

Digital Resilience

AI and Cultural Democracy at the National Museum of Korea

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The COVID-19 pandemic served as a brutal stress test for museum resilience. While many institutions relied on a 'substitutive model' of mere digital replacement, the National Museum of Korea (NMK) achieved anomalous growth through a strategic pivot. This study employs an explanatory single-case study design to investigate the mechanisms behind this success. Applying pattern matching logic, the research validates the efficacy of a 'Transformative Model' grounded in Cultural Democracy. Findings reveal that the NMK's integration of AI-driven personalization, immersive Extended Reality (XR) experiences, and radical inclusivity reconfigured the visitor relationship from passive consumption to active co-creation. Crucially, empirical data confirms a positive correlation where high-level digital engagement functioned as a catalytic gateway that drove, rather than cannibalized, physical attendance. This case illustrates how sustainable resilience can be achieved when technology is strategically deployed to democratize heritage access and empower the visitor as an active participant.

digital resilience transformative model, cultural democracy, digital heritage engagement, museum digital ecosystem

1 Introduction

The COVID-19 pandemic precipitated an unprecedented crisis within the global museum sector. A UNESCO (2020) report documented that nearly 90% of the world's museums were forced to close temporarily, with over 10% facing permanent shutdown. This trend was starkly evident among the world's leading institutions; data from The Economist (2021) revealed a 77% drop in attendance for the top 100 art museums from 2019 to 2020.

In stark contrast to this global decline, the National Museum of Korea (NMK) presents a significant anomaly. While the aggregate attendance of the world's top 100 museums remained 38% below pre-pandemic levels in 2022, the NMK had already surpassed its 2019 figures, achieving a 2% growth. This made it the only institution in the Top 10 to post positive growth that year, while iconic museums like the Louvre, the Vatican Museums, and the British Museum continued to report significant deficits (Cheshire, Da Silva, 2023). The NMK's upward trajectory accelerated into 2023, culminating in a 25% increase over its pre-pandemic visitor numbers. This performance dramatically improved its global ranking from 15th in 2019 to 5th in 2022 and 6th in 2023 (Cheshire, Da Silva, 2024). The case of the NMK – a national history museum often considered peripheral to the dominant Western art canon – thus raises a critical question: How did this institution achieve such an anomalous growth trajectory while its peers struggled?

This inquiry is situated within the specific context of pandemic-era literature, where the strict control of external variables – such as international tourism flows and funding streams – isolated digitalization as the singular critical variable determining institutional resilience. The dominant approach was a 'substitutive model', a reactive pivot where digital tools functionally replaced physical presence to ensure survival (Giannini, Bowen, 2022; Larkin et al., 2023), though this strategy proved insufficient and amplified existing inequalities (NEMO, 2020). In contrast, a 'transformative model' emerges from theories of Cultural Democracy, which reframes visitors as active co-creators (Bonet, Négrier, 2018) and utilizes technology to reconfigure the museum – visitor relationship toward active participation (e.g., Trunfio et al., 2022; Simon, 2010). While these paradigms are often conceptualized as distinct paths, it is important to acknowledge the potential for hybrid configurations where substitu-

tive digital infrastructures – such as online repositories – serve as a functional baseline for transformative engagement layers. However, this study focuses on the strategic pivot where the underlying institutional logic shifts fundamentally from content delivery to visitor agency.

While the literature theoretically delineates these diverging paths, a critical gap remains in empirically validating the efficacy of the transformative strategy through a successful case study. Addressing this lacuna, this paper argues that the NMK's anomaly is directly attributable to its swift and strategic pivot from a substitutive to a transformative model. This study contends that the museum's resilience is rooted in a guiding philosophy of Cultural Democracy, where the Artificial Intelligence (AI) and digital ecosystem were deployed not as functional substitutes, but as catalysts to empower visitors as active participants and co-creators. The NMK's transition from a substitutive to a transformative model was not an instantaneous replacement but a phased strategic evolution occurring between 2019 and 2021. This shift unfolded in three distinct stages: (1) the Foundational Phase (2019–2020), where initial AI infrastructures like the 'QI' robot and Digital Immersive Galleries were established; (2) the Strategic Pivot Point (2021), marked by the announcement of 'Digital Strategy 2025', which formally reoriented the museum's logic from content delivery to visitor agency; and (3) the Transformative Saturation Phase (2022–2023), where inclusive technologies like AI Barrier-Free Kiosks were scaled up. During this transition, the two models coexisted as hybrid layers, with digital continuity in 2020 providing the functional baseline for the subsequent transformative engagement outcomes observed in 2022 and 2023.

2 Literature Review

2.1 The dominant paradigm: The 'substitutive model' of crisis digitalization

The imperative for digitalization and the critical importance of online audience engagement long predate the COVID-19 crisis (Kelly, 2009; Proctor, 2010), having been established as a form of "normativity" in museum discourse (Parry, 2013). However, the pandemic acted as a brutal litmus test, exposing a critical disconnect between this aspiration and operational reality. Faced with immediate physical closure, the dominant institutional reflex was not to reimagine the museum experience, but to functionally replicate it in a virtual environment (Giannini, Bowen, 2022). This study defines this prevailing response as the 'substitutive model', characterized by the ontological substitution of physical presence and the preservation of a traditional, unidirectional transmission paradigm where museums merely broadcast content to a passive audience (Finnis, Kennedy, 2020).

In the crisis's early phase, this approach was mistakenly conflated with successful adaptation. Surveys cited a surge in online output (NEMO, 2021), yet these initiatives primarily utilized platforms as static repositories, reinforcing the museum as a monologic authority. This initial optimism, however, was dismantled by longitudinal data revealing the model's inherent fragility. Analyzing over 3300 UK museums, Larkin et al. (2023) demonstrated that the "digital pivot" was largely ephemeral; there was no substantial, sustained increase in engagement over time. This indicates that without strategic depth, the mere availability of online content fails to retain audience interest.

Furthermore, the substitutive model exacerbated structural inequities. Its reliance on replicating physical assets made implementation highly "uneven" (NEMO, 2020), highlighting deep-seated deficits in the "backstage of museums" – specifically in digital literacy and infrastructure – that paralyzed smaller institutions (Nikolaou, 2024). Consequently, the substitutive model proved structurally unsustainable. It offered a reactive survival mechanism that, while bridging the immediate gap, failed to provide a viable methodology for long-term engagement, ultimately amplifying the digital divide and underscoring the urgent necessity for a paradigm shift beyond functional substitution.

2.2 The emergent paradigm: The 'transformative model' of visitor engagement

In stark contrast to the reactive limitations of the substitutive model, a 'transformative model' emerges from the literature, defined by the strategic integration of technology to fundamentally reconfigure the museum–visitor relationship. The conceptual anchor of this paradigm is Cultural Democracy, which challenges expert-driven hierarchies and repositions the visitor from a passive consumer to an active agent and co-creator (Bonet, Négrier, 2018). While Cultural Democracy provides the philosophical imperative, advanced technologies provide the operational means to actualize this shift at scale.

This transformation is realized through two interconnected technological avenues: a pedagogical pivot via AI and an experiential pivot via Extended Reality (XR). First, the model leverages AI to move beyond uniform information delivery toward personalized 'edutainment' (Yap et al., 2024). Intelligent recommender systems and machine learning frameworks analyze visitor behavior to create self-directed, adaptive learning pathways, transforming the museum from a static broadcaster into a responsive learning environment (Li, Liu, 2025; Hughes-Noehrer, 2022). Second, XR technologies and Digital Twins serve as catalysts for active 'memory-making'. By blurring the boundaries between physical and digital realms, these immersive tools empower visitors to customize content and engage in co-creation, thereby deepening emotional connections and transforming the visit into a powerful, memorable experience (Trunfio et al., 2022; Bekele et al., 2018).

However, a critical review of the current landscape reveals a distinct bifurcation. One stream of literature largely documents the structural failures of the crisis-driven substitutive model (Larkin et al., 2023), while another theoretically outlines the aspirations of the transformative model without sufficient empirical grounding. A significant research gap exists at this intersection: there is a scarcity of empirical case studies demonstrating a successful institutional *transition* from a substitutive footing to a transformative strategy in the post-pandemic context. Existing scholarship remains divided between the critique of operational reality and the discussion of theoretical ideals. Consequently, this study addresses this lacuna by utilizing the NMK case to empirically investigate the mechanisms of this transformative framework, thereby bridging the gap between theoretical aspiration and practical implementation.

3 Methodology

3.1 Research design: An explanatory single-case study

This study employs an explanatory single-case study design to investigate the causal mechanisms behind the NMK's post-pandemic resilience. The NMK is selected as a critical and revelatory case (Yin, 2018) that defies the global trend of stagnation in the museum sector. While standard case studies often utilize representative samples to illustrate common phenomena, this study isolates the NMK as an 'extreme case' to adjudicate between the two competing theoretical frameworks identified in the literature: the 'substitutive' versus the 'transformative' model. By focusing on this specific unit of analysis, the research moves beyond descriptive documentation to explain how specific strategic choices, by facilitating visitor interaction with the museum's digital ecosystem, produced these anomalous growth outcomes.

3.2 Data collection

This study adopts a mixed-methods approach that integrates quantitative metrics with qualitative archival data through a convergent design. The primary dataset for both dimensions relies on the NMK's official *Annual Reports* covering the period from 2019 to 2023. The selection of this timeframe is methodologically deliberate, it is designed to capture the full trajectory of the 'stress test' cycle: the pre-pandemic baseline (2019), the crisis peak (2020–2021), and the critical recovery phase (2022–2023). Furthermore, as the NMK's comprehensive Annual Reports are typically published in the year following the period of record, the 2023 figures represented the most recent validated and complete dataset available at the time of this study's execution in 2024. Including subsequent partial data would have compromised the longitudinal consistency required for the pattern matching analysis.

For the quantitative dimension, longitudinal statistics of physical visits, website traffic data, and engagement metrics were extracted from these reports. To objectively substantiate the museum's classification as a global statistical outlier, these internal figures were cross-verified against industry-standard rankings from *The Art Newspaper*. Complementing these metrics, the qualitative inquiry focused on elucidating the strategic rationale and operational execution. Data collection involved a systematic review of three distinct archival streams: (1) governance documents, principally *Digital Strategy 2025*, which outlines the roadmap; (2) the *Annual Reports* documenting actual implementation; and (3) official press releases detailing the specifications of flagship initiatives.

3.3 Data analysis

The analysis employs a pattern matching logic (Yin, 2018), a technique that compares empirically observed patterns with predicted theoretical ones. The collected textual data is coded against the three key constructs of the 'Transformative Model': Cultural Democracy (Philosophical Intent), AI Personalization (Pedagogical Shift), and XR/Immersive Engagement (Experiential Shift).

To ensure the construct validity of these matched patterns, the study utilizes data triangulation (Yin, 2018). This involves cross-verifying the consistency across three distinct evidence sources: (1) the museum's declared strategic intent (institutional documents), (2) the objective record of technological implementation (annual reports), and (3) the resultant performance outcomes (quantitative statistics). This convergent line of inquiry minimizes potential bias and confirms that the observed resilience is not coincidental, but structurally linked to the proactive adoption of the transformative framework.

4 The Case: NMK's Digital Ecosystem

4.1 The strategic vision: "Digital Strategy 2025"

The NMK's digital transformation culminated in the "Digital Strategy 2025", announced in June 2021. This blueprint consolidated sporadic efforts into a unified vision to create a "museum for all" through an "Intelligent, Hyper-Personalized, Immersive Tour Service" (Cho, 2021). The strategy reframes digitalization not as a technical upgrade but as a philosophical shift toward Cultural Democracy, aiming to engage digital natives and ensure radical inclusivity. Its execution relies on a tripartite technological foundation – AI, XR, and Digital Twins – structured into two operational layers: the On-site AI Layer for physical media-tion and the Digital Layer for hybrid engagement.

4.2 The on-site AI layer: Physical mediators for inclusivity

The On-site AI layer transforms the physical visitor experience from passive observation to active dialogue through the deployment of two complementary AI-powered agents. The primary mediator in this ecosystem is the autonomous robot docent, 'QI'. Since its deployment in 2019, 'QI' has evolved into a core service provider, operational in 14 national institutions as of 2024 (MCST, 2024). Moving beyond the static scripts of conventional audio guides, the robot leverages Natural Language Processing (NLP) to facilitate responsive, two-way dialogue in four languages. It embodies the pedagogical shift toward personalized learning by allowing visitors to query artifacts directly. Crucially, it serves as an active agent of inclusivity, offering simplified content for children and sign language interpretation for the hearing impaired, thus democratizing access to expert knowledge (Seo, 2022).

Complementing this mobile mediator is the AI Barrier-Free Kiosk, which represents the museum's commitment to providing a "minimum of ordinariness" for disabled visitors. Initiated in 2022 and expanded to 12 units as of 2025, these kiosks integrate comprehensive accessibility features, including auto-height adjustment and Braille pads. Its most transformative feature is the AI Sign Language Avatar, which attempts two-way recognition, allowing users to ask questions in sign language with nearly 90% accuracy (National Museum of Korea, 2025). This technology serves as powerful evidence that the NMK prioritizes equitable access as a fundamental right rather than a special service.

4.3 The digital layer: Hybridizing the visitor experience

The digital layer utilizes software to extend the museum experience beyond physical walls, creating a seamless hybrid environment through mobile integration and immersive content. The central engine for this 'Hyper-Personalized' strategy is the "National Museum of Korea Exhibition Guide" mobile application. Evolving from a conventional beacon guide, the app incorporates the "My Exhibition Tour", which empowers visitors to curate their own paths based on personal interests (Seo, 2025). Enhanced with AR indoor navigation and Digital Twin technology, the app repositions the personal mobile device from a passive information carrier into an interactive lens for augmented engagement, guiding visitors to artifacts and offering 3D interactions in real-time.

In parallel with these personalizing tools, the NMK strategically employs XR not merely as a spectacle, but as a method to transcend physical limitations and democratize engagement with geographically inaccessible heritage. This approach is paradigmatically illustrated by the digital reconstruction of the Goguryeo Tomb Murals, which are located in North Korea. To disseminate this content, the museum utilizes a dual-platform strategy that harmonizes communal immersion with individual exploration. Within the physical museum, Digital Immersive Gallery 3 utilizes four-sided projection mapping to virtually transport visitors inside the tombs, fostering a shared, visceral sensory experience. Simultaneously, this spatial immersion is mirrored in the digital realm through the Online Exhibition Portal, which provides remote access to the same high-fidelity content via VR and 360-degree views. This recursive structure ensures that the visceral impact of the on-site visit can be intellectually deepened through subsequent online self-directed study, establishing a continuous cycle of engagement that transcends the temporal boundaries of a single visit.

5. Findings

The empirical findings derived from the pattern matching analysis demonstrates that the NMK's digital ecosystem did not merely function as a substitute during the crisis but actively drove a transition toward the 'Transformative Model'. The findings are organized according to the model's three key constructs: the pedagogical shift via AI, the experiential shift via XR, and the philosophical commitment to Cultural Democracy.

5.1 The pedagogical shift: From information delivery to personalized engagement

The first identifiable pattern is the fundamental shift from unidirectional information delivery to personalized, self-directed learning. This transition is validated through a triangulation of evidence: the strategic mandate for "Hyper-Personalization" outlined in *Digital Strategy 2025* (Intent), the operational deployment of NLP-driven 'QI' robots (Implementation), and the subsequent surge in engagement intensity (Outcome).

Qualitative analysis reveals that the NMK utilized AI to empower visitors as active learners. The 'QI' robot docent, powered by NLP, transcends the fixed scripts of conventional audio guides to engage in real-time dialogue. This allows visitors to construct customized learning pathways based on their own curiosity (Seo, 2022). Similarly, the "My Exhibition Tour" feature in the mobile app shifts the locus of control from the curator to the visitor, transforming the museum visit into a process of self-led discovery.

This qualitative shift is empirically substantiated by the quantitative usage data of the 'QI' robot. As illustrated in Figure 1, the total engagement with AI docents has shown explosive growth, recording a year-over-year increase of 61.3% in 2022 and 57.5% in 2023.

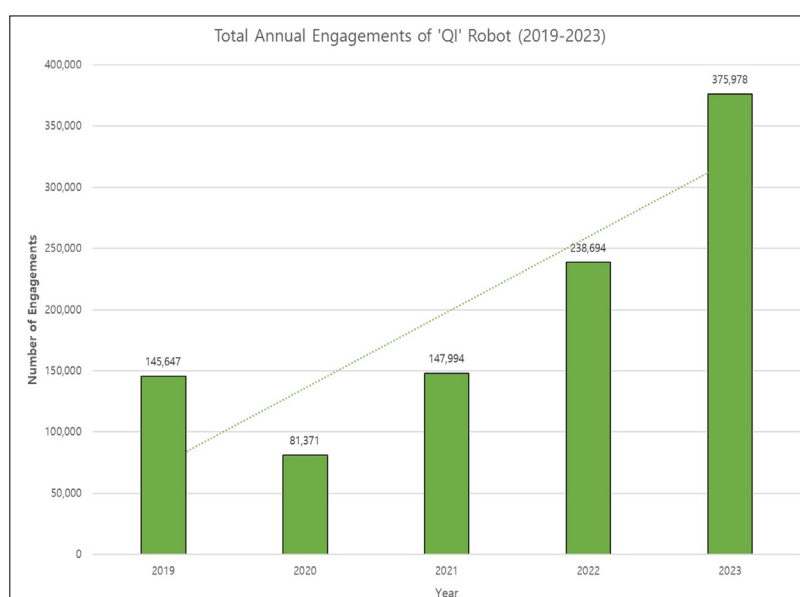


Fig. 1: Total Annual Engagements of 'QI' Robot (2019–2023). Source: Data compiled from NMK Annual Reports (2019–2023).

Crucially, this upward trend is not solely attributable to the recovery in visitor numbers. To assess the relative intensity of this engagement independent of attendance fluctuations, this study normalized the data by calculating 'QI Engagements per 100 Visitors', as detailed in Table 1.

Table 1: 'QI' Robot Engagements per 100 Physical Visitors (2019–2023). Source: Data compiled from NMK Annual Reports (2019–2023).

Year	Total Annual QI Engagements	Total Annual Physical Visitors	QI Engagements per 100 Visitors
2019	145,647	3,354,161	4
2020	81,371	773,621	11
2021	147,994	1,262,562	12
2022	238,694	3,411,381	7
2023	375,978	4,180,285	9

Note: QI Engagements per 100 Visitors = (Total Annual QI Engagements / Total Annual Physical Visitors) * 100

The results, visualized in Figure 2, present a compelling narrative. The engagement intensity peaked at 12 per 100 visitors in 2021 – triple the pre-pandemic rate of 4. While the rate naturally adjusted as mass tourism resumed, it stabilized at a "new normal" of 9 in 2023, still more than double the 2019 baseline. This pattern confirms that the AI docent has evolved from a peripheral technological novelty into a core pedagogical tool, proving that the museum's strategy has successfully embedded personalized education into the visitor experience.

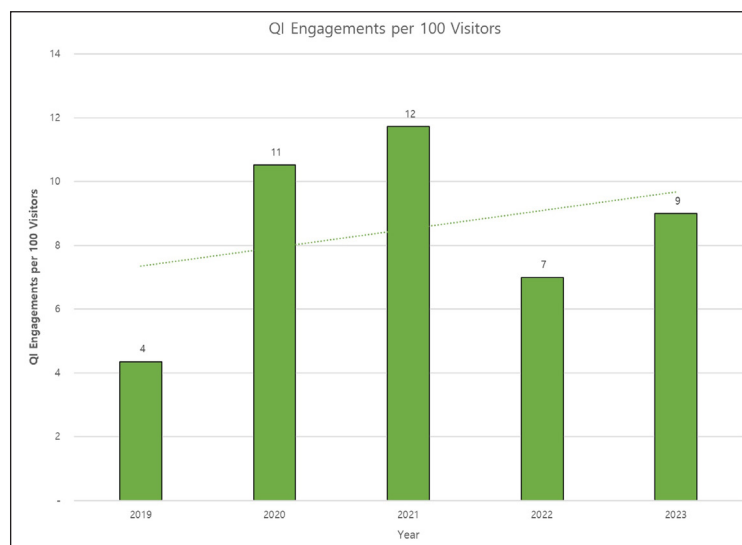


Fig. 2: 'QI' Robot Engagements per 100 Physical Visitors (2019–2023). Source: Data compiled from NMK Annual Reports (2019–2023).

5.2 The experiential shift: From passive viewing to immersive memory-making

The second pattern matches the theoretical construct of the 'Experiential Shift', where XR technologies transform visitors from passive observers into active participants. This shift is validated through data triangulation: the museum's strategic mandate to democratize heritage via digital reconstruction (Intent), the physical construction of the Digital Immersive Galleries (Implementation), and the resultant visitor saturation despite operational constraints (Outcome).

5.2.1 Immersive technologies as catalysts for engagement

The Experiential Shift is realized through a dual-layered strategy involving both individual mobile AR and the Digital Immersive Galleries. Qualitatively, the latter exemplifies the transition from observation to co-creation.

Unlike conventional static displays, these spaces blur the boundaries between physical artifacts and digital interpretation. A prime example is Gallery 1, featuring an interactive panoramic screen of the *Chaekgado* (Scholars' Bookshelves), where visitors use tablets to customize content and digitally place objects onto the projected painting in real-time. This mechanism transforms the visitor from a viewer into a creator, aligning with the transformative premise that digital tools should deepen the emotional connection to heritage.

5.2.2 Quantitative verification: Strategic importance of immersive content

The efficacy of this experiential shift is substantiated by quantitative indicators derived from the NMK Annual Reports (2020–2023). Since Digital Immersive Galleries were newly established in 2020, there is no pre-pandemic baseline; however, the growth trajectory since their launch is compelling. To analyse their intrinsic popularity while controlling for closure periods, this study calculated Daily Average Visitors and Visitor Share (%) of Digital Immersive Galleries (D.I.G.), as detailed in Table 2.

Table 2: Statistics of D.I.G. (Digital Immersive Galleries) (2020–2023). Source: Data compiled from NMK Annual Reports (2020–2023).

Year	2020	2021	2022	2023
D.I.G. Total Visitors	121,578	361,260	778,020	996,823
D.I.G. Operating Days	105	343	359	360
D.I.G. Daily Average Visitors	1,158	1,053	2,167	2,769
Total Physical Visitors	773,621	1,262,562	3,411,381	4,180,285
D.I.G. Visitor Share (%)	16	29	23	24

Note: 'Total Digital Immersive Galleries Visitors', 'Operating Days', and 'Total Annual Physical Visitors' represent raw data extracted from the reports. 'Daily Average Visitors' and 'Visitor Share' act as derived metrics calculated by this study based on the following formulas:

① Daily Average Visitors = Total Digital Immersive Gallery Visitors / Operating Days

② Visitor Share (%) = (Total Digital Immersive Gallery Visitors / Total Annual Physical Visitors) × 100

First, the Daily Average Visitors metric reveals the galleries' drawing power. As illustrated in Figure 3, attendance shows a consistent upward trajectory, more than doubling from 1053 in 2021 to 2769 in 2023. This indicates that the demand for immersive experiences was not a transient crisis phenomenon but a sustained growth trajectory.

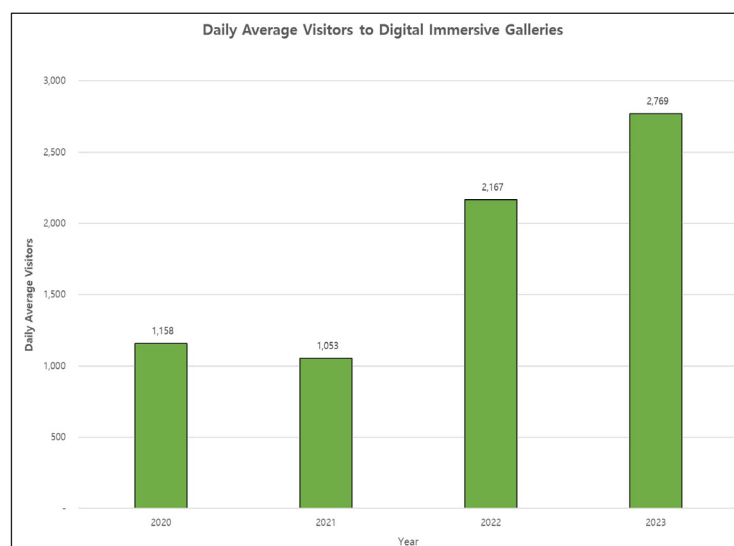


Fig. 3: Daily Average Visitors to Digital Immersive Galleries (2020–2023). Source: Data compiled from NMK Annual Reports (2020–2023).

Note: Data collection for D.I.G. has been conducted since its opening in 2020.

Second, the Visitor Share metric confirms the strategic centrality of these galleries. As visualized in Figure 4, approximately 23–24% of all physical visitors consistently engaged with these digital galleries in the post-pandemic period.

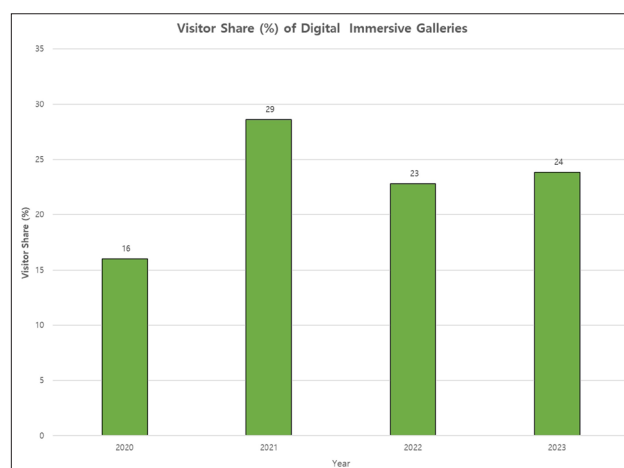


Fig. 4: Visitor Share (%) of Digital Immersive Galleries (2020–2023). Source: Data compiled from NMK Annual Reports (2020–2023).
Note: Data collection for D.I.G. has been conducted since its opening in 2020.

Crucially, this figure must be interpreted within the context of operational constraints. Unlike general exhibition halls, the Digital Immersive Galleries operate on a strict reservation system with a capped capacity per session to ensure optimal viewing conditions. The fact that nearly a quarter of all museum visitors secured a spot despite these entry barriers suggests a state of near-saturation. Consequently, this high participation rate signifies a shift beyond incidental curiosity, demonstrating a deliberate and proactive visitor intent to engage with the immersive experiences defining the transformative model.

5.3 The philosophical shift: Radical inclusivity and cultural democracy

The final pattern matches the construct of the 'Philosophical Shift', where technology serves as a tool for Cultural Democracy. This is validated through triangulation: the institutional mandate to ensure a "minimum of ordinariness" (Intent), the deployment of the AI Barrier-Free Kiosk (Implementation), and its rapid institutional expansion (Outcome).

5.3.1 Democratizing access via AI

The 'AI Barrier-Free Kiosk' embodies the institutional shift from efficiency to equity. By implementing the AI Sign Language Avatar, the NMK addresses the profound information gap for the hearing impaired, enabling access in their primary language (Baek, 2023). This initiative confirms that the digital ecosystem is designed not merely to 'accommodate' disabilities for compliance, but to actively 'empower' marginalized visitors as equal agents within the museum.

5.3.2 Quantitative verification: Institutional expansion as a success indicator

In the absence of public user logs, the scale of resource allocation and technical advancement serve as objective proxies for success. First, the rate of expansion proves institutional confidence. Since the 2022 pilot, the kiosks have expanded to twelve units across the NMK and regional branches by 2025 (National Museum of Korea, 2025). This rapid expansion indicates the model has passed internal validation.

Second, technical performance confirms the commitment to quality. The AI sign language recognition accuracy has reached nearly 90%, a metric that validates the system's practical efficacy. These indicators confirm that inclusivity is a scalable and core mandate of the NMK's digital transformation.

5.4 Overall outcome: From digital engagement to physical resilience

Finally, the pattern matching analysis culminates in the empirical verification of the Transformative Model. The integration of the pedagogical (AI), experiential (XR), and philosophical (Inclusivity) shifts has yielded tangible outcomes that confirm the synergy between digital strategy and institutional resilience.

The data reveals two critical phases of this resilience. First, during the crisis peak in 2020, while physical attendance plummeted by 77% (to 0.77 million), website traffic remained robust at over 3 million visits. This indicates that the digital ecosystem functioned as a mechanism for relational continuity, maintaining the audience connection when physical access was severed. Second, the post-pandemic recovery phase (2021–2023) demonstrates a catalytic effect. As website traffic surged to record highs – reaching 6.5 million in 2023 – physical attendance followed a remarkably synchronized upward trajectory, surpassing the pre-pandemic baseline to reach 4.18 million.

While this synchronized growth does not inherently prove a direct causal link, it strongly suggests a synergistic relationship that challenges the notion of digital tools as mere provisional substitutes. The observed patterns align with the study's hypothesis that high-level online engagement functions as a catalytic gateway, where digital outreach actively incentivizes and reinforces physical visitation. By isolating the period when external variables – such as international tourism – remained suppressed, this result provides analytical substantiation for the central thesis: rather than cannibalizing the physical museum, the Transformative Model leverages digital engagement to amplify its perceived value and secure its long-term growth trajectory.

6. Discussion and Conclusion

6.1 Discussion: Validating the Transformative Model

The application of pattern matching logic to the empirical data provides robust analytical support for the Transformative Model. While a single-case design does not constitute universal validation, these findings strongly substantiate the alignment between the NMK's strategic trajectory and the proposed framework.

However, the data reveals the opposite: a synergistic growth pattern where record-breaking digital engagement (6.5 million web visits) co-occurred with and mirrored a full recovery of physical attendance (Figure 5). While the longitudinal dataset's specific sample size (N=5) precludes the application of frequentist significance tests, the observed alignment provides strong analytical substantiation through pattern matching logic (Yin, 2018), confirming that the two variables followed a synchronized upward trajectory rather than a substitutive decline.

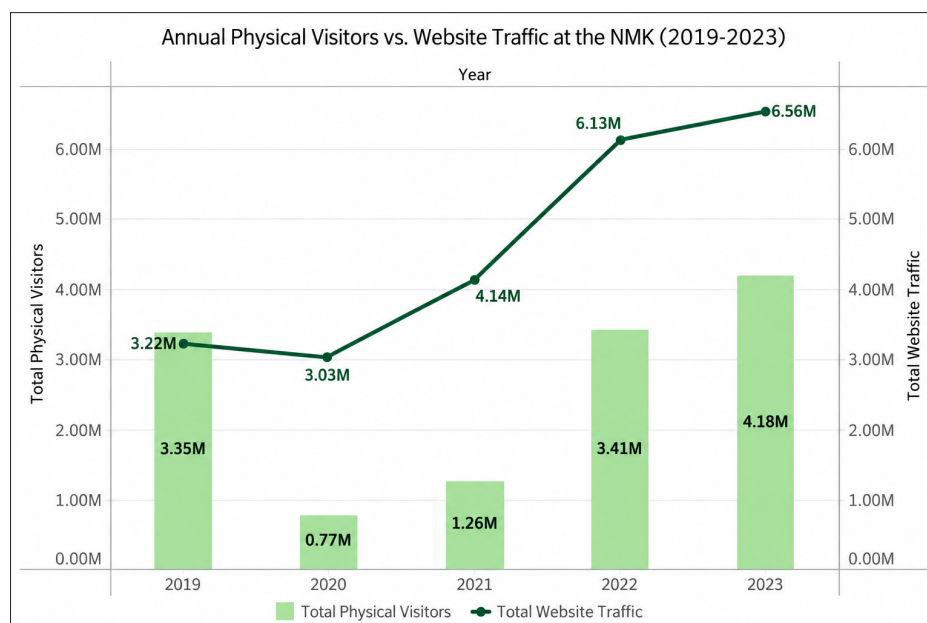


Fig. 5: Annual Physical Visitors vs. Website Traffic at the NMK (2019–2023). Source: Data compiled from NMK Annual Reports (2020–2023).

This resilience is structurally linked to the three pillars of the transformative framework identified in this study. First, the Pedagogical Shift via AI (Section 5.1) transformed the visitor from a passive recipient to a self-directed learner. The explosive growth in 'QI' robot usage intensity (from 4 to 9 engagements per 100 visitors) confirms that visitors actively seek personalized, two-way interaction. Second, the Experiential Shift via XR (Section 5.2) fulfilled the demand for active memory-making.

The sustained 24% visitor share of the Digital Immersive Galleries, despite capacity constraints, proves that immersive content has become a core driver of visitation, not a peripheral novelty. Third, the Philosophical Shift toward Cultural Democracy (Section 5.3) ensured that this transformation remained inclusive. The rapid institutional expansion of the AI Barrier-Free Kiosks demonstrates that equity was prioritized alongside efficiency.

In synthesis, the NMK's success was not achieved by simply digitizing existing assets (substitution). Instead, it emerged from a fundamental reconfiguration of the museum's core logic – from a model based on content delivery to one centred on visitor agency, experiential depth, and inclusive engagement.

6.2 Theoretical Implications

This study contributes to the field of Museum Studies and Digital Heritage by charting a theoretical pathway from the critique of crisis digitalization toward a model for sustainable transformation.

First, it challenges the prevailing narrative in the literature that describes pandemic digitalization as largely "uneven," "reactive," and "ephemeral" (Larkin et al., 2023; NEMO, 2020). The NMK case provides robust evidence that digitalization, guided by a philosophy of Cultural Democracy, can foster sustainable resilience rather than short-lived reactive gains. Second, this paper theoretically refines the concept of the 'Transformative Model'. While existing studies have discussed AI and XR separately (e.g., Hughes-Noehrer, 2022; Trunfio et al., 2022), this study integrates them into a unified framework. It posits that technological adoption (AI/XR) is a necessary but insufficient condition, contingent upon a philosophical commitment to empowerment – empowering the visitor to curate (App), to question (AI Robot), and to co-create (Digital Immersive Gallery). This holistic framework offers a new theoretical lens for analysing institutional digital maturity.

6.3 Practical Implications

For museum practitioners and policymakers, the NMK case offers an actionable blueprint for the post-pandemic era. The primary lesson is the necessity of moving beyond the "Digital Twin as a Backup" mentality. The data shows that digital platforms should not mimic the physical museum but offer distinct values – personalization and immersion – that the physical space cannot provide. The synergistic correlation between the online portal and on-site visits suggests that museums should invest in a unified digital-physical ecosystem, where digital exploration continuously enriches and amplifies the physical experience. Furthermore, the success of the AI Barrier-Free Kiosk demonstrates that inclusivity is a growth strategy. By using advanced technology to serve marginalized groups, museums can expand their relevance and audience base, proving that democratic values and operational resilience are mutually reinforcing.

6.4 Limitations and Future Research

The insights of this study are derived from a single-case design, a methodological choice that prioritizes analytical depth over broad generalizability. Consequently, the replicability of this high-tech intensive model is necessarily bounded by the NMK's unique context: South Korea's exceptionally high ICT infrastructure and strong government-led digital policy support. This inherent limitation, however, illuminates a crucial agenda for future research: comparative studies are urgently needed to analyze how the core principles of the transformative model – personalization, active engagement, and inclusivity – can be effectively translated and adapted in diverse institutional and cultural contexts with varying levels of digital maturity.

6.5 Conclusion

The COVID-19 pandemic served as a brutal stress test for the global museum sector, distinguishing fragile institutions from resilient ones. This study reveals that the NMK's anomalous growth is not a product of chance, but the result of a deliberate strategic pivot to a Transformative Model. By deploying AI and XR not as substitutes for presence, but as catalysts for Cultural Democracy, the NMK successfully reconfigured its relationship with the public. It empowered visitors as active agents – learners, creators, and participants – thereby proving that the future of the museum lies not in the technology itself, but in how that technology is used to democratize the human experience of heritage.

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