

Digital Cultural Platforms: Visual Arts Learning and Heritage Engagement

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ABSTRACT: This study examines digitally mediated visual arts learning and cultural engagement using four open secondary datasets that cover virtual art education, community cultural participation, smart museum interactions, and cultural heritage mobile applications. The study responds to a common limitation in digital arts research: broad claims about transformation are often made without connecting educational, cultural, and platform evidence within one empirical design. A secondary quantitative design was used to analyze 1,483 virtual art-learning records, 8,737 cultural engagement records, 2,834 smart heritage interaction records, and 174 cleaned cultural heritage app records. The analysis combined descriptive statistics, feature coding, correlation analysis, robust ordinary least squares models, and logistic regression for binary outcomes. Results show that improvements in learning in virtual art education were strongly associated with creativity, engagement, and collaboration, whereas session duration, peer count, and uptake of automated suggestions did not show meaningful independent effects. Art-quality scores were mainly explained by composition and creativity. In the cultural engagement dataset, event type, participation frequency, social interaction frequency, duration, and recommendation score explained little variation in high engagement, indicating that generic platform indicators are insufficient for interpreting cultural value. In the smart museum data, content clicking was the strongest predictor of visitor satisfaction, and lower crowd density increased the likelihood of interacting with content. Heritage apps most frequently emphasized tours, maps, and audio functions, while accessibility features were rare. The study contributes an integrated empirical framework showing that digital cultural value depends less on the presence of technology than on learning design, interaction quality, inclusion, and meaningful measurement.

Keywords: digital cultural platforms; virtual art education; smart museums; cultural heritage; cultural engagement; creative industries.

I. INTRODUCTION

Digital transformation in the arts is often presented as a technological shift, yet its strongest scholarly value emerges when examined as a cultural, educational, and institutional process. Digital tools do not simply add screens to existing practices. They alter how learners experiment with form, how audiences encounter cultural content, how museums interpret objects, how cultural organizations distribute experiences, and how users evaluate creative services. In visual arts learning, digital environments allow students to experiment with color, composition, space, movement, and feedback at a pace that traditional classroom materials cannot always match. In cultural participation, platforms make it easier to discover and revisit exhibitions, festivals, workshops, language activities, and local heritage content. In museums and heritage sites, mobile guides, text overlays, audio tours, three-dimensional models, maps, and interaction tracking create new relationships between visitors, objects, and cultural knowledge.

The central problem is that many studies of digital arts remain conceptually broad. They often claim that digital tools improve access, creativity, participation, or innovation, but they do not always show which measurable mechanisms are associated with improvements in learning, visitor satisfaction, or platform value. A title such as digital transformation in visual and performing arts can therefore become too broad if

it is not connected to real variables. The present study narrows the topic to the empirical material available in the uploaded data. The paper focuses on digital cultural platforms in visual arts learning and heritage engagement because the strongest files represent virtual art education, cultural participation records, smart museum interaction logs, and cultural heritage app information. This revised title is more accurate than a broad title covering all visual and performing arts because the data are strongest for visual art learning, cultural events, museums, and heritage platforms.

The study addresses three linked research needs. First, arts education needs clearer evidence on whether digital learning outcomes are associated with creativity, engagement, collaboration, duration, peer interaction, or system-supported suggestions. Second, cultural participation research needs to determine whether platform indicators such as event frequency, recommendation score, language, and interaction duration actually explain engagement levels or whether richer measures are required. Third, creative-industry and heritage-policy discussions need evidence on what cultural apps offer in practice, including tours, maps, audio, multilingual content, accessibility support, and social sharing. These needs are not separate. They belong to the same digital cultural ecosystem in which learning, cultural participation, museum interpretation, and platform design interact.

The study therefore uses a secondary empirical design rather than a general review. It analyses four open secondary datasets: a virtual art-learning dataset, a cultural engagement dataset, a smart museum context dataset, and a cultural heritage app dataset. The empirical strategy is deliberately conservative. It does not claim that technology automatically improves culture. Instead, it tests where associations are strong, where they are weak, and where the available measures are insufficient. This approach is important because cultural value cannot be reduced to the presence of digital tools. A long session may not improve learning if it does not involve creative exploration. A recommendation score may not indicate meaningful participation if it is detached from interpretive depth. A museum app may have many features yet still fail users if it is not accessible, reliable, or pedagogically useful.

The paper contributes to the field by building an integrated empirical architecture for digital cultural platforms. It connects individual learning records, platform-level engagement records, visitor-interaction records, and app-feature records within one manuscript. This design allows the study to compare several layers of digital cultural transformation without pretending that all datasets measure the same construct. The contribution is not a universal causal model. It is a structured evidence map that shows which measurable indicators appear most meaningful for visual arts learning and heritage engagement. The results support a more careful interpretation of digital cultural change: technology is most useful when it strengthens creativity, engagement, collaboration, active content interaction, inclusive access, and interpretable measurement.

The rest of the paper is organized as follows. The literature review discusses digital cultural participation, creative industries, museums, heritage applications, and virtual art education. The research gap, conceptual framework, and proposed method are then presented as separate sections. The methodology describes the data sources, variables, cleaning procedure, analytical models, and ethical safeguards. The results present descriptive statistics, regression results, and app feature patterns. The discussion explains the implications for education, culture, and creative industries. The paper ends with theoretical contributions, practical and policy implications, limitations, and future research directions.

II. LITERATURE REVIEW

Digital theatre distribution can complement, rather than merely substitute for, live attendance, suggesting that online access may extend rather than displace physical cultural participation [1]. Augmented, virtual, and mixed-reality technologies can support visualization, interaction, and interpretation in cultural-heritage environments [2]. Effective augmented-reality applications nevertheless depend on user experience, design quality, and contextual relevance [3].

Augmented-reality heritage visualization can also support history education, although immersive overlays require clear pedagogical structure [4]. Comparative cultural data demonstrate the importance of measuring digital access and participation at the population level [5]. Museums increasingly use social media

for communication, participation, and evaluation, but institutional practices and levels of adoption remain uneven [6].

The contribution of digital museum technologies to visitor experience varies considerably across applications and settings [7]. Augmented mobile applications can reactivate cultural heritage when they are designed around user needs and meaningful interpretive content [8]. Museum co-creation through social media also involves a continuing balance between institutional control and visitor creativity [9].

Online museum engagement is shaped by institutional framing and should not be interpreted as a neutral count of digital activity [10]. Virtual-reality strategies in public art education require scaffolding and curricular purpose to strengthen learning and environmental literacy [11]. Alternate-reality learning designs can improve cultural-heritage awareness and engagement when digital tasks are aligned with educational objectives [12].

Arts-participation evidence reveals varied patterns of cultural involvement and provides a useful basis for distinguishing attendance frequency from the quality or depth of engagement [13]. Crowdsourcing can expand public participation in cultural heritage, although it creates challenges related to motivation, quality control, and institutional workflow [14]. Virtual technology may influence creativity performance, learning engagement, and mental flow, supporting the inclusion of these outcomes in digital art-learning analysis [15].

Creative industries can be understood as social-network markets in which interaction and reputation shape both supply and demand [16]. Usability and spatial experience influence satisfaction in virtual art and design learning environments [17]. Digital technology, innovation, and diversity are also closely interconnected within cultural and creative-industry systems [18].

Gamified mobile sensing and storytelling can support cultural-heritage education and increase user interest [19]. The value of augmented reality at heritage sites depends on how effectively it is integrated into the experiences of visitors, managers, and other stakeholders [20]. Culture should be measured using multidimensional indicators that capture its contribution to sustainable development, rather than through isolated measures of attendance or technology [21].

Cultural policy frameworks further emphasize cultural diversity, inclusive participation, and the importance of culture as a global public good [22]. Museum digitalization can foster dialogue among cultural heritage, historical meaning, and younger audiences when connection is prioritized over technological novelty [23]. Cultural and creative activities also operate within broader innovation ecosystems shaped by institutions, services, knowledge, and infrastructure [24].

Mobile augmented-reality exploration games can enrich cultural storytelling through active and place-based interaction [25]. Taken together, the alphabetically reviewed evidence indicates that digital cultural platforms are most effective when technological features are connected to pedagogical structure, meaningful participation, interpretive depth, usability, and inclusive access.

The literature also indicates that creativity, engagement, collaboration, and output quality should be distinguished analytically. A learner may remain in a digital session for an extended period without producing better artwork or achieving stronger learning, whereas focused creative decision-making and collaboration may generate more substantial outcomes. Accordingly, the present study models learning improvement separately from art quality and treats platform-frequency measures as distinct from deeper cultural value.

Table 1. Comparison table between the studies.

Study	Domain	Main contribution	Relevance to this study
Bakhshi and Throsby (2014) [1]	Digital theatre distribution	Online cultural access can complement live attendance.	Supports the complementarity assumption.
Bekele et al. (2018) [2]	Immersive heritage technologies	AR, VR, and MR support cultural visualization and interaction.	Supports smart museum interaction analysis.

Boboc et al. (2022) [3]	Augmented reality in cultural heritage	Reviews AR applications and design trends in cultural heritage.	Supports interpretation of apps and AR design.
Challenor and Ma (2019) [4]	AR history and heritage visualization	Connects immersive heritage visualization with educational structure.	Links immersive tools with pedagogical heritage interpretation.
Eurostat (2024) [5]	Digital cultural participation	Reports ICT use for cultural purposes across European populations.	Provides a population-level context for digital access and participation.
Fletcher and Lee (2012) [6]	Museum social media	Museums use digital platforms for communication, participation, and evaluation.	Supports platform-level engagement analysis.
Hijazi and Baharin (2022) [7]	Digital museum visitor experience	Reviews the effectiveness of digital technologies for museum visitor experience.	Supports visitor-experience and satisfaction analysis.
Hincapie et al. (2021) [8]	Heritage mobile apps	Mobile heritage apps can reactivate cultural content.	Supports app-feature coding.
Holdgaard and Klasttrup (2014) [9]	Museum co-creation	Digital participation balances visitor creativity and institutional control.	Supports interpretation of user participation.
Kidd (2011) [10]	Museums and online engagement	Digital engagement requires institutional framing.	Warns against simple engagement counts.
Liao et al. (2025) [11]	Virtual public art education	Immersive teaching requires scaffolding and curricular structure.	Supports educational design interpretation.
Lin et al. (2024) [12]	Immersive cultural learning	Alternate-reality learning can strengthen heritage awareness.	Links cultural heritage and learning design.
National Endowment for the Arts (2023) [13]	Arts participation	Documents varied patterns of arts attendance and participation.	Supports distinction between participation frequency and depth.
Oomen and Aroyo (2011) [14]	Cultural heritage crowdsourcing	Public participation can enrich heritage but requires quality control.	Explains the need for meaningful contribution measures.
Oubibi and Hryshayeva (2024) [15]	Virtual art education	Virtual learning can affect creativity, engagement, and flow.	Supports learning-improvement hypotheses.
Potts et al. (2008) [16]	Creative industries	Creative markets operate through social networks.	Justifies social interaction as a cultural indicator.
Serna-Mendiburu and Guerra-Tamez (2024) [17]	Virtual art learning	Usability and spatial experience affect learning satisfaction.	Supports the virtual art-learning model.
Snowball et al. (2021) [18]	Digital cultural and creative industries	Digital technology, innovation, and diversity shape creative industries.	Links platform design with creative-sector innovation.
Tan et al. (2024) [19]	Mobile cultural storytelling	Gamified mobile sensing and storytelling can support heritage education.	Supports mobile learning and active engagement design.

tom Dieck and Jung (2017) [20]	Augmented heritage sites	Augmented heritage value depends on stakeholder experience.	Supports the visitor satisfaction model.
UNESCO (2020) [21]	Cultural measurement	Provides multidimensional Culture 2030 indicators for sustainable development.	Supports broader measurement of cultural value.
UNESCO (2022) [22]	Cultural and creative policy	Emphasizes diversity, inclusion, and culture as a global public good.	Supports policy and inclusion interpretation.
Wang (2024) [23]	Museum digitalisation	Museum digitalisation can create dialogue with heritage and younger audiences.	Supports institutional interpretation of digital heritage platforms.
WIPO (2025) [24]	Innovation ecosystems	Places cultural and creative activity within broader innovation systems.	Supports the creative-platform policy context.
Xu et al. (2024) [25]	Mobile heritage exploration	Mobile AR games can enrich cultural storytelling.	Supports interpretation of active content interaction.

The reviewed studies show that digital cultural transformation should be measured through learning design, social interaction, visitor behavior, and platform affordances rather than through technology presence alone.

III. RESEARCH GAP

Existing research provides rich evidence about digital arts, museums, cultural heritage, and creative industries, but several gaps remain. First, much of the literature studies one setting at a time: a museum app, a virtual classroom, a heritage site, or a platform campaign. Less work connects learning outcomes, cultural participation, smart museum interaction, and cultural app features within one empirical architecture. Second, broad claims about digital transformation are often stronger than the available measurements. Participation frequency, app installs, satisfaction ratings, and creative scores may all be useful, but they do not measure the same construct.

Third, digital arts research often celebrates innovation while underexamining weak or null empirical relationships. The present study treats weak findings as valuable. If event type and recommendation scores do not explain engagement, this indicates a measurement problem rather than a failure of culture. If app descriptions rarely mention accessibility, that points to a practical design gap. If improvements in virtual art learning are strongly predicted by creativity, engagement, and collaboration, this suggests that educational design matters more than exposure time alone.

Fourth, the creative-industries dimension is frequently discussed through national trade or employment indicators, but the uploaded data here are stronger at the platform and app level. The paper therefore reframes creative industries as a digital cultural service ecosystem rather than as a macroeconomic trade study. This makes the title more faithful to the available evidence and prevents unsupported claims.

IV. CONCEPTUAL FRAMEWORK AND HYPOTHESES DEVELOPMENT

The conceptual framework links four layers. The first layer is virtual visual art learning, where creativity, engagement, collaboration, and design scores are expected to influence improvements in learning and art quality. The second layer is cultural engagement, in which event frequency, social interaction, duration, and recommendation score are expected to relate to the engagement level. The third layer is smart museum interaction, where content clicking, crowd density, time spent, and interaction type are expected to relate to satisfaction. The fourth layer is cultural app design, in which tours, maps, audio, video, multilingual options, sharing, and accessibility are digital service features.

Based on this framework, the study tests four hypotheses. H1 states that creativity, engagement, and collaboration are positively associated with improvements in learning in virtual art education. H2 states that art quality is associated more strongly with creative and compositional indicators than with system-suggestion indicators. H3 states that the level of cultural engagement is associated with participation frequency, social interaction frequency, duration, recommendation score, and event type. H4 states that smart museum satisfaction is associated with active content clicking and interaction conditions. The app analysis is treated as descriptive because the app records are smaller and feature-based rather than behavioral.

V. PROPOSED METHOD

The proposed method is a multi-source secondary empirical design. It does not merge all records into one artificial dataset because the files represent different units of analysis. Instead, each dataset is analyzed at the level for which it is meaningful. The virtual art-learning file is analyzed at the student-session level. The cultural engagement file is analyzed at the user-event level. The smart museum context file is analyzed at the level of visitor interaction. The cultural app file is analyzed at the application level after removing empty records and duplicate app entries.

The empirical logic is comparative and integrative. The study first estimates whether virtual art-learning outcomes are associated with creativity, engagement, collaboration, and design scores. It then examines whether general platform variables explain cultural engagement levels. Next, it analyses whether smart museum satisfaction is associated with content clicking, interaction type, crowd density, and visitor characteristics. Finally, it codes cultural app descriptions to identify common service features such as tours, maps, audio, video, multilingual content, accessibility, sharing, and guide functions. This design allows the paper to compare strong, weak, and descriptive evidence without forcing dissimilar indicators into a single index.

Figure 1 summarizes the empirical architecture. The figure shows that the study moves from four sources of evidence to a shared interpretation of digital cultural value. The architecture is appropriate because digital transformation in the arts is multidimensional. It includes learning processes, cultural participation, museum interpretation, and platform services.

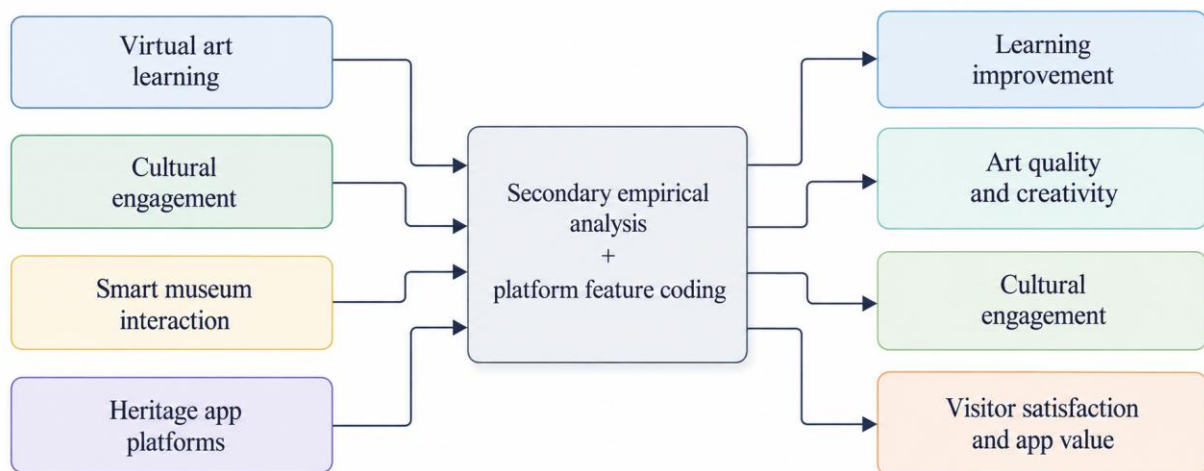


FIGURE 1. Empirical architecture of the study.

This figure summarizes the four empirical sources, the analytical strategy, and the outcome domains examined in the manuscript.

VI. METHODOLOGY

1. RESEARCH DESIGN

The study uses a secondary quantitative research design supported by descriptive platform-feature coding. The design is appropriate because the research question concerns measurable associations in existing digital arts and cultural engagement records. The paper does not claim experimental causality. Instead, it estimates robust associations and interprets them as evidence of how various digital cultural indicators relate to improvements in learning, engagement, satisfaction, and platform design.

The design is cross-sectional because the records do not provide a complete longitudinal panel for the same participants over time. The cultural engagement records include event dates, but they cannot be used to infer long-term individual change because repeated users cannot be reliably treated as a longitudinal cohort without additional documentation. The findings are therefore interpreted as association-based evidence.

2. DATA SOURCES AND SAMPLE SELECTION

Table 2. Dataset selection and analytical role.

Source	Analytical sample	Unit of analysis	Relevant variables	Use in manuscript
Virtual art learning	1,483	Student/session	Creativity, engagement, collaboration, art quality, learning improvement	Main educational dataset
Cultural engagement	8,737	User-event	Event type, participation frequency, social interaction, recommendation score, engagement level	Main cultural participation dataset
Smart museum context	2,834	Visitor interaction	Interaction type, crowd density, satisfaction, content click, visit history	Main museum-interaction dataset
Cultural apps	174 cleaned records	Mobile application	Ratings, reviews, installs, update recency, description-based features	Supporting creative-platform dataset
Small museum experience	270	Visitor interaction	Interaction type, feedback rating, satisfaction	Optional robustness context only
Smart gallery interaction	500	Visitor interaction	Engagement, interaction rate, wait time, satisfaction	Optional robustness context only

The main empirical analysis uses four datasets. The two smaller museum and gallery files are retained only as background evidence because their variable depth is weaker than the selected main sources.

3. VARIABLES AND OPERATIONAL DEFINITIONS

Table 3. Variables and operational definitions.

Variable	Role	Source	Operational definition
Learning improvement	Dependent	Virtual art learning	Normalized learning progress score.
Art quality score	Dependent	Virtual art learning	Final quality score for produced artwork.
Creativity score	Independent	Virtual art learning	Learner creativity indicator.

Engagement score	Independent	Virtual art learning	Level of attention and task involvement.
Collaboration efficiency	Independent	Virtual art learning	Efficiency of peer collaboration.
System suggestion count / adoption	Independent	Virtual art learning	Number and uptake of automated suggestions.
Engagement level score	Dependent	Cultural engagement	Low, medium, and high levels coded as 1, 2, and 3.
Participation frequency	Independent	Cultural engagement	Frequency of event participation.
Social interaction frequency	Independent	Cultural engagement	Frequency of social interaction around cultural events.
Satisfaction score	Dependent	Smart museum context	Visitor satisfaction score from 1 to 10.
Content clicked	Independent / binary outcome	Smart museum context	Whether recommended content was clicked.
App feature indicators	Descriptive	Cultural heritage apps	Binary coding of tours, map, audio, video, language, access, and sharing features.

Variables were selected only when they directly supported the revised title and research objectives. Broad variables that did not measure digital cultural engagement were excluded from the main interpretation.

4. ANALYTICAL PROCEDURE

First, each dataset was inspected for sample size, missingness, unit of analysis, and relevance to the revised title. Empty app rows and duplicate app entries were removed. The cultural engagement duration variable was converted from text into numeric hours. The cultural engagement outcome was coded as an ordinal score from 1 to 3. The smart museum content-click variable was retained as a binary indicator.

Second, descriptive statistics summarized the distribution of the main variables. Third, robust ordinary least squares models were estimated for continuous outcomes, including learning improvement, art quality, cultural engagement score, smart museum satisfaction, and app rating. Robust standard errors were used to reduce sensitivity to heteroskedasticity. Fourth, logistic models were used for binary outcomes where appropriate, including high cultural engagement and content clicking. Fifth, app descriptions were coded for common feature indicators.

5. MODEL SPECIFICATIONS

The first model estimates improvements in learning in virtual art education as a function of creativity, engagement, collaboration, duration, peer interaction, communication, and system-supported suggestion variables.

$$LIS_i = \beta_0 + \beta_1 CR_i + \beta_2 EN_i + \beta_3 COL_i + \beta_4 DUR_i + \beta_5 PEER_i + \epsilon_i \quad (1)$$

The second model estimates the level of cultural engagement using participation frequency, social interaction frequency, duration, recommendation score, event type, language, location, and preferred time of activity.

$$CES_i = \gamma_0 + \gamma_1 PF_i + \gamma_2 SF_i + \gamma_3 DUR_i + \gamma_4 REC_i + \delta_i \quad (2)$$

The third model estimates smart museum satisfaction using active content clicking, interaction type, crowd density, time spent, previous visits, and user age.

$$SAT_i = \alpha_0 + \alpha_1 CLICK_i + \alpha_2 TIME_i + \alpha_3 CROWD_i + \alpha_4 MODE_i + \eta_i \quad (3)$$

The app-feature profile is calculated as the share of cleaned app records whose descriptions mention each feature category.

$$FeatureShare_k = \text{sum}(F_{jk}) / N_j \quad (4)$$

6. STUDY CONTRIBUTION

The study makes three methodological and empirical contributions. First, it integrates four distinct sources of digital cultural evidence—virtual art-learning records, cultural participation data, smart museum interactions, and heritage-app features—within one comparative architecture while retaining the appropriate unit of analysis for each dataset. This avoids artificial data merging and permits comparison of educational, behavioral, and platform-level evidence. Second, the design distinguishes learning improvement, artistic output quality, cultural engagement, visitor satisfaction, and app affordances rather than treating them as interchangeable indicators of digital transformation. Third, it gives equal analytical attention to strong, weak, and null relationships, allowing measurement limitations to inform interpretation. The resulting framework provides a reproducible basis for evaluating digital cultural platforms through learning quality, active interaction, interpretive design, and inclusive access.

7. VALIDITY, RELIABILITY, AND ETHICAL CONSIDERATIONS

Validity was addressed by aligning each dataset with the construct it was designed to measure. The virtual art-learning file was used for educational outcomes; the cultural engagement file for participation patterns; the smart museum file for visitor interaction; and the app file for cultural service features. The study does not treat app installs as cultural value, nor does it treat event frequency as artistic learning. This construct separation reduces the risk of overclaiming.

Reliability was addressed through reproducible coding decisions, consistent variable transformations, and transparent reporting of both null and significant findings. Feature coding in app descriptions used explicit keyword groups for tours, maps, audio, video, multilingual support, accessibility, social sharing, and guide functions. Ethical risk is low because the analysis uses anonymized secondary records. No direct personal identifiers are reported, and all findings are presented in aggregate form.

VII. RESULTS

1. DESCRIPTIVE STATISTICS

Table 4. Descriptive summary of the main analytical sources.

Dataset	N	Main descriptive result	Interpretive relevance
Virtual art learning	1,483	Learning improvement mean = 0.731; art quality mean = 0.747	High outcome = 187; Medium = 1144; Low = 152
Cultural engagement	8,737	Engagement levels are nearly balanced across low, medium, and high categories.	Event types include workshops, art fairs, festivals, language classes, and exhibitions.
Smart museum context	2,834	Mean satisfaction = 5.41 on a 1-10 scale; content click rate = 52.3%	Interaction types include text overlay, audio tour, and 3D model.
Cultural heritage apps	174	Mean rating = 2.16; median rating = 2.75	Most common features: tours, maps, and audio.

The descriptive evidence confirms that the uploaded files support a study of digital learning, cultural engagement, smart museum interaction, and heritage app services.

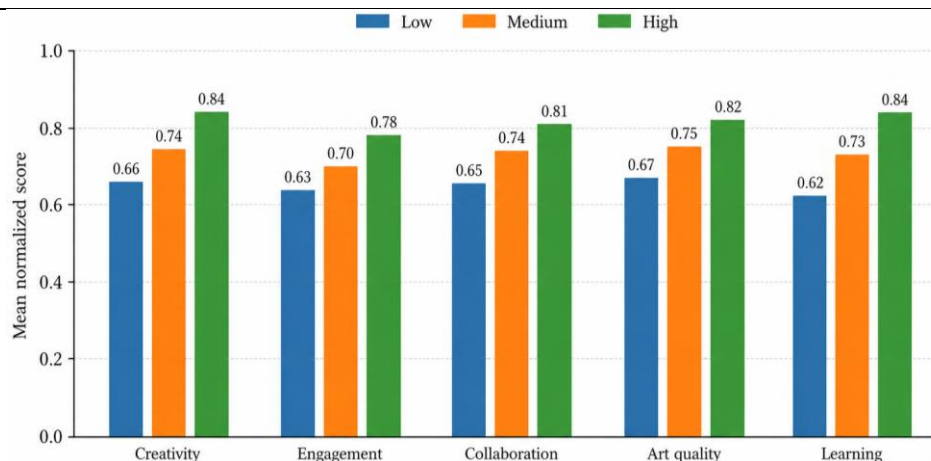


FIGURE 2. Virtual art learning profile by outcome level.

The figure shows that high learning outcomes correspond with higher creativity, engagement, collaboration, art quality, and learning improvement. The differences are educationally meaningful because the scores move consistently across low, medium, and high outcome groups.

2. VIRTUAL ART LEARNING RESULTS

The first empirical model tested H1 by estimating learning improvement in the virtual art-learning dataset. The model explained approximately 79.9% of the variance in learning improvement. Creativity score, engagement score, and collaboration efficiency were positive and statistically significant. Their standardized coefficients were the largest in the model, indicating that learning improvement was primarily associated with creative performance, active engagement, and collaborative efficiency rather than simple exposure time.

Session duration, communication score, number of peers, system suggestion count, and suggestion adoption rate did not show meaningful independent effects after the core learning variables were included. This does not mean that these variables are irrelevant in all settings. It means that in this dataset, their independent explanatory power was small compared with that of creativity, engagement, and collaboration. The result supports H1 and suggests that digital art learning should be evaluated by pedagogical quality rather than by interaction volume alone.

Table 5. Robust ols model predicting learning improvement.

Predictor	Coefficient	Robust SE	p-value
Creativity score	0.403***	0.008	0.000
Session duration	-0.000	0.000	0.268
Interaction frequency	-0.014	0.008	0.074
Engagement score	0.317***	0.012	0.000
Communication score	0.000	0.007	0.981
Collaboration efficiency	0.302***	0.012	0.000
Suggestion adoption rate	0.003	0.005	0.611
Number of peers	0.001	0.001	0.330
System suggestion count	-0.000	0.000	0.856

Significance levels: * $p < .05$, ** $p < .01$, *** $p < .001$. The model R-squared is 0.799.

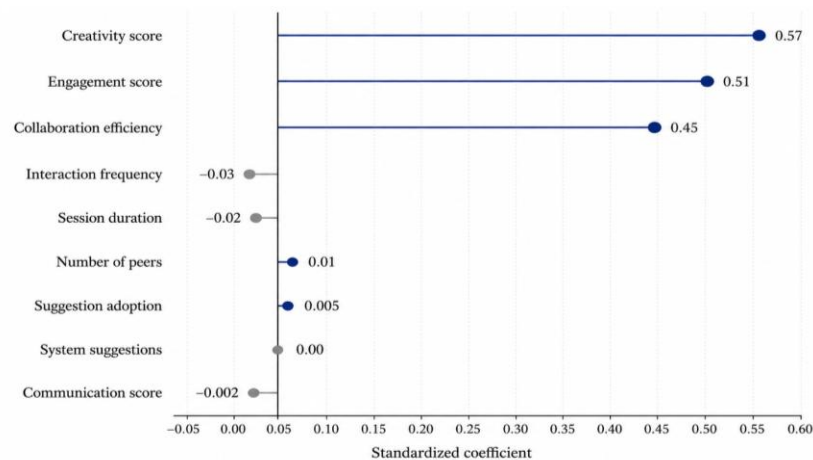


FIGURE 3. Predictors of learning improvement in virtual art learning.

The coefficient plot shows that creativity, engagement, and collaboration are the dominant predictors. Grey bars indicate predictors that did not reach conventional statistical significance.

The second virtual art model tested H2 by predicting art quality. The model explained approximately 92.5% of the variance in art quality. Composition score and creativity score were statistically significant, whereas spatial design, color harmony, engagement, suggestion adoption, and system suggestion count were not significant independent predictors after accounting for composition and creativity. The result supports H2 and indicates that final art quality in the dataset is mainly a creative-compositional outcome.

These findings help refine the digital transformation argument. A virtual art environment may include multiple interactive and automated functions, but the learning value still depends on the learner's creative and compositional work. Digital systems are therefore best understood as enabling environments rather than automatic substitutes for artistic judgement.

Table 6. Robust OLS model predicting art quality score.

Predictor	Coefficient	Robust SE	p-value
Creativity score	0.478***	0.026	0.000
Composition score	0.515***	0.010	0.000
Spatial design score	0.008	0.010	0.381
Color harmony score	0.018	0.012	0.128
Engagement score	-0.001	0.007	0.900
Suggestion adoption rate	0.004	0.005	0.450
System suggestion count	-0.000	0.000	0.666

Significance levels: * $p < .05$, ** $p < .01$, *** $p < .001$. The model R-squared is 0.925.

3. CULTURAL ENGAGEMENT RESULTS

The cultural engagement analysis tested H3. Contrary to expectation, the model explained very little variation in engagement level. Event type, participation frequency, social interaction frequency, interaction duration, and recommendation score were not meaningful predictors of the coded engagement level. The R-squared value was approximately 0.0008, indicating that the available platform indicators were insufficient to explain why a user was classified as low-, medium-, or high-engagement.

This result is important because it prevents overinterpretation. The cultural engagement dataset is useful for describing participation records, event categories, language, location, and recommendation scores, but its current variables do not capture the deeper interpretive qualities of cultural engagement. The finding

weakens H3 and suggests that future datasets should include cultural motivation, perceived learning, artistic relevance, sense of belonging, and post-event reflection.

Table 7. Robust ols model predicting cultural engagement level.

Predictor	Coefficient	Robust SE	p-value
Exhibition event	-0.022	0.028	0.438
Festival event	-0.001	0.028	0.961
Language class	0.009	0.028	0.738
Workshop event	0.035	0.028	0.211
Participation frequency	0.000	0.002	0.836
Social interaction frequency	-0.002	0.003	0.558
Interaction duration	0.000	0.001	0.486
Recommendation score	-0.005	0.033	0.877

The weak explanatory power indicates that generic platform indicators cannot substitute for richer measures of cultural engagement.

4. SMART MUSEUM INTERACTION RESULTS

The smart museum model tested H4. Content clicking was the strongest predictor of visitor satisfaction. Visitors who clicked recommended content had satisfaction scores about 2.05 points higher than those who did not, after adjusting for interaction type, crowd density, time spent, previous visits, and user age. Low crowd density was negatively associated with satisfaction in the satisfaction model but positively associated with the probability of clicking on content. This pattern suggests that satisfaction and interaction behavior may respond differently to contextual conditions.

The logistic model for content clicking showed that low crowd density and higher satisfaction were associated with a greater probability of clicking content. Low crowd density had a strong positive effect on content clicking, while medium crowd density also had a positive effect compared with high crowd density. This supports the interpretation that interaction conditions affect whether visitors actively engage with digital cultural content.

Table 8. Robust OLS model predicting smart museum satisfaction.

Predictor	Coefficient	Robust SE	p-value
Audio tour	-0.202	0.125	0.107
Text overlay	0.023	0.124	0.850
Low crowd density	-0.324**	0.126	0.010
Medium crowd density	-0.134	0.124	0.281
Time spent	0.001	0.002	0.520
Previous visits	-0.002	0.016	0.917
User age	0.006	0.003	0.055
Content clicked	2.051***	0.102	0.000

Significance levels: * $p < .05$, ** $p < .01$, *** $p < .001$. The satisfaction model R-squared is 0.126.

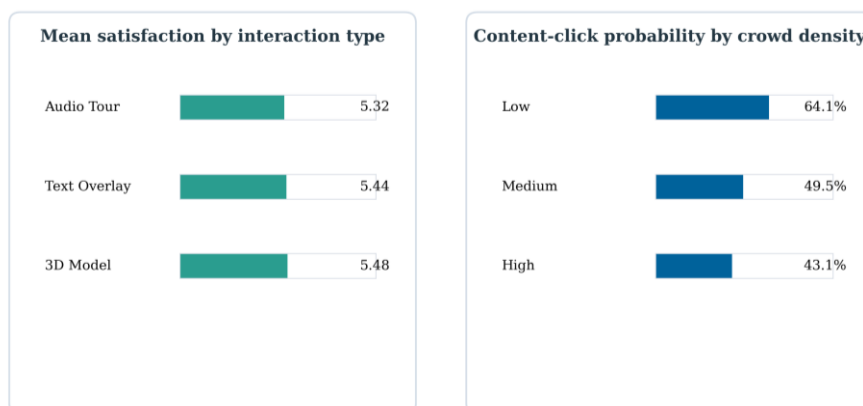


FIGURE 4. Smart museum interaction indicators.

The figure shows that mean satisfaction varies only modestly by interaction type, while content clicking differs more clearly by crowd density. The pattern supports the need to measure active interaction rather than technology format alone.

5. CULTURAL HERITAGE APP RESULTS

The cultural heritage app analysis was descriptive and exploratory. After cleaning, 174 app records were retained. The most common feature category was tours or guides, appearing in 67.8% of app descriptions. Map or navigation features appeared in 50.0%, audio features in 46.6%, video or multimedia in 28.7%, multilingual features in 25.9%, social sharing in 20.7%, and accessibility features in only 5.7%. This distribution shows that cultural apps emphasize interpretation and navigation, but inclusive access is much less visible.

The app rating model explained approximately 0.160 of the variance in ratings. Log review count was positively associated with rating, while video features showed a negative coefficient. This should not be interpreted as evidence that video harms app quality. It is more likely that apps with complex multimedia features place greater demands on usability, storage, or performance. The descriptive feature profile is therefore more important than the regression coefficient when interpreting app ratings.

Table 9. Feature prevalence in cultural heritage apps.

Feature category	Share of cleaned app records
Audio	46.6%
Video/multimedia	28.7%
Navigation/map	50.0%
Multilingual	25.9%
Accessibility	5.7%
Sharing/social	20.7%
Tours/guides	67.8%

Feature prevalence is based on description-based coding of cleaned app records. The low accessibility share identifies an important practical gap for digital cultural inclusion.

Table 10. Exploratory app rating model.

Predictor	Coefficient	Robust SE	p-value
Log reviews	0.348**	0.124	0.005
Log installs	-0.045	0.092	0.628

Days since update	0.000	0.000	0.704
Audio feature	0.397	0.405	0.327
Video feature	-0.909*	0.419	0.030
Map/navigation feature	0.101	0.359	0.778
Multilingual feature	-0.174	0.399	0.663
Accessibility feature	-0.024	0.912	0.979
Sharing/social feature	0.609	0.332	0.067
Tour/guide feature	0.007	0.422	0.987

The app model is treated as exploratory because app records are smaller, feature mentions are description-based, and ratings may be affected by platform visibility and technical maintenance.

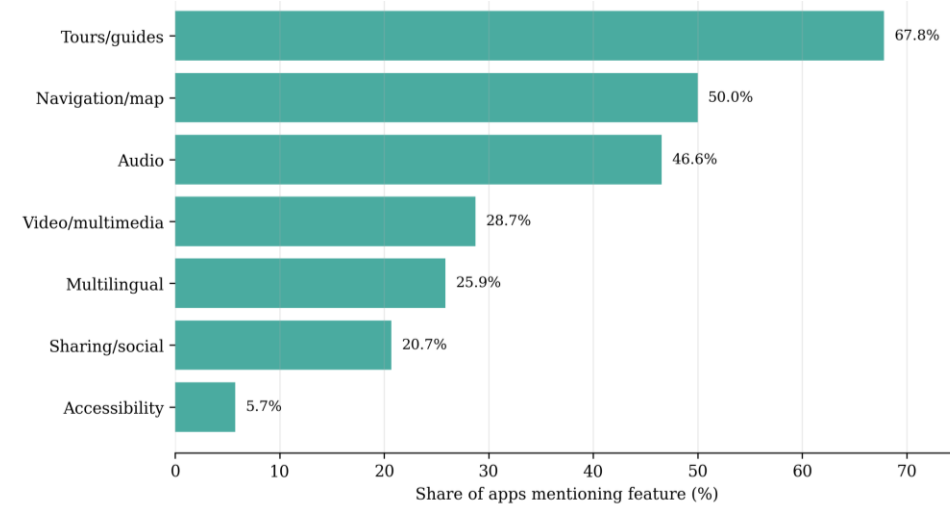


FIGURE 5. Digital heritage app feature profile.

The figure shows that tours, maps, and audio dominate heritage app descriptions, while accessibility appears rarely. This pattern is directly relevant to creative-industries practice because app design choices affect cultural access and user value.

6. SUMMARY OF HYPOTHESES

Table 11. Hypothesis testing summary.

Hypothesis	Statement	Result
H1	Creativity, engagement, and collaboration predict learning improvement.	Supported
H2	Art quality is explained more by creative and compositional indicators than by system-suggestion indicators.	Supported
H3	Cultural engagement is predicted by event frequency, social interaction, duration, recommendation score, and event type.	Not supported
H4	Smart museum satisfaction is associated with active content clicking and interaction conditions.	Partially supported

The results show that digital cultural value is strongest where the available variables measure learning quality or active interaction. Generic platform participation indicators are weaker.

VIII. DISCUSSION

The study shows that digital cultural transformation is not a single effect. It operates differently across learning, participation, museum interaction, and app design. The strongest empirical pattern appears in the virtual art-learning dataset, where creativity, engagement, and collaboration explain improvements in learning. This supports the view that digital tools become educationally valuable when they enable creative exploration and structured participation. It also challenges simple exposure-based assumptions. Session duration and the number of peers were not independently meaningful once creativity, engagement, and collaboration were accounted for.

The art-quality model deepens this interpretation. Composition and creativity dominated the explanation of output quality, while suggestion variables did not provide meaningful independent explanatory power. This suggests that visual arts education should not treat automated support, feedback volume, or interface activity as substitutes for artistic decision-making. Digital platforms can support the conditions of creative practice, but the central educational work remains compositional judgement, experimentation, and reflection.

The cultural engagement findings are equally important because they are weak. The model showed that event type, participation frequency, social interaction frequency, duration, and recommendation score explained very little variation in coded engagement level. In a weaker manuscript, this might be treated as a problem to hide. In a stronger empirical paper, it becomes a useful finding. It shows that cultural engagement cannot be reduced to generic platform metadata. A person may attend many events without deep engagement, while another may attend fewer events but develop a stronger sense of cultural meaning. Recommendation scores may indicate platform fit, but they do not necessarily capture cultural value.

This result aligns with museum and cultural-platform literature that warns against reducing participation to digital trace data. Frequency measures are useful for describing behavior, but they are insufficient to explain cultural learning, belonging, artistic interest, or identity formation. Future cultural engagement datasets should include reflective indicators, post-event learning, perceived cultural relevance, inclusion, language comfort, and community connection. Without these variables, cultural participation models risk mistaking administrative or platform convenience for cultural meaning.

The smart museum results provide a more actionable pattern. Content clicking was the strongest predictor of satisfaction, suggesting that active engagement with interpretive material matters more than the specific interaction format. Mean satisfaction varied only slightly across text overlay, audio tour, and 3D model formats. This does not mean interaction type is unimportant. It means that format alone does not guarantee value. A 3D model may be impressive but shallow; a text overlay may be simple but useful; an audio tour may be valuable if it supports attention and accessibility. The meaningful unit of analysis is not technology category, but the visitor's active engagement with cultural content.

Crowd density also matters. Lower crowd density increased the likelihood of clicking on content, suggesting that digital interaction may depend on the physical environment. A visitor may be less likely to click, listen, explore, or reflect when the space is crowded or uncomfortable. This finding is relevant for museum design because digital interpretation is not separate from visitor-flow management. Institutions should treat digital engagement as part of a broader experience ecology that includes spatial conditions, device usability, object visibility, language, accessibility, and attention.

The app analysis adds a creative-industries dimension. Heritage apps most often emphasized tours, maps, and audio. These features are logical because cultural apps often need to guide visitors through physical spaces and provide interpretive content. However, accessibility features were rare. This is a major practical concern. Digital transformation is often promoted as a way to broaden access, but access is not achieved merely by moving content onto mobile platforms. It requires multilingual design, screen-reader compatibility, captions, visual contrast, adjustable text, offline access, and alternative formats for diverse users.

The negative coefficient for video features in the exploratory app-rating model should be interpreted cautiously. It may reflect the technical burden of multimedia content rather than user dislike of video. Apps with large video files may face download problems, storage issues, unstable playback, or outdated maintenance. This interpretation matches the broader argument that digital cultural value depends on design quality and reliability. Cultural institutions should not add complex features to appear innovative.

They should add features that improve learning, navigation, interpretation, inclusion, and sustained engagement.

Taken together, the findings support a balanced view of digital transformation. The results do not justify a universal claim that digital platforms automatically improve visual arts learning, cultural participation, or creative-industry performance. They show instead that digital value is conditional. It is strong when technology supports creativity, engagement, collaboration, active content interaction, and interpretive design. It is weak when technology is measured only through generic platform indicators. It is incomplete when app ecosystems emphasize navigation and tours but underrepresent accessibility.

Future research should use longitudinal designs, matched cultural events, controlled virtual art learning tasks, and mixed-method visitor studies. Stronger datasets should include pre- and post-learning measures, reflection prompts, cultural identity indicators, accessibility outcomes, and app usage logs. Comparative studies across countries and cultural institutions would also help determine whether the findings generalize beyond the available files.

IX. CONCLUSION

This study revised the original broad title to a more accurate, empirically grounded title that fits the uploaded data: digital cultural platforms in visual arts learning and heritage engagement. Using four open secondary datasets, the paper examined virtual art learning, cultural engagement, smart museum interaction, and cultural heritage app features. The findings show that digital cultural value is strongest when technology supports creativity, engagement, collaboration, and active interaction with cultural content. In the virtual art-learning dataset, creativity, engagement, and collaboration were the main predictors of learning improvement, while composition and creativity were the strongest predictors of art quality. These findings confirm that digital art education should remain centred on artistic thinking and learning design. The cultural engagement analysis produced a different lesson. Generic event and platform indicators explained little variation in engagement level, showing that cultural participation needs richer measurement. Frequency, duration, event type, and recommendation scores are not enough to capture cultural meaning. The smart museum results showed that active content clicking was strongly associated with visitor satisfaction, while crowd conditions shaped interaction behaviour. The app analysis showed that heritage apps commonly emphasize tours, maps, and audio, but rarely mention accessibility. This is a critical gap for inclusive digital culture. The study contributes a cautious empirical framework for evaluating digital cultural platforms. It argues that digital transformation should not be judged by the mere presence of technology, but by the quality of learning, interpretation, interaction, accessibility, and cultural relevance it enables.

Author Contributions

The author conducted the conceptualization, methodology, data analysis, investigation, writing, review, editing, and final approval of the manuscript.

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Data Availability

The dataset will be available from the author upon reasonable request.

Conflicts of Interest

The author declares no conflict of interest.

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