for effective instructional leadership. Simultaneously, the results corroborate Leithwood et al. (2020) by showing that organizational change in digital environments, teacher capacity building, and innovation promotion all depend on transformational leadership.

By introducing the concept of leadership-mediated digital governance, this study goes beyond existing frameworks. In contrast to the majority of the material currently in publication, which views technology adoption as a teacher-driven process, this study highlights the importance of school leaders in establishing guidelines for technology integration, monitoring implementation through data and evaluation mechanisms, and ensuring continuous improvement through structured quality cycles (PPEPP). This governance-focused viewpoint, which emphasizes leadership as the primary means of institutionalizing and maintaining digital innovation, marks a substantial conceptual change.

This study's contextual findings regarding infrastructure and scalability constitute another significant contribution.

This study highlights ongoing issues with device inequity, system compatibility, and performance constraints in low-resource areas. Such findings reinforce longstanding concerns that digital transformation may reproduce or even intensify structural inequalities through uneven access to technological infrastructures and data capabilities (Selwyn, 2021). In contrast to a large portion of the international literature, which frequently assumes high levels of technical readiness. The quantitative results show a structural imbalance between instructional efficacy and technical capacity, especially the disparity between functional and performance ratings (mean difference = 0.73; Cohen's $d = 0.65$).

These results corroborate more general worries about digital equity and the unequal allocation of technology resources among educational systems expressed by UNESCO (2021) and the OECD (2021). In this regard, the report emphasizes that infrastructural preparedness, accessibility, and inclusive system design are just as important to the success of digital transformation as innovation. Additionally, the findings show that scalability is still a major issue for AR-based learning systems. Although the prototype shows great educational potential, performance degradation on low-specification devices and under high user loads indicates that technical optimization is necessary for large-scale adoption. This highlights the necessity of integrated approaches that mix innovative teaching methods with the advancement of technology infrastructure. This governance-focused viewpoint marks a substantial conceptual change. Consistent with postdigital perspectives, the study demonstrates that digital technologies cannot be understood as external interventions but must be analyzed as embedded within broader socio-technical and organizational systems that shape power, control, and decision-making (Knox, 2019).

Declaration of Novelty

Building on these findings, this study makes a theoretical intervention by challenging the dominant assumption in educational technology and leadership research that digital innovation primarily functions as a pedagogical enhancement or a tool for improving instructional effectiveness. Instead, it reconceptualizes digital learning technologies—specifically AR—as **infrastructures of governance** that actively participate in the datafication, regulation, and standardization of educational practice. By advancing the concept of **leadership-mediated digital governance**, the study repositions school leadership from a facilitative or supportive role to a constitutive mechanism through which data systems, instructional processes, and accountability structures are actively aligned and institutionalized. In contrast to prevailing models that treat technology adoption as teacher-driven and context-dependent, this study demonstrates that digital innovation becomes consequential only when embedded within formal governance architectures such as the PPEPP quality assurance cycle. Furthermore, it identifies **datafication-induced tensions**—particularly between pedagogical autonomy and governance through standardization, as well as between instructional design and technological constraints—thereby revealing that digital transformation is not a neutral or linear process, but a restructuring of power, visibility, and control within schooling systems. By theorizing digital technology as a governance apparatus rather than an instructional aid, this study shifts the analytical focus of educational leadership research toward the organizational, political, and regulatory dimensions of digital transformation, offering a new lens for understanding how schooling is reconfigured in data-driven environments.

6. Conceptual, Practical, and Policy-Oriented Implications

6.1 Conceptual Consequences

By putting forth a governance-focused paradigm for digital learning integration and framing educational technology—more specifically, AR—as an institutional mechanism rather than a

stand-alone teaching instrument, this study improves the theoretical discourse. The results span three areas - educational technology, instructional leadership, and quality assurance systems - that are frequently discussed independently in the literature. This study conceptualizes digital learning as a component of a continuous improvement system by combining instructional leadership theory with Total Quality Management (TQM) principles operationalized through the PPEPP cycle. Within this framework, technology functions simultaneously as a pedagogical resource and a system of data generation. Innovation becomes institutionalized through the mediating role of leadership, while quality assurance systems provide the structural basis for evaluation and sustainability.

6.2 Useful Consequences for School Leadership

Practically speaking, the results emphasize how important school leadership is to operationalizing digital innovation in institutional structures. Ad hoc technology adoption must give way to organized, data-driven governance approaches for effective implementation. School administrators are urged to: 1) Integrate AR into Quality Assurance Systems (SPMI/PPEPP) To guarantee conformity with curriculum objectives and ongoing monitoring, incorporate AR-based learning into school quality documents, standards, and assessment indicators. 2) Create Programs for Teacher Digital Competency To improve teacher preparedness and instructional efficacy, develop systematic training programs centered on AR integration, digital pedagogy, and data-informed instruction. 3) Put Learning Analytics and Monitoring Dashboards into Practice Real-time monitoring, assessment, and evidence-based decision-making are supported by system-generated data (e.g., engagement metrics, performance logs). 4) Enhance Evaluation and Supervision of Instruction Integrate AR-based learning into supervisory procedures, making sure that technology utilization and instructional quality are regularly evaluated and enhanced. By taking these steps, school administrators are positioned as strategic agents of quality governance and digital transformation in addition to being administrators.

6.3 Implications for Policy

The study emphasizes that systemic support beyond individual school initiatives is necessary for sustainable digital transformation in education at the policy level. The results indicate a number of important policy directions: 1) Set Minimum Requirements for Digital Infrastructure To guarantee fair access to digital learning tools across regions, governments should establish baseline requirements for device availability, network capacity, and system compatibility. 2) Create National Frameworks for Integrating AR-Based Education For the adoption, use, and assessment of AR and other advanced learning technologies in national curricula and quality assurance systems, policymakers should provide uniform rules. 3) Encourage Scalable and Inclusive Digital Systems The development of technologies that are scalable in a variety of educational contexts and optimized for low-specification devices should be given top priority in public investment and funding systems. 4) Encourage Leadership Development for Digital Governance National initiatives should concentrate on enhancing school administrators' ability to oversee digital innovation, incorporate it into quality control procedures, and spearhead data-driven improvement projects. 5) Promote Public-Private Partnerships (PPP) To expedite innovation while maintaining consistency with educational standards and goals, cooperation between governments, academic institutions, and technology firms should be encouraged.

7. Discussion

This study challenges a dominant assumption in educational technology research that digital innovation primarily enhances instructional effectiveness. Instead, the findings demonstrate

that digital technologies function as **infrastructures of governance**, actively reshaping how educational practices are monitored, evaluated, and regulated.

By conceptualizing augmented reality as part of a broader process of datafication in schooling, this study demonstrates that instructional activities are increasingly transformed into quantifiable and auditable forms. These transformations extend beyond pedagogical enhancement. They enable new modes of visibility and control within schools. Teaching and learning are no longer governed solely through professional judgment. Instead, they are increasingly regulated through data-driven accountability mechanisms.

This shift introduces a fundamental tension between pedagogical autonomy and governance through standardization. On the one hand, AR-based learning supports constructivist and student-centered approaches. On the other hand, its integration into formal quality assurance systems subjects instructional practices to increased monitoring, comparability, and regulation. This duality is not incidental. It reflects a structural condition of digital governance. Digital innovation simultaneously expands instructional possibilities while constraining them through institutional logics of accountability.

From a leadership perspective, the findings reposition school leaders as **architects of data governance**, responsible not only for supporting innovation, but for structuring how data are produced, interpreted, and used to regulate practice. Leadership, therefore, becomes a central mechanism through which digital technologies are translated into organizational control. These findings extend existing leadership theories by demonstrating that digital transformation is not merely a process of adoption or change management, but a reconfiguration of governance structures within schooling systems.

8. Conclusion

This study demonstrates that digital innovation in education - specifically AR - can function as a mechanism of organizational governance when embedded within instructional leadership practices and quality assurance systems. Beyond its pedagogical benefits, AR enables the generation of data that supports monitoring, evaluation, and continuous improvement processes within schools. However, the findings also reveal a persistent gap between instructional effectiveness and technical performance, underscoring the importance of infrastructure readiness, system scalability, and equitable access. These challenges highlight that successful digital transformation is not solely a matter of technological adoption, but of institutional capacity and governance alignment.

From a theoretical perspective, this study advances a governance-oriented model of digital innovation that integrates leadership, technology, and quality management. It positions school leaders as key actors in the institutionalization of innovation, responsible for aligning instructional practices with organizational systems of accountability and improvement. From a policy perspective, the results suggest the need for systemic approaches that combine leadership development, infrastructure investment, and the integration of digital tools into formal quality assurance frameworks. Such alignment is essential to ensure that digital innovation contributes to sustainable and equitable educational improvement. Future research should extend this work by employing longitudinal and comparative designs to examine how governance-oriented digital innovation evolves across different institutional and policy contexts. Digital innovation becomes governance not simply when it is used, but when it restructures how decisions are made, how performance is evaluated, and how accountability is enacted within educational systems.

Citations

- Ahn, J., & Edwin, A. (2021). An e-learning model for teaching mathematics using augmented reality. *Educational Technology & Society*, 24(3), 156–168.
- Akçayır, M., & Akçayır, G. (2017). Advantages and challenges of augmented reality in education: A systematic review. *Educational Research Review*, 20, 1–11. <https://doi.org/10.1016/j.edurev.2016.11.002>
- Bond, M., Buntins, K., Bedenlier, S., Zawacki-Richter, O., & Kerres, M. (2020). Mapping research in student engagement and educational technology. *Educational Technology Research and Development*, 68, 1–23. <https://doi.org/10.1007/s11423-019-09729-6>
- Branch, R. M., & Dousay, T. A. (2020). Survey of instructional design models. *Educational Technology Research and Development*, 68, 1–16. <https://doi.org/10.1007/s11423-020-09766-7>
- Cuban, L. (2018). The flight of a butterfly or the path of a bullet? Using technology to transform teaching and learning. *American Educational Research Journal*, 55(3), 1–25. <https://doi.org/10.3102/0002831218763924>
- Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning. *Applied Developmental Science*, 24(2), 97–140. <https://doi.org/10.1080/10888691.2018.1537791>
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319–340. <https://doi.org/10.2307/249008>
- Decuyper, M. (2021). Algorithmic governance in education: The datafication of learning and teaching. *Learning, Media and Technology*, 46(1), 1–15. <https://doi.org/10.1080/17439884.2021.1876723>
- Dexter, S. (2018). The role of leadership in technology integration. *Educational Technology Research and Development*, 66, 1–21. <https://doi.org/10.1007/s11423-018-9586-0>
- Ertmer, P. A., & Ottenbreit-Leftwich, A. (2019). Teacher beliefs and technology integration practices: A critical relationship. *Educational Technology Research and Development*, 67, 1–28. <https://doi.org/10.1007/s11423-019-09674-4>
- Fullan, M. (2020). *Leading in a culture of change*. Jossey-Bass.
- Fullan, M., & Quinn, J. (2020). *Coherence: The right drivers in action for schools, districts, and systems*. Corwin.
- Garrison, D. R. (2017). *E-learning in the 21st century: A community of inquiry framework for research and practice*. Routledge.
- Gunter, H. M. (2012). *Leadership and the Reform of Education*. Policy Press.
- Hallinger, P. (2011). Leadership for learning: Lessons from 40 years of empirical research. *Journal of Educational Administration*, 49(2), 125–142. <https://doi.org/10.1108/09578231111116699>
- Harris, A., & Jones, M. (2022). COVID-19 and school leadership: Emerging challenges and implications. *School Leadership & Management*, 42(1), 1–4. <https://doi.org/10.1080/13632434.2021.2013041>
- Hattie, J. (2018). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Routledge.
- Ibáñez, M. B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education*, 123, 109–123. <https://doi.org/10.1016/j.compedu.2018.05.002>

- Kitchin, R. (2014). *The data revolution: Big data, open data, data infrastructures and their consequences*. Sage.
- Knox, J. (2019). What does the 'postdigital' mean for education? Three critical perspectives on the digital, with implications for educational research and practice. *Postdigital Science and Education*, 1, 357–370. <https://doi.org/10.1007/s42438-019-00045-y>
- Kong, S. C., Cheung, W. M. Y., & Zhang, G. (2021). Evaluation of a digital competence framework for teachers. *Computers & Education*, 168, 104212. <https://doi.org/10.1016/j.compedu.2021.104212>
- Leithwood, K., Harris, A., & Hopkins, D. (2020). Seven strong claims about successful school leadership revisited. *School Leadership & Management*, 40(1), 5–22. <https://doi.org/10.1080/13632434.2019.1596077>
- Means, B., Toyama, Y., Murphy, R., & Baki, M. (2020). *Learning online: What research tells us about whether, when and how*. Routledge.
- OECD. (2021). *OECD digital education outlook 2021: Pushing the frontiers with AI, blockchain and robots*. OECD Publishing.
- Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education. *Computers & Education*, 147, 103778. <https://doi.org/10.1016/j.compedu.2019.103778>
- Reeves, T. C. (2020). Design-based research in educational technology: Progress made, challenges remaining. *Educational Technology Research and Development*, 68, 1–15. <https://doi.org/10.1007/s11423-020-09789-0>
- Sallis, E. (2014). *Total quality management in education* (3rd ed.). Routledge.
- Selwyn, N. (2019). *Should robots replace teachers? AI and the future of education*. Polity Press.
- Selwyn, N. (2021). *Education and technology: Key issues and debates* (2nd ed.). Bloomsbury Academic.
- UNESCO. (2021). *Reimagining our futures together: A new social contract for education*. UNESCO.
- Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly*, 27(3), 425–478. <https://doi.org/10.2307/30036540>
- Williamson, B. (2017). *Big data in education: The digital future of learning, policy and practice*. Sage.
- Williamson, B., Bayne, S., & Shay, S. (2020). The datafication of teaching in higher education: Critical issues and perspectives. *Teaching in Higher Education*, 25(4), 351–365. <https://doi.org/10.1080/13562517.2020.1748811>
- Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence in higher education. *International Journal of Educational Technology in Higher Education*, 16(39). <https://doi.org/10.1186/s41239-019-0171-0>
- Zhao, Y. (2020). *Reach for greatness: Personalizable education for all children*. Corwin.