Afr. J. Lib, Arch. and Inf. Sc. Vol. 35, No. 2 (July 2025) 179-193

https://doi.org/10.5281/zenodo.20748041

UTAUT Framework Analysis of Transcultural Heritage Education in Digital Libraries: Artificial Intelligence in Action

Jing Guo, Qiqiong Huang* and Haomin Ye
Department of Creativity and Design, Guangzhou Huashang College, Guangzhou, 511300, China.
jingstudio@gdhsc.edu.cn
huangqiqiong@gdhsc.edu.cn
18813381803@163.com

Abstract

The digitisation of cultural heritage resources contributes to the development of transcultural learning, while the integration of AI within online library environments supports more dynamic and participatory user engagement. Despite this potential, empirical evidence examining the acceptance of AI in such contexts remains limited. This study addresses this gap by examining the principal determinants influencing both the intention to use and the actual utilisation of AI tools in transcultural heritage education, through an extension of the Unified Theory of Technology Acceptance and Use (UTAUT). Data were analysed using partial least squares structural equation modelling (PLS-SEM), drawing on survey responses from 365 academic librarians, educators, and students. Construct reliability and internal consistency were assessed using average variance extracted (AVE), composite reliability (CR), and Cronbach's alpha (α), while discriminant validity was confirmed through established discriminant validity criteria and the HTMT ratio. Mediation and moderation effects were examined, and overall model adequacy was evaluated using standard fit indices. The results demonstrate strong predictive capability, with R^2 values of 0.677 for behavioural intention and 0.574 for actual usage. Facilitating conditions (β = 0.345) and effort expectancy (β = 0.284) exerted significant positive effects on behavioural intention, whereas performance expectancy did not exhibit a statistically meaningful influence. Attitude functioned as a mediating mechanism across key relationships, while personal innovativeness significantly moderated acceptance (p = 0.003), and individual readiness also acted as a mediator. The model exhibited high validity, as reflected by SRMR = 0.052 and NFI = 0.921. Overall, the findings indicate that favourable attitudes, user preparedness, perceived ease of use, and institutional support are critical enablers of effective AI adoption in digital heritage contexts. Anchored in the UTAUT framework, the study supports the deployment of culturally adaptable and sustainable AI solutions within online library systems.

Keywords: Digital Libraries, Transcultural Heritage Education, Unified Theory of Acceptance and Use of Technology (UTAUT), Facilitating Circumstances, Behavioural Intent.

Introduction

The rapid digitalisation of cultural assets has transformed the landscape of heritage education, resulting in cultural knowledge becoming increasingly accessible, interactive, and globally interconnected. Digital libraries now play a central role in the preservation, dissemination, and educational utilisation of transcultural heritage, enabling learners to access diverse cultural resources beyond geographical limitations (Lian and Xie, 2024; Odularu et al., 2024). As these platforms continue to evolve, the integration of advanced technologies, particularly

AI, has become a critical requirement for improving user experience, optimising information retrieval, and supporting personalised learning processes (Barman, 2024; Rahmanova, 2025).

Within digital library environments, AI-driven functionalities such as intelligent retrieval systems, automated metadata generation, multilingual accessibility, and digital reproduction of cultural artefacts represent significant technological opportunities (Oyighan et al., 2024). These capabilities offer substantial potential to strengthen cultural understanding, promote cross-cultural learning, and expand pedagogical practices across academic and public heritage institutions (Kwiecien et al., 2025). However, despite these advantages, the adoption of AI within digital library contexts remains inconsistent (Park, 2024; Pinar and Cox, 2025). Many institutions continue to face challenges related to technological preparedness, user acceptance, organisational backing, and levels of digital literacy when implementing AI-based systems intended for educational use (Barbuti, 2021). Consequently, identifying the factors that shape user readiness to adopt and utilise AI technologies has become a critical research priority (Lau, 2024; Mitha and Omarsaib, 2024). UTAUT provides a comprehensive analytical framework for examining how social influence, facilitating conditions, performance expectancy, and effort expectancy affect behavioural intention and actual system use (Zhu and Huang, 2025). Although UTAUT has been widely applied within studies of digital learning environments and information systems, its application remains limited in the specific context of transcultural heritage education and AI-enabled digital libraries.

The UTAUT framework (Figure 1) illustrates how performance expectancy, effort expectancy, social influence, and facilitating conditions shape users' intentions to adopt and utilise technological systems. These relationships are further conditioned by individual and contextual moderators, including age, gender, experience, and levels of technological willingness, all of which influence technology-related decision-making. Although UTAUT has been widely applied within studies of digital learning environments and information systems, its utilisation remains limited in the context of transcultural heritage education supported by AI-enabled digital libraries (Alotaibi et al., 2023; Chong et al., 2025). Existing scholarship rarely explores the interplay between individual attributes, such as technological readiness and personal innovativeness, and UTAUT constructs within AI-supported digital library settings. Similarly, the mediating role of attitude towards AI adoption has received insufficient empirical attention. These limitations constrain current understanding of the psychological and situational mechanisms that shape AI use in transcultural heritage education, highlighting the need for a more comprehensive and analytically robust acceptance model within digital heritage environments.

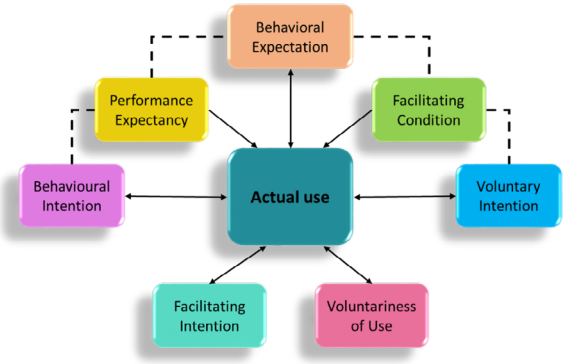

Figure 1: UTAUT Framework.

This study addresses these gaps by extending the UTAUT framework to examine AI adoption in digital libraries designed for transcultural heritage education. It evaluates both direct and indirect determinants of behavioural intention and actual use, incorporating the effects of mediation and moderation to capture more complex relational dynamics. By doing so, the research offers deeper theoretical and practical insights to inform the sustainable and context-sensitive implementation of AI technologies in digital heritage learning environments. The key contributions of this research are as follows:

Model Extension: Broadens the UTAUT framework by integrating Attitude, Individual Readiness, and Personal Innovativeness, thereby strengthening the model's explanatory capacity regarding AI acceptance within transcultural heritage education contexts.

Empirical Evidence through Varying Users: Provides empirical validation derived from diverse stakeholder groups, including academic librarians, educators, and students, highlighting differentiated patterns of AI use in digital heritage learning environments.

Determines Practical Factors Influencing AI Use: Identifies critical enabling factors,

particularly perceived ease of use, institutional support mechanisms, and user readiness, which significantly influence the effective adoption and practical utilisation of AI technologies.

Literature Survey and Hypothesis Development

The integration of technologies, notably AI, mobile services, and digital heritage resources, has become a central focus within educational and library research. The literature frequently applies theoretical models to examine user behaviour across diverse cultural and technological contexts. An investigation using TAM explored how cultural context affects technology acceptance (Dalle et al., 2024). Through interviews with twelve experts, the study identified ten themes related to behavioural intentions, perceived usefulness, and ease of use, emphasising the role of cultural learning preferences and accessibility in shaping attitudes (Camuñas-García et al., 2024). However, the findings were constrained by the small sample size and reliance on expert insights rather than user-level data. Building upon UTAUT, Fang et al. (2025) examined AI adoption among 340 academic librarians, incorporating PIIT and TRI into the model. Using a quantitative PLS-SEM approach, the study found that facilitating conditions and effort expectancy exerted strong positive effects on behavioural intention, while performance expectancy and senior management support showed minimal immediate influence. The model demonstrated high predictive capability, with authors recommending longitudinal and cross-cultural investigations to further explore the development of readiness.

Ali and Warraich (2024) conducted a meta-analysis of research from 2008 to 2022 using PRISMA-P methodology, synthesising UTAUT and UTAUT2 studies to identify general determinants of technology acceptance in digital libraries. Key influences on behavioural intention included performance expectancy, effort expectancy, social influence, facilitating conditions, and habit (Casadei and Di Modica, 2025). Limitations included potential publication bias and inconsistent measurement scales across the analysed studies. A study examining the role of AI literacy in conjunction with UTAUT constructs showed that AI knowledge significantly affects behavioural intention, mediated by performance expectancy, effort, and social influence (Ke et al., 2025). Facilitating conditions were found to be non-significant, highlighting the need for AI literacy programmes, though applicability beyond China was limited.

Research on UTAUT2 determinants for mobile phone use in Iranian universities surveyed 438 students, analysing the impact of hedonic motivation, habit, trust, and self-efficacy using SPSS and AMOS. Most UTAUT2 constructs significantly influenced behavioural intention, except for price value. The study, extending UTAUT2 to library settings, was geographically restricted and conducted in a non-English-speaking environment. Roy (2024) qualitatively investigated factors influencing the adoption of information analytics in Australian university libraries. Results indicated that all UTAUT2 constructs shaped librarians' attitudes towards analytics use, with barriers including limited training, algorithmic knowledge, and privacy concerns. While offering rich contextual insights, the findings may not generalise beyond the specific institutional settings.

Mashaba and Pretorius (2023) examined virtual library resource usage among South African postgraduate students through UTAUT-based quantitative surveys. Behavioural intention was consistently determined by performance expectancy, effort expectancy, social influence, and facilitating conditions affecting actual use. Limitations included reliance on self-reported data and confinement to a single institution. Khan et al. (2021) conducted a UTAUT-informed survey of 389 library staff in Chinese universities to study IoT adoption. Structural equation modelling revealed the significance of strong managerial practices and technological infrastructure for successful implementation. Constraints involved focus on public-sector institutions in one region and potential variability in technological resources. Raaj S et al. (2024) proposed a conceptual UTAUT2-based framework for AI applications in library financial services. By integrating explainability, trust, privacy, and algorithmic accountability, the model was developed for future empirical testing. Its limitation was the absence of real-world validation. Andrews et al. (2021) applied UTAUT to survey North American librarians' intentions regarding AI adoption. Structural equation modelling demonstrated that performance expectancy and attitude were significant predictors of adoption intention, while social influence and work expectations were not. Limitations included reliance on online surveys and potential sampling bias.

Ali et al. (2025) surveyed 245 Pakistani academic librarians using an adapted UTAUT model. Behavioural

intention was strongly influenced by performance expectancy, social influence, and facilitating conditions, while actual usage was affected by behavioural intention and service quality. The study was restricted by its cross-sectional design and limited institutional scope. Gupta and Gupta (2023) conceptually examined AI adoption in libraries, focusing on the interaction between NBE and CBE. Findings suggested that NBE promotes exploration of AI tools aligned with institutional needs, while CBE encourages collaboration and innovation. The study's reliance on observational insights limited empirical applicability. Ishengoma and Shao (2025) analysed the applicability of UTAUT3 for understanding AIoT system adoption in libraries. While UTAUT3 captured basic adoption factors, it was insufficient for addressing complex legal, ethical, and tracking concerns associated with AIoT. The proposed framework remains conceptual and untested. Ye et al. (2025) applied Immersion Theory and UTAUT2 to investigate digital Intangible Cultural Heritage (ICH) adoption. Analyses of 311 responses using fsQCA and NCA identified multiple motivational pathways and user profiles. Despite the robustness of the multi-method design, results were limited by prior experience with digital ICH, potentially excluding first-time users.

Research Gap

The rapid expansion of AI within digital education presents significant opportunities for cultural learning, yet its deployment across learning and library environments has remained uneven. Although UTAUT-based models offer important explanatory power, their utilisation in culturally focused technological contexts is limited. Existing research predominantly concentrates on AI applications within library systems and learning platforms, often overlooking transcultural heritage education and relying on restricted or homogeneous research samples. Furthermore, many studies fail to account for cultural context variables and do not fully integrate all UTAUT constructs, omitting critical psychological determinants such as attitudinal readiness and personal innovativeness within heritage-oriented digital platforms. This study extends the UTAUT model to investigate AI adoption in transcultural heritage digital libraries by incorporating attitudinal mediation alongside the moderating influences of personal readiness and individual innovativeness. Employing a large and diverse participant sample, the research seeks to enhance predictive accuracy and provide a holistic understanding of user adoption through PLS-SEM. The approach is designed to yield deeper insights into cultural influences and enrich empirical knowledge regarding AI implementation in heritage-focused digital learning environments. Hypotheses are formulated based on prior UTAUT research and recent investigations of AI adoption in library contexts. The conceptual framework is illustrated in Figure 2.

Hypothesis Development

H1: Performance Expectancy (PE) → Behavioural Intent (BI)

- Students who think that the AI tools will enhance their learning in digital heritage are more likely to have purposes to use them.

H2: Effort Expectancy (EE) → Behavioural Intent (BI)

- Users have the desire to use AI systems when they believe that it is easy to use.

H3: Social Influence (SI) → Behavioural Intent (BI)

- The intention to use AI in digital heritage settings is more likely when encouraged by peers, colleagues, or institutions.

H4: Facilitating Circumstances (FC) → Behavioural Intent (BI)

- The presence of sufficient technical and institutional support has a positive impact on the intention of users to use AI.

H5: Behavioural Intent (BI) → Actual Usage (AU)

- The intention to utilize AI tools increases the actual utilization of the same in digital heritage education.

H6a: Effort Expectancy (EE) → Attitude (Att) → Behavioural Intent (BI)

- Attitudes of the users mediate the connection between the purpose and perceived simplicity of usage to adopt AI.

H6b: Social Influence (SI) → Attitude (Att) → Behavioural Intent (BI)

- Attitude serves as an intermediary between the desire to employ AI tools and social impact.

H7: Effort Expectancy (EE) → Individual Readiness (IR) → Behavioural Intent (BI)

- Personal preparedness boosts the favourable correlation between the perceived ease of use and the Behavioural Intent.

H8: Performance Expectancy (PE) → Personal Innovativeness (PI) → Behavioural Intent (BI)

- The relation between forecasted AI performance and the desire to utilize such tools is reinforced by personal innovativeness.

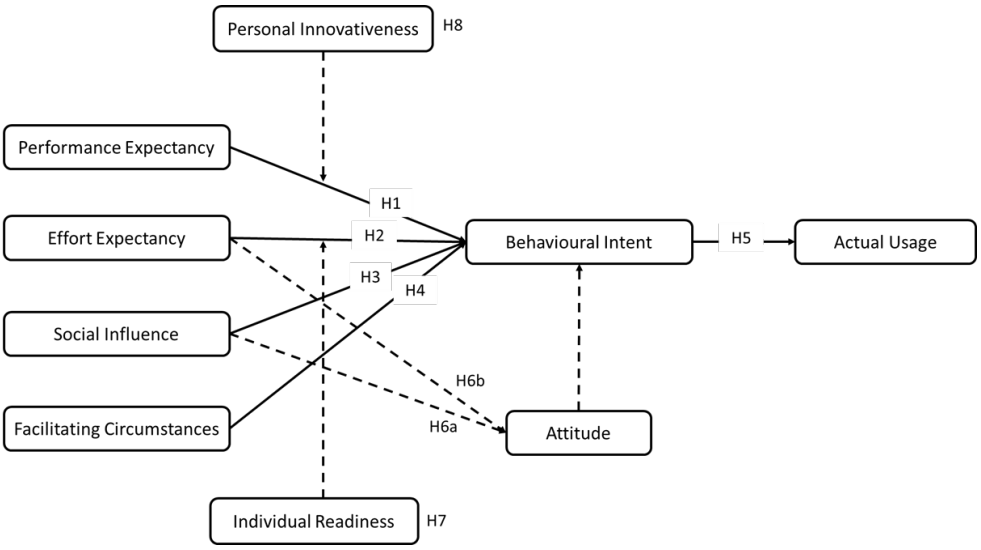

Figure 2: Conceptual Framework.

Methodology

The proposed study employs a systematic, quantitative research design to examine the influence of UTAUT constructs on the adoption of AI-based transcultural heritage learning within digital libraries among learners. This methodological approach ensures empirical rigor while establishing reliability and validity in the findings.

Research Design

To examine the relationships between UTAUT constructs and AI integration in digital libraries, a cross-sectional quantitative survey design was employed. This approach is commonly used in technology acceptance research and facilitates empirical investigation of determinant factors. It aligns with prevailing UTAUT literature and supports the application of PLS-SEM for statistical modelling.

Data Collection Methods and Population Sampling

The study population comprised individuals engaging with AI-enabled digital library systems to access and learn from transcultural heritage materials. Three distinct respondent groups were targeted, representing the primary users of digital library technologies:

- Academic librarians responsible for managing and organising digital library systems.
- Educators who incorporate digital heritage resources into their teaching practices.
- Students who routinely utilise digital platforms for study and research purposes.

Participants were selected through purposive sampling to ensure practical experience with AI tools in digital libraries, enabling informed assessments of factors such as ease of use, perceived usefulness, and organisational support. The survey conducted within university populations yielded 396 valid responses after excluding 345 incomplete or unsuitable questionnaires. The resulting dataset met the adequacy requirements for PLS-SEM, providing sufficient statistical power to test the proposed model effectively.

Instrument Development

A reliable and valid measurement instrument was developed to examine the effects of UTAUT constructs on the adoption of AI-enabled transcultural heritage education in digital libraries. The study incorporated nine constructs: Effort Expectancy (EE), Attitude (Att), Performance Expectancy (PE), Behavioural Intent (BI), Personal Innovativeness (PI), Social Influence (SI), Individual Readiness (IR), Facilitating Conditions (FC), and Actual Usage (AU). Each construct was operationalised using five items, measured on a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). To ensure content validity, the questionnaire underwent a preliminary review by subject-matter experts in digital libraries, AI in education, and UTAUT-based research. Their feedback improved item clarity and adjusted terminology to align with the context of transcultural

heritage education. The final questionnaire contained clear and concise statements and was organised into two primary sections tailored to librarians, educators, and students.

Demographic Information: This section collected participant background data, including user group, gender, age, educational qualification, professional experience, familiarity with AI usage, frequency of digital library engagement, and type of institution. Table 1 and Figure 3 present these demographic details, providing an overview of participant distribution and contextualising the sample.

Table 1: Demographics of Participants of the Usage Digital Library.

Demographic Factor	Category	Frequency (N=365)	Percentage (%)
User Group	Academic Librarians	103	28.2
	Educators	95	26.0
	Students	167	45.8
Gender	Female	187	51.2
	Male	178	48.8
Age Group	18–25	142	38.9
	26–35	121	33.2
	36–45	67	18.4
	Above 45	35	9.6
Educational Qualification	Undergraduate	148	40.5
	Postgraduate	143	39.2
	Doctoral Degree	51	14.0
	Other Professional Degrees	23	6.3
Academic/Professional Experience	Less than 1	69	18.9
	1–5	142	38.9
	6–10	92	25.2
	More than 10	62	17.0
Experience Using AI Tools	Less than 1	84	23.0
	1–3	156	42.7
	More than 3	125	34.2
Frequency of Using Digital Libraries	Daily	109	29.9
	Weekly	158	43.3
	Monthly	72	19.7
	Rarely	26	7.1
Type of AI Tools Used *(Multiple Response)*	Search/Recommendation Systems	201	55.1
	Classification/Tagging Tools	134	36.7
	Virtual Assistants/Chatbots	121	33.2
	Digital Heritage Visualization Tools	98	26.8
Institution Type	Public Institutions	167	45.8
	Private Institutions	129	35.3
	Cultural/Heritage Institutions	69	18.9

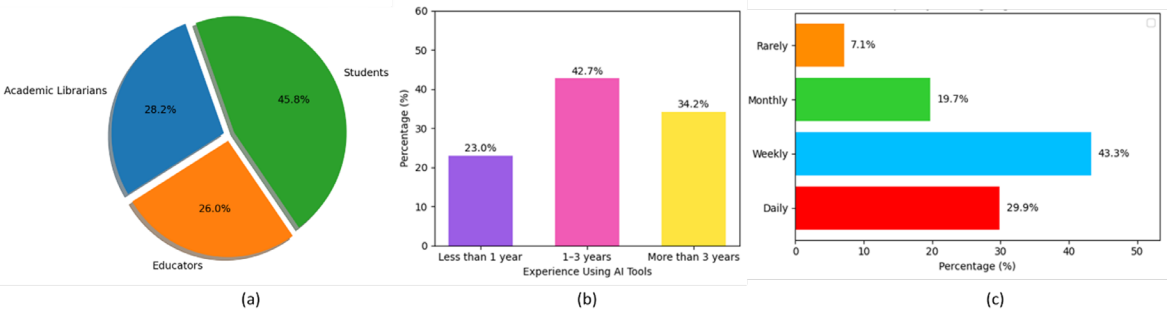

Figure 3: Demographics Participants of (a) User Group, (b) Experience of AI Tool Usage, (c) Frequency of Using Digital Libraries.

UTAUT and AI-Usage Constructs: This section comprised all measurement items employed to test the study hypotheses. Each construct was represented by three to five validated items, grounded in the UTAUT

framework and relevant AI adoption literature. Table 2 details all constructs, indicators, and scale formats, ensuring transparency and enabling reproducibility of the measurement model.

Table 2: Measurement Items for UTAUT Constructs in AI-Enabled Transcultural Heritage Education.

Construct	Question Items
Performance Expectancy (PE)	How much do AI-enabled digital library tools improve your learning efficiency? To what extent do AI systems help you understand transcultural heritage content better? How effectively do AI tools enhance the quality of your learning or teaching process?
Effort Expectancy (EE)	How simple is it for you to acquire and use AI-enabled digital library tools? To what extent does using AI in digital libraries require minimal mental effort? How easy is it to understand the functions of AI tools within digital library platforms?
Social Influence (SI)	How strongly do people who matter to you encourage the use of AI-enabled library systems? Does your institution motivate or expect you to use AI tools in digital libraries? How much influence do your peers or colleagues have on your decision to use AI-based library systems?
Facilitating Circumstances (FC)	Are you provided possessing the tools required to utilize digital libraries powered by AI? Does your institution offer sufficient technical assistance for tools based on AI? How sufficient is your knowledge or training to use AI systems effectively?
Attitude (Att) Toward Using AI	How favourable is your overall attitude toward using AI for transcultural heritage learning? How positive do you feel about integrating AI tools into digital library activities? To what extent do you feel motivated to use AI-enabled digital library systems?
Behavioural Intent (BI)	How likely are you to continue using AI-enabled digital library tools regularly? Do you plan to use AI systems for future learning or teaching tasks? How willing are you to recommend AI-enabled digital libraries to others?
Actual Usage (AU)	How often do you use AI-based features in digital library platforms? To what extent do you use AI tools when accessing digital heritage materials? How often do your academic activities involve AI-supported digital resources?
Individual Readiness (IR)	Do you feel ready to use AI-enabled digital library tools? Do you feel confident adapting to new AI features? Do you feel prepared to use AI tools without difficulty?
Personal Innovativeness (PI)	Do you enjoy trying new AI-based technologies in digital libraries? Do you like exploring unfamiliar AI features? Do you often try new digital tools before others?

This systematic procedure ensured both theoretical alignment and contextual relevance of the questionnaire for assessing user perceptions and intentions regarding AI-enabled transcultural heritage learning in digital libraries. Clarity, reliability, and internal consistency were evaluated in a pilot test involving several participants. Cronbach's alpha indicated minor inconsistencies in some items, which were subsequently refined. The final instrument demonstrated strong internal consistency, confirming its readiness for large-scale data collection.

Data Analysis Technique

The collected data were analysed using the Statistical Package for the Social Sciences (SPSS), applying a systematic quantitative approach to evaluate the proposed comprehensive UTAUT model. After cleaning, a dataset of 365 valid responses was subjected to PLS-SEM, which served as the primary analytical method due to its suitability for complex models, predictive research objectives, and datasets that may not conform to normal distribution assumptions.

Results

This section presents the PLS-SEM analysis, including the assessment of the measurement model, the structural model, and the mediation and moderation effects. The findings support the proposed hypotheses and illustrate the relationships among the key UTAUT constructs applied in this study.

Descriptive Statistics

Descriptive statistics were employed to summarise respondents' perceptions of the UTAUT constructs in relation to the adoption of AI within transcultural heritage digital libraries. The descriptive statistics for each construct were computed using the mean (M_j) and standard deviation (SD_j) based on the responses of 365 participants. The overall descriptive statistics can be represented using the following equation (Eq. 1):

$$M_j = \frac{1}{n}\sum_{i=1}^{n} X_{ji}, SD_j = \sqrt{\frac{\sum_{i=1}^{n}(X_{ji}-M_j)^2}{n-1}} \quad (1)$$

Where X_{ji} denotes the response score of participant i for construct j; M_j is the mean value

of construct *j*; and SD_j is the standard deviation of construct *j*. In this equation, n denotes the total number of respondents. Table 3 presents the mean (M) and standard deviation (SD) for all constructs based on the responses of the 365 participants. The descriptive results for the UTAUT and AI-usage constructs (N=365) are illustrated in Figure 4. The mean scores for all variables were relatively high (M = 3.67–4.02), reflecting generally positive attitudes toward the use of AI in transcultural digital libraries. The standard deviation values (SD = 0.72–0.83) were within acceptable ranges, indicating adequate variability in participants' responses.

Table 3: Descriptive Information of UTAUT and AI-Usage Constructs (N=365).

Variables	Standard Deviation (SD)	Mean (M)	Minimum	Maximum	No. of Items
PE	0.76	3.89	3.13	4.65	4
EE	0.72	3.95	3.23	4.67	3
SI	0.81	3.67	2.86	4.48	3
FC	0.78	3.84	3.06	4.62	3
Att	0.74	4.02	3.28	4.76	3
BI	0.79	3.96	3.17	4.75	3
AU	0.83	3.71	2.88	4.54	3
IR	0.77	3.88	3.11	4.65	3
PI	0.82	3.74	2.92	4.56	3

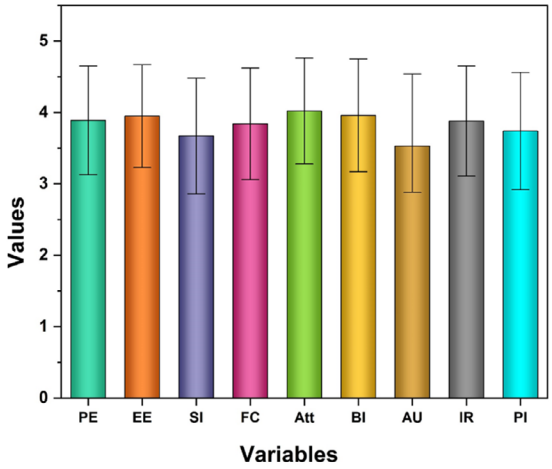

Figure 4: Descriptive Statistics of UTAUT Constructs in AI-Enabled Digital Library Context.

Reliability and Validity Test

The assessment of validity and reliability indicates that all measurement constructs in this study exhibit high internal consistency and strong convergent validity, confirming the suitability of the instrument for analysing UTAUT constructs and AI-enabled transcultural heritage education. Construct reliability and validity were evaluated using factor loadings, Composite Reliability (CR), Average Variance Extracted (AVE), and Cronbach's Alpha (α) to ensure both internal consistency and convergent validity. The overall measurement model is represented by the following equations (2) to (4):

$$CR = \frac{(\Sigma \lambda_i)^2}{(\Sigma \lambda_i)^2 + \Sigma(1-\lambda_i^2)} \quad (2)$$

$$AVE = \frac{\Sigma \lambda_i^2}{n} \quad (3)$$

$$\alpha = \frac{k \cdot \bar{r}}{1+(k-1)\bar{r}} \quad (4)$$

Where λ_i is standardized factor loading of item $_i$, *n* is the number of items in the construct, *k* is the total number of items, $\bar{r}$ is the average inter-item correlation. Table 4 presents the reliability and validity measures, confirming the suitability of the constructs for analysing AI adoption in transcultural heritage digital education. The results indicate that the measurement model exhibits strong convergent

reliability and validity, as summarised in Table 4. Factor loadings exceed the 0.70 threshold, confirming that each item makes a substantial contribution to its respective latent construct. Cronbach's alpha (α) and composite reliability coefficients range from 0.84 to 0.93, demonstrating high internal consistency. Moreover, all AVE values surpass 0.50, verifying that the constructs PE, EE, SI, FC, Att, BI, and AU were reliably measured. These outcomes provide a solid foundation for the subsequent structural analysis using PLS-SEM, particularly in examining AI adoption within digital heritage learning environments.

Table 4: Evaluation of Construct Reliability and Convergent Validity in the AI Adoption Framework.

Potential Variables	Question Item	Factor Load	Reliability Coefficient	CR	AVE	Cronbach (α)
PE	PE1	.803	.645	.905	.689	0.871
	PE2	.857	.735			
	PE3	.842	.709			
EE	EE1	.873	.762	.923	.715	0.892
	EE2	.889	.790			
	EE3	.796	.634			
SI	SI1	.812	.659	.894	.679	0.846
	SI2	.847	.717			
	SI3	.804	.646			
FC	FC1	.833	.694	.914	.679	0.881
	FC2	.879	.773			
	FC3	.848	.719			
Att	Att 1	.826	.682	.902	.696	0.864
	Att 2	.854	.729			
	Att 3	.823	.677			
BI	BI1	.884	.781	.932	.773	0.903
	BI2	.913	.834			
	BI3	.861	.741			
AU	AU1	.846	.715	.920	.740	0.889
	AU2	.884	.781			
	AU3	.851	.724			

Discriminant Validity Test

Discriminant validity was assessed using the Heterotrait-Monotrait Ratio of Correlations (HTMT), confirming that all constructs in the model are empirically distinct. HTMT is regarded as a more robust indicator of discriminant validity compared with the traditional Fornell–Larcker criterion. Table 5 presents the HTMT values for all construct pairs. All HTMT values fall below the 0.85 threshold, indicating the absence of excessive construct overlap. This distinction is particularly important in a UTAUT-based model, where constructs such as PE, EE, and Att may appear conceptually related. The analysis confirms that these constructs represent empirically unique measures of user acceptance in AI-enabled digital heritage platforms. The high discriminant validity demonstrates that respondents could clearly differentiate between factors such as EE, PE, SI, FC, BI, and AU, ensuring that the relationships and predictive capability of the model are not compromised by construct redundancy. This strengthens the overall validity and accuracy of the study's findings.

Table 5: Discriminant Validity Analysis of UTAUT Constructs in AI-Enabled Digital Libraries.

Construct Factors	PE	EE	SI	FC	Att	BI	AU
PE	-	.73	.70	.66	.71	.78	.59
EE		-	.67	.71	.76	.72	.55
SI			-	.62	.68	.74	.53
FC				-	.67	.70	.63
Att					-	.81	.58
BI						-	.73
AU							-

Structural Modelling Result

The structural framework was assessed using PLS-SEM. This analysis examined the significance and impact of the hypothesized relationships among UTAUT constructs to predict BI and AU of AI in

transcultural heritage education. The significance of the proposed paths illustrated in Figure 5 was tested using bootstrap resampling with replicates.

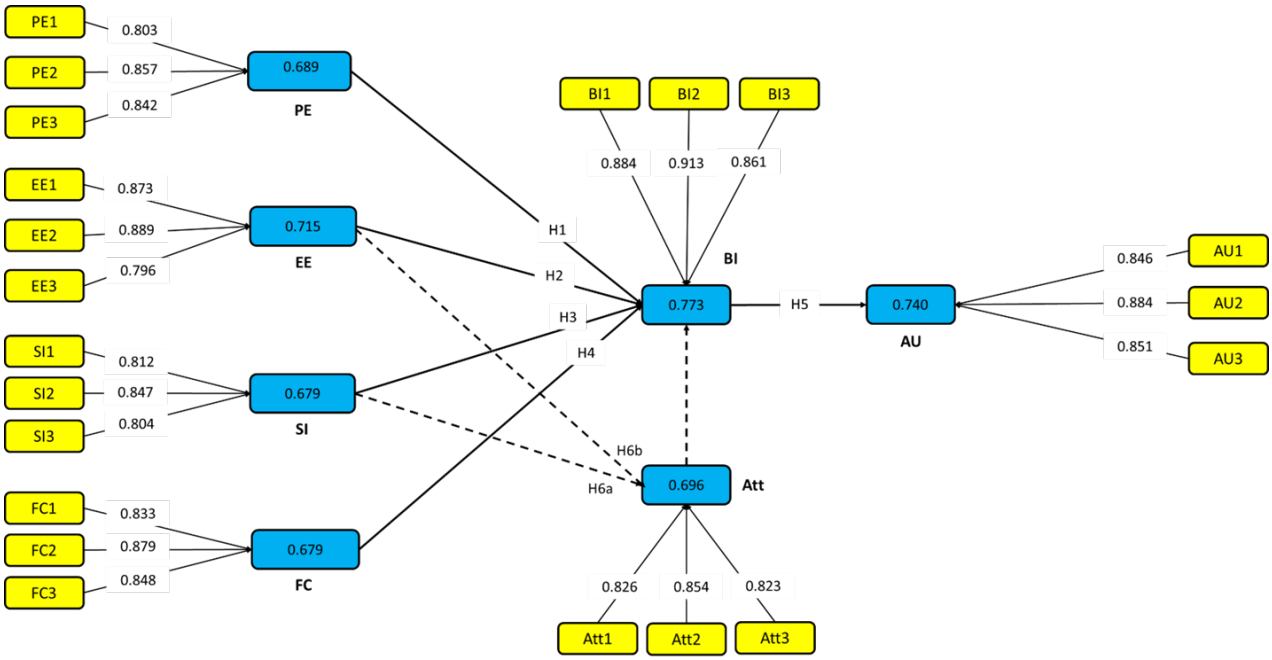

Figure 5: Path Analysis of UTAUT Construct Influencing AI Usage in Digital Library.

Path Coefficient and Hypothesis Testing

Path coefficients (β), t-values, and p-values were estimated through a bootstrapping procedure. These metrics were used to assess the strength, significance, and direction of the hypothesized relationships among constructs. The PLS-SEM structural model is represented by Equation (5):

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \varepsilon \quad (5)$$

Y is the dependent variable, X_i is the independent variables β_i is the path coefficient representing the strength and direction of the relationship between X_i and Y, β_0 is the constant term ε is the error term representing unexplained variance. The results of the structural model analysis are summarised in Table 6.

Table 6: SEM-PLS Path Coefficient and Hypothesis Testing.

Hypothesis	*T*-Value	Coefficient (*β*)	*P*-Value	Decision
H1: PE → BI	1.421	.112	0.156	Not Supported
H2: EE → BI	4.912	.284	< 0.001	Supported
H3: SI → BI	2.842	.163	0.005	Supported
H4: FC → BI	6.327	.345	< 0.001	Supported
H5: BI → AU	5.104	.329	< 0.001	Supported
H6a: EE → Att → BI (Indirect)	3.914	.147	< 0.001	Supported (Mediated)
H6b: SI → Att → BI (Indirect)	2.732	.098	0.007	Supported (Mediated)
H7: EE × IR → BI (Moderation)	2.511	.098	0.012	Supported
H8: PE × PI → BI (Moderation)	2.948	.121	0.003	Supported

The structural model demonstrates that EE, SI, and FC significantly influence BI for AI-enabled transcultural heritage education, with FC exerting the strongest effect (β = 0.345), emphasising the critical role of institutional and technological support. PE does not have a significant impact on BI (p = 0.156), indicating that users prioritise ease of use and available support over performance-related gains. BI, in turn, strongly predicts AU (β = 0.329). Att was observed to mediate the effects of EE and SI on BI, while IR and PI moderate the relationships between technological constructs and individual attributes. Overall, the PLS-SEM results corroborate the hypothesised UTAUT-based model and demonstrate strong predictive validity in explaining AI adoption behaviour within transcultural heritage education.

Mediation and Moderation Analysis

The bootstrapping procedure in PLS-SEM was employed to examine the mediation effects hypothesised in H6a and H6b. Standard bootstrap resampling, a conventional approach in PLS-SEM, was used to obtain robust statistical inferences. The analysis assessed whether Att mediates the influence of EE and SI on BI, with the results presented in Table 7. Both mediation hypotheses were supported, demonstrating that Att significantly influences the effects of EE and SI on BI in AI-enabled digital libraries. Positive user attitudes are shaped by perceptions of EE and social encouragement (SI), underscoring the psychological importance of Att in facilitating AI adoption within transcultural digital heritage learning.

Table 7: Mediation Analysis Results for the UTAUT-Based AI Adoption Model.

Hypothesis	Mediating Path	Indirect Effect (β)	T-Value	P-Value	95% CI (Bias-Corrected)	Result
H6a	EE → Att → BI	.147	3.914	< .001	[0.073, 0.224]	Supported
H6b	SI → Att → BI	.098	2.732	.007	[0.041, 0.172]	Supported

To evaluate hypotheses H7 and H8, a moderation analysis was conducted using interaction terms generated in PLS-SEM. Moderation assesses how the relationship between an independent and dependent variable changes depending on the level of a third variable (moderator). The results of these interactions are presented in Table 8. Both moderation effects were significant. IR strengthens the relationship between EE and BI, indicating that users who are better prepared, confident, and technologically ready experience a stronger influence of AU on their intention to adopt AI. Similarly, PI amplifies the effect of PE on BI, suggesting that users with a preference for experimenting with new technologies perceive AI features as more valuable, thereby increasing their intention to use AI-enabled heritage learning tools. These findings emphasise the critical role of individual factors in shaping learner acceptance of AI applications within digital library environments.

Table 8: Moderation Analysis Results for the UTAUT-Based AI Adoption Model.

Hypothesis	Moderation Effect	Interaction Term (β)	T-Value	P-Value	Direction	Result
H7	EE × IR → BI	.098	2.511	.012	Strengthening Effect	Supported
H8	PE × PI → BI	.121	2.948	.003	Strengthening Effect	Supported

Model Fit Indices

The Standardized Root Mean Square Residual (SRMR) and Normed Fit Index (NFI) were evaluated to assess the overall fit of the structural model in PLS-SEM. The results indicate a satisfactory model fit, as summarised in Table 9. The UTAUT-based structural model demonstrated strong adequacy and predictive relevance, with an SRMR of 0.052 and an NFI of 0.921, indicating a good overall fit. Key determinants of AI adoption in digital heritage learning were FC (β = 0.345), EE (β = 0.284), and SI (β = 0.163), whereas PE had a negligible influence across the 365 participants. BI exhibited a strong relationship with AU (β = 0.329), while Att, IR, and PI further facilitated adoption. These findings highlight that institutional support, ease of use, and user readiness are critical factors for successful AI integration.

Table 9: Model Fit Indices for the UTAUT-Based AI Adoption Model.

Model Fit Measure	Obtained Value	Recommended Threshold	Interpretation
SRMR	.052	< .08	Good Fit
NFI	.921	> .90	Strong Model Fit
R^2 for BI	.677	≥ .50	High Predictive Accuracy
R^2 for AU	0.574	≥ .50	Substantial Predictive Power
Q^2 (Cross-Validated Redundancy)	> 0	Must be > 0	Predictively Relevant

Discussion and Future Direction

To situate the current findings within the broader context of smart technology adoption in academic libraries, it is important to compare them with prior research and assess their contributions to the field (Trifi et al., 2025). Previous studies, such as those by Mashaba and Pretorius (2023) and Andrews

et al. (2021), primarily focused on digital or mobile services using UTAUT frameworks, providing limited insights into the adoption of advanced AI systems. Barriers in mobile services were often linked to infrastructural constraints and user behaviours, while low system responsiveness hindered interaction with electronic resources. Additionally, librarians' limited knowledge and practical difficulties in using AI tools indicate that contemporary digital library systems generally lack personalisation, operational flexibility, and optimisation (Valencia Arnica et al., 2023).

This study extends the UTAUT framework to the domain of transcultural heritage education, incorporating attitudinal mediation and personal readiness to use AI within digital libraries. PLS-SEM results indicate strong model performance (R^2 = 0.677 for BI; R^2 = 0.574 for AU), with FC and EE significantly influencing BI. PE exerted minimal direct effect, suggesting that in cross-cultural settings, users prioritise ease of use over performance. Att mediated critical UTAUT relationships, while IR and PI moderated technology acceptance ($p = 0.003$). The model's strong fit (SRMR = 0.052; NFI = 0.921) underscores the importance of user-centred factors and institutional support in facilitating AI adoption for immersive, culturally rich learning experiences within digital libraries. Despite these contributions, the study has limitations, including a sample restricted to academic institutions and reliance on self-reported survey data. Future research should broaden the demographic and geographical scope, employ longitudinal or experimental designs, and incorporate additional constructs such as AI trust, data privacy concerns, and experiences of cultural immersion.

Conclusion

AI is increasingly integrated into digital libraries, providing immersive and culturally enriched learning experiences; however, user adoption behaviour remains insufficiently understood. This study employed an extended UTAUT model to examine AI adoption in transcultural heritage education, demonstrating high predictive validity, explaining 67.7% of BI and 57.4% of AU. FC emerged as the strongest predictor (BI = 0.345, $p = 0.001$), while EE and SI also significantly influenced BI. Att mediated key relationships ($p = 0.003$), and PI moderated effects, highlighting the importance of user readiness and positive perceptions in enhancing adoption outcomes. The findings underscore that AI adoption depends not only on technological features but also on user attitudes, willingness, and supportive institutional environments. These insights offer practical guidance for policymakers, educators, and system designers in developing culturally responsive, user-centred AI solutions for digital heritage learning.

Funding: This research was supported by the *Research Project of Guangzhou Huashang College, Supported by National-level Research Project Research Team, Li Hongfu Research Team (Project No.: 2023HSKT01)* and by the project *"Intelligent Space Construction and Path Design for the Revitalization of Intangible Cultural Heritage Based on Rural Health and Wellness Needs: A Case Study of the Renovation of Ancient Residences in Yongning Street for Cultural Tourism" (Project No.: 2025HSHX11).*

References

Ali, I. and Warraich, N. F. (2024). Use and acceptance of technology with academic and digital libraries context: A meta-analysis of UTAUT model and future direction. *Journal of Librarianship and Information Science*, 56(4): 965-977. https://doi.org/10.1177/09610006231179716

Ali, M. Y., Bin Naeem, S., Bhatti, R. and Richardson, J. (2025). Factors affecting intention of academic librarians in Pakistan universities to use AI tools: an extension of the UTAUT model. *Global Knowledge, Memory and Communication*. https://doi.org/10.1108/GKMC-08-2024-0560

Alotaibi, F. A. A., Johnson, F. and Rowley, J. (2023). Google Scholar or University Digital Libraries: A comparison of student perceptions and intention to use. *Journal of Librarianship and Information Science*, 55(4): 906-920. https://doi.org/10.1177/09610006221111197

Andrews, J. E., Ward, H. and Yoon, J. (2021). UTAUT as a Model for Understanding Intention to Adopt AI and Related Technologies among Librarians. *The Journal of Academic Librarianship*, 47(6): 102437. https://doi.org/10.1016/j.acalib.2021.102437

Barbuti, N. (2021). Thinking digital libraries for preservation as digital cultural heritage: by R to R4 facet of FAIR principles. *International Journal on Digital Libraries*, 22(3): 309-318. https://doi.org/10.1007/s00799-020-00291-7

Barman, B. (2024). Artificial Intelligence and Machine Learning in Libraries: Transforming

Information Access and Management. *RGU Journal of Social Science and Research*, 1(1): 1-7. https://doi.org/10.3254/rgujssr.v1i1.4

Camuñas-García, D., Cáceres-Reche, M. P., Cambil-Hernández, M. d. l. E. and Lorenzo-Martín, M. E. (2024). Digital Game-Based Heritage Education: Analyzing the Potential of Heritage-Based Video Games. *Education Sciences*, 14(4): 396. https://doi.org/10.3390/educsci14040396

Casadei, V. and Di Modica, G. (2025). Access to Digital Cultural Heritage: Exploring Future Perspectives Through Open Tools of Research. *Engineering Proceedings*, 96(1): 10. https://doi.org/10.3390/engproc2025096010

Chong, S.-E., Looi, K. H. and Shahudin, F. (2025). Beyond the prompt: exploring technostress, flow and personality in generative AI behaviors. *The Electronic Library*, 43(5): 733-756. https://doi.org/10.1108/EL-05-2025-0171

Dalle, J., Aydin, H. and Wang, C. X. (2024). Cultural Dimensions of Technology Acceptance and Adaptation in Learning Environments. *Journal of Formative Design in Learning*, 8(2): 99-112. https://doi.org/10.1007/s41686-024-00095-x

Fang, W., Na, M. and Alam, S. S. (2025). Usage Intention of AI Among Academic Librarians in China: Extension of UTAUT Model. *Sustainability*, 17(7): 2833. https://doi.org/10.3390/su17072833

Gupta, V. and Gupta, C. (2023). Synchronizing innovation: unveiling the synergy of need-based and curiosity-based experimentation in AI technology adoption for libraries. *Library Hi Tech News*, 40(9): 15-17. https://doi.org/10.1108/LHTN-07-2023-0127

Ishengoma, F. and Shao, D. (2025). The efficacy of UTAUT3 in AIoT integration within library systems. *Aslib Journal of Information Management*: 1-24. https://doi.org/10.1108/AJIM-11-2024-0889

Ke, Q., Gong, Y. and Ke, C. (2025). Bridging AI literacy and UTAUT constructs: structural equation modeling of AI adoption among Chinese university students. *Humanities and Social Sciences Communications*, 12(1): 1452. https://doi.org/10.1057/s41599-025-05775-y

Khan, A. U., Zhang, Z., Chohan, S. R. and Rafique, W. (2021). Factors fostering the success of IoT services in academic libraries: a study built to enhance the library performance. *Library Hi Tech*, 40(6): 1976-1995. https://doi.org/10.1108/LHT-06-2021-0179

Kwiecien, K., Chansanam, W. and Tuamsuk, K. (2025). Digital Cultural Heritage in Southeast Asia: Knowledge Structures and Resources in GLAM Institutions. *Informatics*, 12(3): 96. https://doi.org/10.3390/informatics12030096

Lau, K. W. (2024). The potential use of immersive virtual environments for collecting and archiving heritage gameplay activities in digital libraries. *Digital Library Perspectives*, 41(1): 91-99. https://doi.org/10.1108/DLP-05-2024-0075

Lian, Y. and Xie, J. (2024). The Evolution of Digital Cultural Heritage Research: Identifying Key Trends, Hotspots, and Challenges through Bibliometric Analysis. *Sustainability*, 16(16): 7125. https://doi.org/10.3390/su16167125

Mashaba, M. C. and Pretorius, A. B. (2023). Electronic library resource use by postgraduate students at a university of technology in South Africa. *South African Journal of Information Management*, 25(1): 1602. https://doi.org/10.4102/sajim.v25i1.1602

Mitha, S. B. and Omarsaib, M. (2024). Emerging technologies and higher education libraries: a bibliometric analysis of the global literature. *Library Hi Tech*, 43(2-3): 1248-1270. https://doi.org/10.1108/LHT-02-2024-0105

Odularu, O., Sone, E. and Puzi, M. (2024). Globalisation Perspective of Libraries as Curators of Oral Tradition and Storytelling Activities. *Journal of Culture and Values in Education*, 7(2): 136-156. https://doi.org/10.46303/jcve.2024.16

Oyighan, D., Ukubeyinje, E. S., David -West, B. T. and Oladokun, B. D. (2024). The Role of AI in Transforming Metadata Management: Insights on Challenges, Opportunities, and Emerging Trends. *Asian Journal of Information Science and Technology*, 14(2): 20-26. https://doi.org/10.70112/ajist-2024.14.2.4277

Park, H. E. (2024). The double-edged sword of generative artificial intelligence in digitalization: An affordances and constraints perspective. *Psychology & Marketing*, 41(11): 2924-2941. https://doi.org/10.1002/mar.22094

Pinar, A. and Cox, A. (2025). An Analysis of Artificial

Intelligence (AI) Capability in Libraries and Archives. *Cataloging & Classification Quarterly*, 63(6-7): 566-599. https://doi.org/10.1080/01639374.2025.2539790

Raaj S, S. K., Fathima, G. N., Rathod, V. P. and Mishra, P. (2024). Improving the Adoption of Artificial Intelligence in Library Financial Services: A Comprehensive UTAUT2 Framework with AI-Specific Variables. *Library of Progress-Library Science, Information Technology & Computer*, 44(3): 10111-10127. https://doi.org/10.48165/bapas.2024.44.2.1

Rahmanova, A. (2025). Evolution of Libraries in the Digital Era: Redefining Access, Education, and Cultural Preservation. *Library Archive and Museum Research Journal*, 6(1): 23-38. https://doi.org/10.59116/lamre.1540033

Roy, P. (2024). What drives the adoption of data analytics at Australian university libraries in the perspective of UTAUT2? *The Journal of Academic Librarianship*, 50(5): 102927. https://doi.org/10.1016/j.acalib.2024.102927

Trifi, D., Altaba, P., Barreda-Juan, P., Monrós-Andreu, G., Menéndez, L., García-Esparza, J. A. *et al.* (2025). Enhancing Heritage Education Through ICT: Insights from the H2OMap Erasmus+ Project. *Education Sciences*, 15(9): 1164. https://doi.org/10.3390/educsci15091164

Valencia Arnica, Y. K., Ccasani Rodriguez, J. L., Rucano Paucar, F. H. and Talavera-Mendoza, F. (2023). The Status of Didactic Models for Heritage Education: A Systematic Review. *Heritage*, 6(12): 7611-7623. https://doi.org/10.3390/heritage6120400

Ye, X., Ruan, Y., Xia, S. and Gu, L. (2025). Adoption of digital intangible cultural heritage: a configurational study integrating UTAUT2 and immersion theory. *Humanities and Social Sciences Communications*, 12(1): 23. https://doi.org/10.1057/s41599-024-04222-8

Zhu, Z. and Huang, W. (2025). A meta-analysis of mobile learning adoption using extended UTAUT. *Information Development*, 41(2): 512-528. https://doi.org/10.1177/02666669231176428

Jing Guo is a semiotics scholar and lecturer specializing in Intelligent Design and Digital Humanities. She holds a PhD in Semiotics from Shinawatra University (2021–2025), a Master's degree in Animation and Illustration from Coventry University, and a Bachelor's degree in Digital Media Art from South China Normal University.

Qiqiong Huang is a PhD researcher and full-time university lecturer whose work spans Artificial Intelligence, Cultural and Creative Product Design, Interaction Design, and Illustration Design. She is currently pursuing her PhD in Design at City University Malaysia. She holds a Master of Design and a Bachelor of Arts and Design from Hunan Normal University.

Haomin Ye is an undergraduate student specializing in Visual Communication Design at Guangzhou Huashang College (2022–2026). His academic interests focus on creative visual expression and design communication.

Appendix

Abbreviation	Full Form
AI	*Artificial Intelligence*
TAM	*Technology Acceptance Model*
UTAUT	*Unified Theory of Acceptance and Use of Technology*
UTAUT2	*Unified Theory of Acceptance and Use of Technology 2*
UTAUT3	*Unified Theory of Acceptance and Use of Technology 3*
TRI	*Technology Readiness Index*
PIIT	*Personal Innovativeness in Information Technology*
SEM	*Structural Equation Modeling*
PLS-SEM	*Partial Least Squares Structural Equation Modeling*
fsQCA	*Fuzzy Set Qualitative Comparative Analysis*
NCA	*Necessary Condition Analysis*
NBE	*Need-Based Experimentation*
CBE	*Curiosity-Based Experimentation*
ICH	*Intangible Cultural Heritage*
IoT	*Internet of Things*
AIoT	*Artificial Intelligence of Things*