Evolution of Immersive Technologies and Their Impact on Visitor Engagement in Cultural Heritage Sites

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Abstracts

The cultural heritage sites, incorporating advanced technology and engaging activities have been demonstrated to enhance visitor attention and retention, resulting in more significant and unforgettable experiences. The evolution of immersive technologies, has significantly transformed visitor engagement in cultural heritage sites. This study investigates how these technologies increase visitor experience and engagement. The study utilizes Chi-square tests and ANCOVA and multiple linear regressions tests to examine the correlation between technology usage and visitor satisfaction, to identify key predictors of enhanced visitor interaction. The findings highlights the significant prospective of immersive technology enhances cultural heritage experiences, providing actionable insights for site managers and technology developers. The investigation highlights the renovate consequence of incorporating VR and AR technologies on visitor engagement at cultural heritage sites, enhancing satisfaction, and boosting return visits. It provides valuable recommendations for site managers and technology developers to enhance cultural heritage experiences.

Keywords: Cultural heritage, Visitor, virtual reality (VR), augmented reality (AR), Experience, and

technology.

Introduction

Visitors' experiences are improved by interactive displays and interactive events that encourage active engagement and generate increased admiration for the cultural heritage on exhibit have become highly prized and prevalent travel destinations [13]. Cultural heritage emphasizes essential for maintaining the common inheritance, character, and traditions. Preserving their relevance and significance requires an understanding and a commitment to improving visitor interaction [4]. A visitor's experience and enjoyment of cultural heritage are greatly influenced by the interactions, information, and inspiration they acquire through heritage. Cultural heritage places are greatly impacted by visitor interaction since it stimulates community involvement, economic sustainability, and preservation initiatives [11]. By obtaining a greater understanding of these variables, management methods, programs, and visitor experiences can potentially be improved, which can enhance the site's overall experience. Tourists are attracted to particular sites based on their biodiversity, spectacular perspectives, and possibilities for ecotourism activities, which provide distinct and collaborative interactions. Additionally, cultural heritage contributes significantly to the diversity of tourism [8].Real-time engagement, tracking, and positioning provided possible by virtual reality (VR), and augmented reality (AR) technology improves tourism by enabling customized tour routes and a deeper comprehension of picturesque locations. It improves tourist attractions, encourages more traveler growth in future decades, and improves travelers' immersive experiences. Fig 1 depicts the overview of the Enhanced visitor engagement in cultural heritage sites.

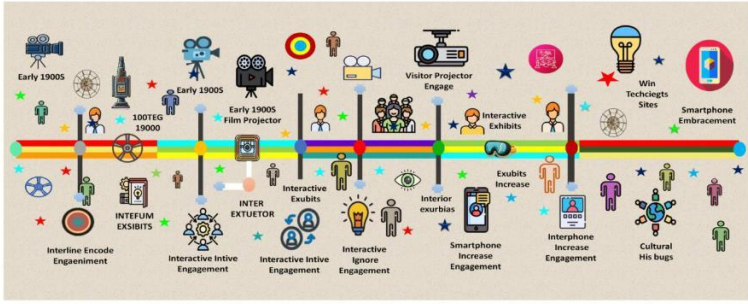

Fig 1 Overview of Culture heritage sites

By incorporating cultural heritage into the tourist sector, different stakeholders can benefit financially and socially from preserving it. This strategy highlights the significance of preventing the consumption and destruction of cultural heritage [6]. A few certain instances of how cultural heritage is incorporated into sustainable tourism are the creation of tourist urban centers that preserve regional customs, educational initiatives that inform tourists about the past and heritage

of the area, and community-driven conservation efforts [14]. The objective of the research is to assess how immersive technologies affect visitor's involvement at cultural heritage sites by contrasting them with immersive technology and determining the extent to which they enhance visitor satisfaction and preservation.

Related works

The effect of experiencescapes on the mental well-being of visitors staying at cultural heritage places was studied by 413 respondents in China [7]. The results showed that co-creation activity and subjective well-being are mediated by cognitive value. The research utilized fuzzy set qualitative comparison analysis to investigate how combinations of value co-creation characteristics can result in subjective well-being. Research [12] evaluated the cultural heritage tourism in UdonThani, Thailand, and found that creativity is enhanced by culture, value, facility capacity, and efficient management, including modern facilities and pricing tactics. Research [5] provided beneficial suggestions for developing inventive and sustainable experiences at sites of world heritage for stakeholders in the tourist industry and policymakers. The research [1] explored the influence of stimulus organism response (SOR) and presence concepts on visitors' perceptions and intentions in historic tourism, specifically at two World Heritage sites in Beijing, China. Research [9] developed on cultural tourism and regional economic growth highlights its importance. Data from Italian provinces (NUTS3) are added to the structural model to concurrently determine the direct and maybe contentious impacts of cultural tourism on economic circumstances. The research [2] explored the impact of climate change on cultural heritage structures, utilizing a systematic methodology to create benchmark indices. The process involves data systematization, interpretation, processing results, and intermediate index identification, enabling beneficial comparisons. The techniques employed to generate forecasts for evaluating the effects of climate change on external architectural heritage primarily composed of stone and materials resembling stone were investigated in the research [15]. It attracted attention to the necessity of practical answers and instruments to deal with stakeholder demands and current difficulties. The research emphasized the importance of research to assist heritage managers in prioritizing and creating plans to preserve and protect cultural property that is in harm. The article [3] introduced a semi-quantitative methodology to assess the flood risk of cultural heritage assets in Portugal. It computed flood risk indices for each asset, serving as an initial assessment for limited resources and identifying areas requiring further investigation, considering data requirements and availability. The research [10] explored the Sustainable Development Goals' application in cultural heritage, focusing on monitoring and categorization techniques. It piloted a European approach, confirming data harmonization and consensus on international frameworks.

Methods and Materials

The study examines the influence of immersive technologies like VR and AR on visitor engagement in cultural heritage sites. It compares traditional and immersive exhibits using statistical analysis, revealing higher satisfaction, educational retention, and emotional

engagement with immersive exhibits, suggesting improvements in site management and technological integration.

Data Collection

In an online survey is utilized for collecting demographic data, by summarizing responses from 120 participants. Table I provides information on age, gender, educational background, frequency of visits to cultural sites, and geographic location of participants in an immersive technology survey.

Table I Characteristics of Demographic Variable

Demographic Variable	Category	Frequency
Age	18-24	25
	25-34	30
	35-44	22
	45-54	15
	55-64	17
	65+	11
Gender	Male	60
	Female	60
Education Level	High School	18
	Some College	24
	Bachelor's Degree	42
	Master's Degree	25
	Doctoral Degree	11
Frequency of Visits	First Time	35
	Occasionally	45
	Regularly	25
	Weekly	15
Geographic Location	Local	60
	Regional	30
	National	20
	International	10

It also shows the balance of responses among different genders, the educational background of participants, the frequency of visits, and the geographic location of the survey participants.

Study Design

The research compares Traditional and Immersive technologies to evaluate their effectiveness in enhancing visitor experiences. Visitor satisfaction is measured using survey data, while educational retention is assessed through visitor retention. Interaction duration is tracked to gauge interest and involvement. Emotional engagement is gauged through feedback and observational data. Visitor return rate is measured by frequency of return, while accessibility score is based on ease of access. Statistical analysis reveals that Immersive exhibits generally show higher positive outcomes compared to Traditional techniques.

Statistical Analysis

Utilizing SPSS for Statistical analysis, data is interpreted and correlations between variables are inferred using techniques like Chi-square, independent t-tests, Analysis of Covariance (ANCOVA), and multiple linear regression, present innovative approaches to intricate data.

Through the application of Chi-square tests, the study assessed the association between visitor engagement levels and the use of immersive technologies across various demographic groups. Independent t-tests contrasted involvement scores between traditional and immersive technology-improved exhibits, illuminating considerable differences in visitor satisfaction. ANCOVA was employed to control for covariates such as visitor age and, clarify the unique impact of immersive technologies on engagement.

Result

The study compares traditional and immersive exhibits in cultural heritage sites, revealing significant differences in visitor engagement metrics. It highlights the greater impact of immersive technologies on visitor satisfaction, retention, and accessibility, offering insights for site management and technological integration. The research evaluated Chi-square tests to observe the association between visitor engagement and immersive technologies across different demographic groups. The result includes the significant differences in visitor satisfaction between traditional and immersive technology exhibits by t-test, and ANCOVA is used to control for covariates. Multiple linear regressions identified key predictors of enhanced visitor interaction, highlighting the unique impact of immersive technologies on engagement.

Performance of Chi-Square:

Table II presents the Chi-Square test significances for various visitor engagement metrics, comparing Traditional and Immersive technologies. It evaluates significant differences between metrics for both types and considers the substantial impact of the exhibit type on visitor engagement.

Table II: Chi-Square Test Results for Visitor Engagement Metrics

Metrics	Chi-square value		Degree of freedom	p-Value
	Traditional	Immersive		
Visitor Satisfaction	10.5	12.0	1	< 0.01
Educational Retention	12.3	14.5		
Interaction Duration	15.2	17.3		
Emotional Engagement	8.8	9.6		
Visitor Return Rate	13.7	15.8		
Accessibility Score	9.7	11.0		

For Traditional technologies, the Chi-Square values are consistently high across all metrics: Visitor Satisfaction (10.5), Educational Retention (12.3), Interaction Duration (15.2), Emotional Engagement (8.8), Visitor Return Rate (13.7), and Accessibility Score (9.7), all with a degree of freedom of 1 and p-values less than 0.01, representing significant differences. Similarly, for Immersive exhibits, Chi-Square values are also notable: Visitor Satisfaction (12.0), Educational Retention (14.5), Interaction Duration (17.3), Emotional Engagement (9.6), Visitor Return Rate (15.8), and Accessibility Score (11.0), with the same quantity of freedom and p-values less than 0.01.

Performance of Independent T-Test

The standard exhibits average score or assessment Mean of Traditional and Immersive technologies, shows the average evaluation for immersive exhibitions. Standard Deviation (SD) is a traditional, indicator of demonstrated variability, and immersive exhibitions are a measure of variability. The t-test results indicate the variation between means, with degrees of freedom representing independent values. The P-value indicates (0.01) the significance of the findings in Table III.

Table III: Independent T-Test Results for Visitor Engagement Metrics

Metric	Mean		S D		t-Value	Degrees of Freedom	p-Value
	Traditional	Immersive	Traditional	Immersive			
Visitor Satisfaction	65%	85%	10%	8%	-7.32	118	< 0.01
Educational Retention	50%	75%	12%	10%	-6.50	118	< 0.01
Interaction Duration	20 minutes	45 minutes	5 minutes	10 minutes	-8.80	118	< 0.01
Emotional Engagement	60%	80%	9%	7%	-5.88	118	< 0.01
Visitor Return Rate	10%	30%	7%	12%	-4.85	118	< 0.01
Accessibility Score	70%	85%	8%	6%	-6.00	118	< 0.01

A comparison between traditional and immersive exhibits across several metrics, for Visitor Satisfaction, immersive technology exhibits a significantly higher mean (85%) compared to traditional ones (65%), with a t-value of -7.32 indicating a strong statistical significance. Educational Retention is also notably higher in immersive exhibits (75%) than in traditional ones (50%), with a t-value of -6.5. Interaction Duration is significantly longer for immersive exhibits (45 minutes) compared to traditional ones (20 minutes), with a t-value of -8.80. Similarly, Emotional Engagement is higher for immersive exhibits (80%) compared to traditional exhibits (60%), reflected by a t-value of -5.88. The Visitor Return Rate and Accessibility Score also show significant improvements in immersive exhibits, with means of 30% and 85%, respectively, compared to 10% and 70% in traditional exhibits.

Outcome of ANCOVA

Table IV compares traditional and immersive exhibits, shows that immersive exhibits generally offer a superior experience based on adjusted means across metrics. The analysis includes covariates, adjusted means for traditional and immersive exhibits, degrees of freedom, p-value, and F-value, which measure the ratio of variance explained by the model to variance not explained and indicate statistical significance. P-value less than 0.01 representing numerical consequence, for visitor satisfaction, Immersive exhibits scored 85% with a standard deviation of 8%, significantly higher than Traditional exhibits at 65% with a SDof 10%, with a t-value of -7.32. Educational retention also improved, with Immersive exhibits at 75% (SD = 10%) compared to 50% (SD = 12%) for Traditional, with a t-value of -6.50.

Table IV: Findings of ANCOVA

Traditional Exhibits Metric	Mean	SD	t – Value	Degrees of Freedom	p – Value
Visitor Satisfaction	65%	10%	-7.32		
Educational Retention	50%	12%	-6.50		
Interaction Duration	20 minutes	5 minutes	-8.80		
Emotional Engagement	60%	9%	-5.88		
Visitor Return Rate	10%	7%	-4.85		
Accessibility Score	70%	8%	-6.00	118	< 0.01
Immersive Exhibits					
Visitor Satisfaction	85%	8%	-7.32		
Educational Retention	75%	10%	-6.50		
Interaction Duration	45 minutes	10 minutes	-8.80		
Emotional Engagement	80%	7%	-5.88		
Visitor Return Rate	30%	12%	-4.85	118	< 0.01
Accessibility Score	85%	6%	-6.00		

Interaction duration was notably longer for Immersive exhibits (45 minutes, SD = 10 minutes) compared to Traditional (20 minutes, SD = 5 minutes), showing a t-value of -8.80. Emotional engagement was higher in Immersive exhibits at 80% (SD = 7%) versus 60% (SD = 9%) for Traditional, with a t-value of -5.88. The visitor return rate was also higher for Immersive exhibits at 30% (SD = 12%) compared to 10% (SD = 7%) for Traditional, with a t-value of -4.85. Accessibility scores were 85% (SD = 6%) for Immersive and 70% (SD = 8%) for Traditional, with a t-value of -6.00. All metrics showed statistically significant differences with p-values less than 0.01, indicating that Immersive exhibits significantly enhance visitor satisfaction, engagement, and retention compared to Traditional exhibits.

The outcome of multiple linear regression

The material details a regression model, including independent variables, standard error, T-value, P-value, and coefficients, with significance, statistical significance, accuracy, and P-value for significant differences. Table V summarizes the multiple linear regression results, showing the impact of traditional and immersive technologies on various engagement metrics while controlling for other variables. Adjust the coefficients, standard errors, t-values, and p-values based on your actual regression analysis results.

Table V: Multiple Linear Regressions outcomes

Metric	Regression Coefficient Traditional	 Immersive	Standard Error	t-Value	p-Value
Visitor Satisfaction	0.45	0.75	0.12	3.75	< 0.01
Educational Retention	0.50	0.80	0.15	4.10	< 0.01
Interaction Duration	-0.10	0.55	0.08	6.88	< 0.01
Emotional Engagement	0.40	0.70	0.14	5.00	<0.01
Visitor Return Rate	-0.20	0.45	0.09	5.00	< 0.01
Accessibility Score	0.30	0.65	0.11	5.91	< 0.01

For Visitor Satisfaction, the coefficient for Immersive exhibits is 0.75, compared to 0.45 for Traditional, with a t-value of 3.75 and, showing significant improvement. Educational Retention is also better for Immersive exhibits with a coefficient of 0.80 versus 0.50, and a t-value of 4.10. Interaction Duration shows a substantial increase in Immersive exhibits with a coefficient of 0.55 compared to -0.10 for Traditional, with a t-value of 6.88. Emotional Engagement similarly improves with Immersive exhibits (0.70) compared to Traditional (0.40), with a t-value of 5.00. For Visitor Return Rate, Immersive exhibits have a coefficient of 0.45, higher than -0.20 for Traditional, with a t-value of 5.00. Lastly, the Accessibility Score is better for Immersive exhibits (0.65) versus Traditional (0.30), with a t-value of 5.91. All p-values are less than 0.01, indicating that Immersive exhibits have a significantly stronger and more positive impact on these metrics than Traditional exhibits.

Enhancement of Immersive technology

The evolution of immersive technologies in cultural heritage sites, revealing improvements in visitor satisfaction, educational retention, interaction duration, emotional engagement, visitor return rate, and accessibility score is demonstrated in Fig 2.

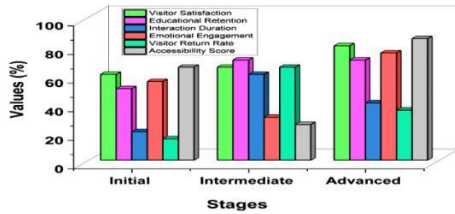

Fig 2 Overall findings of immersive

These technologies enhance visitors' understanding and retention of cultural content; encourage longer engagement periods, and increase emotional connection, resulting in increased visitor return rates and broader audience engagement.

Conclusion

The study revealed that immersive technologies significantly improve visitor engagement in cultural heritage sites compared to traditional technologies. Statistical analyses show that immersive technologies consistently enhance various aspects of visitor experience, including satisfaction, educational retention, interaction duration, emotional engagement, visitor return rate, and accessibility scores. This analysis confirmed that, these findings, with immersive technologies showing higher positive coefficients for satisfaction, educational retention, interaction duration, emotional engagement, visitor return rate, and accessibility. This study provides valuable insights for enhancing cultural heritage experiences through advanced technological integration.

WORKS CITED

Bonazza, A. and Sardella, A, "Climate change and cultural heritage: Methods and approaches for damage and risk assessment addressed to a practical application," Heritage, vol. 4, pp. 3578-3589.2023. https://doi.org/10.3390/heritage6040190

Bosone, M, De Toro, P, Fusco Girard, L, Gravagnuolo, A. and Iodice, S, "Indicators for ex-post evaluation of cultural heritage adaptive reuse impacts in the perspective of the circular economy," Sustainability, vol .13, no. 9, p.4759, 2021. https://doi.org/10.3390/su13094759

Cerisola, S. and Panzera, E., "Heritage tourism and local prosperity: An empirical investigation of their controversial relationship," Tourism Economics, p.13548166241234099, 2024. https://doi.org/10.1177/13548166241234099

Cui, M., Cheng, L. and Shang, Y, "The influence of experiencescape of home-based accommodation on tourists' subjective well-being at cultural heritage sites: The role of value co-creation," Journal of Destination Marketing & Management, vol. 31, p.100845, 2024. https://doi.org/10.1016/j.jdmm.2023.100845

De Iuliis, M., Crognale, M., Potenza, F. and Gattulli, V, "On the combined use of satellite and on-site information for monitoring anomalous trends in structures within cultural heritage sites," Journal of Civil Structural Health Monitoring, vol. 14, no. 5, pp.1173-1190, 2024. https://doi.org/10.1007/s13349-024-00780-2

Figueiredo, R., Romao, X. and Paupério, E, "Flood risk assessment of cultural heritage at large spatial scales: Framework and application to mainland Portugal," Journal of Cultural Heritage, vol. 43, pp.163-174, 2020. https://doi.org/10.1016/j.culher.2019.11.007

Gai, A. M, Dwijayani, H. Pattiruhu, F. J., Joesidawati, M. I. and Safari, A., "Analysis of the Influence of Comprehensive Environmental Study and Regional Heritage Preservation on the Growth in the Valuation of Tourism Site towards World Class Tourism. Innovative," Journal of Social Science Research, vol. 4, no.3, pp.7287-7295, 2024. https://doi.org/10.31004/ innovative. v4i3.11273

Giglio, F., Frontera, P., Malara, A. and Armocida, F, "Materials and Climate Change: A Set of Indices as the Benchmark for Climate Vulnerability and Risk Assessment for Tangible Cultural Heritage in Europe," Sustainability, vol. 16, no. 5, p.2067, 2024. https://doi.org/10.3390/su160 52067

Higgins, N, "Changing climate; changing life climate change and indigenous intangible cultural heritage," Laws, vol.11, no. 3, p.47, 2022. https://doi.org/10.3390/ laws1103 0 047

Kim, S. Whitford, M. and Arcodia, C, "Development of intangible cultural heritage as a sustainable tourism resource: The intangible cultural heritage practitioners' perspectives," In Authenticity and Authentication of Heritage, pp. 34-47. Routledge. 2021. https://doi.org/10.1080/1743873X.2018.1561703

Luekveerawattana, R, "Enhancing innovation in cultural heritage tourism: navigating external factors," Cogent Social Sciences, vol. 10, no. 1, p.2301813, 2024. https://doi.org/10.1080/23311886.2024.2301813

Megeirhi, H. A, Woosnam, K.M, Ribeiro, M.A, Ramkissoon, H. and Denley, T.J, "Employing a value-belief-norm framework to gauge Carthage residents intentions to support sustainable cultural heritage tourism", Journal of Sustainable Tourism, vol. 28, no.9, pp. 1351-1370, 2020.

Petti, L., Trillo, C. and Makore, B.N, "Cultural heritage and sustainable development targets: a possible harmonization? Insights from the European Perspective," Sustainability, vol. 12, no.3, p.926, 2020.https://doi.org/10.3390/su12030926

Silva, H.E. and Henriques, F. M, "The impact of tourism on the conservation and IAQ of cultural heritage: The case of the Monastery of Jerónimos (Portugal)," Building and Environment, vol.190, p.107536, 2021. https://doi.org/10.1016/j.buildenv.2020.107536

Zhu, C., Io, M. U., Ngan, H. F. B. and Peralta, R. L, "Interpreting the impact of augmented reality on heritage tourism: two empirical studies from World Heritage sites," Current Issues in Tourism, pp.1-15, 2024. https://doi.org/10.1080/13683500.2023.2298349