

Research Paper

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Unpacking User Satisfaction and Loyalty Toward Educational Augmented Reality (AR) Applications

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Publication Details: Received 28/9/2025; Revised 14/12/2025; Accepted: 16/12/2025

ABSTRACT

Augmented Reality (AR) applications are increasingly embedded in higher education to enhance learner engagement and outcomes. Yet, user satisfaction and loyalty to educational AR apps remain uneven, particularly among technologically proficient young adults. This study advances an integrated framework grounded in the Unified Theory of Acceptance and Use of Technology 3 (UTAUT3), the Information Systems Success Model (ISSM), and Sustainable Consumption Practices (SCP) to identify determinants of satisfaction and loyalty. Data from 384 university students aged 18–34 were collected through an online survey and analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). Results indicate that performance expectancy, effort expectancy, system quality, hedonic motivation and related constructs significantly predict satisfaction, which subsequently drives loyalty. Furthermore, SCP moderates the satisfaction–loyalty relationship, highlighting the salience of environmental and ethical concerns in sustaining engagement. The findings contribute to multidisciplinary scholarship on educational technologies and offer actionable guidance for AR developers and higher education institutions.

Keywords: Augmented Reality, UTAUT3, User Satisfaction, Loyalty, Sustainable Consumption Practices, Higher Education

Introduction

The rapid advancement of immersive technologies has transformed the landscape of higher education, particularly through the integration of Augmented Reality (AR) in teaching and learning. AR overlays digital elements such as 3D models, simulations, and contextual information onto real-world environments, providing students with interactive and engaging learning experiences. In recent years, the educational sector has embraced AR to promote active participation, foster deeper understanding, and support self-paced learning, particularly among young adult learners who are increasingly technology-literate.

Despite its pedagogical potential, widespread adoption and sustained use of AR applications in education remain limited. Many students discontinue use after initial trials, suggesting a gap in satisfaction and loyalty toward AR apps. Previous research has primarily focused on the technological benefits or usability of AR in education, with less attention given to behavioral and attitudinal factors that contribute to continued engagement. Moreover, limited

empirical studies have examined how satisfaction and loyalty are shaped by multidimensional constructions, particularly within comprehensive theoretical frameworks.

This study addresses this gap by integrating the Unified Theory of Acceptance and Use of Technology 3 (UTAUT3) and the Information Systems Success Model (ISSM) to investigate factors influencing user satisfaction and loyalty toward educational AR applications. In addition, this study incorporates Sustainable Consumption Practices (SCP) as a moderating variable to reflect the growing importance of ethical, environmental, and sustainable considerations in digital technology usage. The research targets young adult learners aged 18–34, who represent a crucial demographic in the future of higher education and technology adoption.

By offering a holistic framework, this study contributes to theoretical discourse on digital education technologies and provides practical insights for AR developers, educators, and policymakers aiming to foster sustained engagement through responsible and user-centered AR solutions.

Literature Review

Conceptual Foundation of the Study

The conceptual foundation of this study is grounded in four prominent theories: the Unified Theory of Acceptance and Use of Technology 3 (UTAUT3), the Information Systems Success Model (ISSM), the Expectation-Confirmation Theory (ECT), and Sustainable Consumption Practices (SCP) as a moderating perspective. Together, these theories provide a robust lens to understand the antecedents of satisfaction and loyalty among young adult users of educational augmented reality (AR) applications.

Unified Theory of Acceptance and Use of Technology 3 (UTAUT3)

The UTAUT3 model (Venkatesh et al., 2012) extends UTAUT and UTAUT2 by incorporating personal innovativeness along with key predictors such as performance expectancy (PE), effort expectancy (EE), social influence (SI), facilitating conditions (FC), hedonic motivation (HM), price value (PV), and habit (HB). In AR-based educational platforms, these constructs explain users' acceptance of immersive technologies in learning environments.

H1: *Performance Expectancy has a significant positive effect on Satisfaction.*

H2: *Effort Expectancy has a significant positive effect on Satisfaction.*

H3: *Social Influence has a significant positive effect on Satisfaction.*

H4: *Facilitating Conditions have a significant positive effect on Satisfaction.*

H5: *Hedonic Motivation has a significant positive effect on Satisfaction.*

H6: *Price Value has a significant positive effect on Satisfaction.*

H7: *Habit has a significant positive effect on Satisfaction.*

H8: *Personal Innovativeness has a significant positive effect on Satisfaction.*

Information Systems Success Model (ISSM)

The Information Systems Success Model (DeLone & McLean, 2003) offers a systematic approach to assess system performance and its influence on user satisfaction and subsequent

use. The core constructs system quality, information quality, and service quality are particularly relevant in AR contexts where interactivity, information accuracy, and technical support shape the learning experience and continued engagement (Alzahrani et al., 2017).

H9: *System Quality has a significant positive effect on Satisfaction.*

H10: *Information Quality has a significant positive effect on Satisfaction.*

H11: *Service Quality has a significant positive effect on Satisfaction.*

Expectation-Confirmation Theory (ECT)

The Expectation-Confirmation Theory (Bhattacharjee, 2001) explains satisfaction and continued usage intentions. In AR education, confirmation of expectations such as improved engagement or comprehension drives satisfaction and loyalty (Chung et al., 2015).

H12: *Satisfaction has a significant positive effect on Loyalty.*

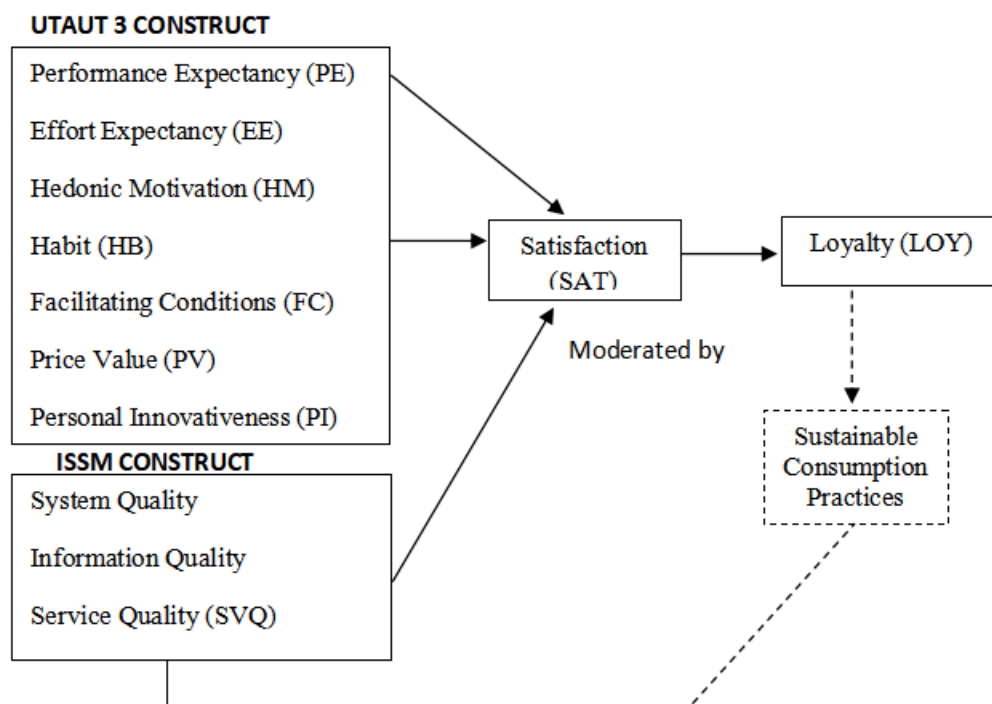
H13a–h: *Satisfaction mediates the relationship between UTAUT3/ISSM predictors and Loyalty.*

Sustainable Consumption Practices (SCP)

This study integrates SCP as a moderating variable between satisfaction and loyalty. SCP reflects users' ethical considerations, environmental awareness, and conscious digital behavior. Individuals who value sustainability may exhibit stronger loyalty toward technologies aligned with their values (Papista et al., 2018; Lim et al., 2022).

H14: *Sustainable Consumption Practices significantly moderate the relationship between Satisfaction and Loyalty, such that the relationship is stronger when SCP is high.*

Figure 1: Research Model



This study presents an integrated research model combining the Unified Theory of Acceptance and Use of Technology 3 (UTAUT3), the Information Systems Success Model (ISSM), and the concept of Sustainable Consumption Practices (SCP) to examine the key determinants of user satisfaction and loyalty toward educational Augmented Reality (AR) applications among young adults in higher education.

This study proposes an integrated research model to investigate the factors influencing user satisfaction and loyalty toward educational Augmented Reality (AR) applications among young adults in higher education. The model is grounded in the Unified Theory of Acceptance and Use of Technology 3 (UTAUT3), the Information Systems Success Model (ISSM), and incorporates Sustainable Consumption Practices (SCP) as a moderating factor. This multidisciplinary approach enables a holistic understanding of user behavior in the context of educational AR technology.

The UTAUT3 model, introduced by Venkatesh, Thong, and Xu (2012), provides a comprehensive framework for understanding technology adoption in consumer environments. In this study, several key constructs from UTAUT3 are employed, including performance expectancy, effort expectancy, hedonic motivation, habit, facilitating conditions, price value, and personal innovativeness. Performance expectancy refers to the extent to which users believe that using AR applications will improve their academic performance. Prior research confirms that performance expectancy significantly contributes to user satisfaction, particularly when technology is perceived as enhancing learning effectiveness (Alalwan et al., 2017; Cheng, 2019). Effort expectancy, or the perceived ease of using the AR app, also plays a critical role in user satisfaction. When students find the application easy to navigate and interact with, their level of satisfaction increases accordingly (Venkatesh et al., 2012; Hoque & Sorwar, 2017).

Hedonic motivation, which refers to the enjoyment derived from using the application, contributes positively to user satisfaction by making the learning process more engaging and immersive (Thong et al., 2006; Alzahrani et al., 2022). Habit, defined as the extent to which behavior becomes automatic, also influences satisfaction, especially when users repeatedly engage with the app as part of their learning routines (Venkatesh et al., 2012). Facilitating conditions, such as the availability of technical support and necessary infrastructure, are shown to reduce usage barriers and improve satisfaction with the AR app experience (Yuen et al., 2021). Price value, which captures the perceived trade-off between the app's benefits and its associated costs (including time and effort), is particularly relevant in educational settings and has a positive effect on satisfaction (Zhou et al., 2020). Furthermore, personal innovativeness, defined as an individual's willingness to try new technologies, has been linked to higher satisfaction levels among early adopters and tech-savvy students (Agarwal & Prasad, 1998; Zhang et al., 2023).

Complementing these individual-level constructs, the Information Systems Success Model (ISSM) focuses on system-level qualities that determine user satisfaction. Developed by DeLone and McLean (2003), the ISSM includes system quality, information quality, and service quality as core dimensions. System quality refers to the technical reliability, usability,

and responsiveness of the AR application. Studies have consistently shown that high system quality leads to enhanced user satisfaction (DeLone & McLean, 2003; Lin, 2007). Information quality represents the relevance, clarity, accuracy, and timeliness of the educational content delivered by the AR system. High-quality information supports cognitive engagement and contributes to overall satisfaction (Wang & Strong, 1996). Service quality pertains to the support services provided, including technical assistance and user guidance. When students receive adequate help and prompt responses to technical issues, their satisfaction with the AR system improves significantly (Petter et al., 2008).

The model posits that satisfaction serves as a key mediating construct between the independent variables and the dependent variable, loyalty. Satisfaction in this context reflects the user's emotional response and contentment after using the AR application. According to the Expectation-Confirmation Theory (Oliver, 1980), users who perceive their expectations to be met or exceeded are more likely to experience satisfaction, which in turn leads to behavioral loyalty. Bhattacharjee (2001) further supports this by asserting that satisfaction significantly influences users' intention to continue using an information system. In the educational technology domain, this implies that when students are satisfied with the AR learning experience, they are more inclined to remain loyal to the application, recommending it to peers and continuing its usage over time (Lee, 2010; Shin & Shin, 2011).

In addition to direct effects, this model introduces Sustainable Consumption Practices (SCP) as a moderating variable between satisfaction and loyalty. SCP encompasses users' environmental awareness and ethical considerations when engaging with digital technologies. Peattie and Collins (2009) argue that consumers increasingly seek technologies that align with sustainability values, and this trend is particularly pronounced among younger generations. When users perceive that an AR application supports sustainable practices such as reducing the use of physical materials or promoting responsible digital learning they may feel more committed to continued use. Liu, Li, and Yu (2021) found that sustainability awareness can amplify the relationship between satisfaction and loyalty, suggesting that SCP acts as a value-driven enhancer. The inclusion of SCP is also aligned with the Triple Bottom Line (TBL) framework introduced by Elkington (1997), which emphasizes environmental, social, and economic sustainability in organizational practices. By integrating SCP into the model, the study recognizes that digital behavior is not only shaped by functionality and quality but also by broader values related to ethical and responsible technology use.

In conclusion, the proposed research model offers a comprehensive lens to examine the factors driving satisfaction and loyalty in the use of educational AR applications. By combining UTAUT3, ISSM, and SCP, the model provides a robust theoretical foundation that captures both technological and sustainability dimensions. This integrated framework has practical implications for AR developers and higher education institutions aiming to design and implement engaging, high-quality, and sustainable learning environments.

Research Method

This study employed a quantitative research design to examine the factors influencing user satisfaction and loyalty toward educational-based augmented reality (AR) applications among young adults in Malaysia. The research utilized a cross-sectional survey approach to collect data from target users aged between 18 and 34 years, who had prior experience using AR apps in educational settings.

The proposed conceptual framework integrated constructs from the Unified Theory of Acceptance and Use of Technology 3 (UTAUT3), the Information Systems Success Model (ISSM), and the Expectation-Confirmation Theory (ECT). The UTAUT3 variables included performance expectancy (PE), effort expectancy (EE), hedonic motivation (HM), habit (HB), facilitating conditions (FC), price value (PV), and personal innovativeness (PI). The ISSM constructs consisted of system quality, information quality, and service quality. Satisfaction served as the mediating variable, loyalty as the dependent variable, and sustainable consumption practices (SCP) as the moderating variable between satisfaction and loyalty.

Sampling and Data Collection

The sampling frame comprised Malaysian young adults aged 18–34 who had prior experience using augmented reality (AR) applications for educational purposes. A purposive sampling technique was employed to ensure that the selected respondents possessed relevant exposure to and engagement with AR technology. Consistent with the recommendations of Hair et al. (2019), an adequate sample size in partial least squares structural equation modeling (PLS-SEM) should be determined based on statistical power and model complexity, with sample sizes exceeding 200 generally considered sufficient to produce robust and reliable results. Accordingly, this study obtained 384 valid responses, which exceeds the recommended minimum sample size and is therefore deemed adequate for subsequent data analysis.

Data were collected using an online self-administered questionnaire distributed through educational platforms, social media channels, and academic networks. To ensure the suitability of respondents, a screening question was included at the beginning of the survey to confirm that participants had prior experience using AR applications for educational or learning-related purposes.

Instrumentation

The survey instrument consisted of structured items measured on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). All constructs were adapted from validated scales in prior literature, with minor contextual modifications to fit the AR education environment. UTAUT3 items were adapted from Venkatesh et al. (2012), ISSM items from DeLone and McLean (2003), satisfaction and loyalty measures from Bhattacharjee (2001) and Oliver (1999), and SCP items from Papista et al. (2018). A pre-test and expert review ensured content validity, followed by a pilot study involving 30 respondents to verify internal consistency and reliability.

Data Analysis

Data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) via SmartPLS 4.0. The analysis consisted of two stages: (1) measurement model assessment to evaluate construct reliability, convergent validity, and discriminant validity, and (2) structural model assessment to examine path relationships and test hypotheses. Mediation and moderation analyses were also performed to examine the indirect effects of satisfaction and the interaction effect of SCP, respectively.

Results and Findings

Hair et al. (2011) suggested confirming if the data were normal. The data generated by the SPSS provides information on the continuous variables (kurtosis and skewness) in the score distribution. The distribution of "peakedness" is explained by kurtosis, while the skewness value explains the symmetry of the distribution (Pallant, 2020). When the values for skewness and kurtosis are both zero, the data is said to be regularly distributed (0). Skewness and kurtosis measurements were employed in this investigation to ascertain the normality of the data distribution. According to Hair et al. (2011), data is considered regularly distributed if the values of kurtosis and skewness fall between -7 and +7. Table 1 summarises the variables based on kurtosis and skewness values and presents the items of the present study between the values of between +2.00 and -2.00 for skewness and -7 to 7 for kurtosis. Consequently, the data in the present study was normally distributed.

Table 1: Normality Test

Item	Skewness		Kurtosis	
	Statistic	Std. Error	Statistic	Std. Error
SQ1	-0.326	0.125	-0.750	0.250
SQ2	-0.572	0.125	0.126	0.250
SQ3	-0.568	0.125	0.271	0.250
SQ4	-0.580	0.125	-0.427	0.250
CQ1	-0.481	0.125	-0.277	0.250
CQ2	-0.565	0.125	-0.057	0.250
CQ3	-0.613	0.125	0.190	0.250
CQ4	-0.543	0.125	-0.129	0.250
SYQ1	-0.388	0.125	-0.608	0.250
SYQ2	-0.608	0.125	0.279	0.250
SYQ3	-0.967	0.125	1.215	0.250
SYQ4	-0.761	0.125	0.710	0.250
SI1	-1.422	0.125	3.320	0.250
SI2	-0.543	0.125	-0.477	0.250
SI3	-0.555	0.125	-0.606	0.250
FC1	-0.531	0.125	-0.350	0.250
FC2	-0.858	0.125	0.837	0.250
FC3	-0.618	0.125	0.059	0.250
FC4	-0.766	0.125	0.087	0.250
HM1	-0.623	0.125	0.101	0.250
HM2	-0.778	0.125	0.491	0.250

HM3	-0.984	0.125	1.113	0.250
HB1	-0.359	0.125	-0.258	0.250
HB2	-0.233	0.125	-0.562	0.250
HB3	-0.521	0.125	-0.097	0.250
PV1	0.039	0.125	-0.671	0.250
PV2	-0.236	0.125	-0.590	0.250
PV3	-0.288	0.125	-0.672	0.250
PI1	-0.565	0.125	-0.309	0.250
PI2	-0.596	0.125	-0.114	0.250
PS1	-0.885	0.125	1.357	0.250
PS2	-0.947	0.125	1.603	0.250
PS3	-0.675	0.125	0.498	0.250
PS4	-0.619	0.125	-0.205	0.250
PS5	-0.555	0.125	-0.530	0.250
PI3	-0.456	0.125	-0.535	0.250
L1	-0.166	0.125	-0.632	0.250
L2	-0.400	0.125	-0.167	0.250
L3	-0.288	0.125	-0.579	0.250
L4	-0.311	0.125	-0.741	0.250

Outliers

Following the completion of the multiple regression process in SPSS, the normality test is followed by a look into of the Mahalanobis distances to identify any outliers. To identify the outliers, the crucial chi-square value is calculated using the number of independent variables as a symbol for the degrees of freedom (df) (Tabachnick & Fidell, 2013). Based on an alpha level of 0.01 and two independent variables (df = 10), the critical value table 2 yielded a value of 23.21.

Table 2: Outliers

Degrees of Freedom	Percentage Points of the Chi-Square Distribution								
	Probability of a larger value of χ^2								
	0.99	0.95	0.90	0.75	0.50	0.25	0.10	0.05	0.01
1	0.000	0.004	0.016	0.102	0.455	1.32	2.71	3.84	6.63
2	0.020	0.103	0.211	0.575	1.386	2.77	4.61	5.99	9.21
3	0.115	0.352	0.584	1.212	2.366	4.11	6.25	7.81	11.34
4	0.297	0.711	1.064	1.923	3.357	5.39	7.78	9.49	13.28
5	0.554	1.145	1.610	2.675	4.351	6.63	9.24	11.07	15.09
6	0.872	1.635	2.204	3.455	5.348	7.84	10.64	12.59	16.81
7	1.239	2.167	2.833	4.255	6.346	9.04	12.02	14.07	18.48
8	1.647	2.733	3.490	5.071	7.344	10.22	13.36	15.51	20.09
9	2.088	3.325	4.168	5.899	8.343	11.39	14.68	16.92	21.67
10	2.558	3.940	4.865	6.737	9.342	12.55	15.99	18.31	23.21
11	3.053	4.575	5.578	7.584	10.341	13.70	17.28	19.68	24.72
12	3.571	5.226	6.304	8.438	11.340	14.85	18.55	21.03	26.22
13	4.107	5.892	7.042	9.299	12.340	15.98	19.81	22.36	27.69
14	4.660	6.571	7.790	10.165	13.339	17.12	21.06	23.68	29.14
15	5.229	7.261	8.547	11.037	14.339	18.25	22.31	25.00	30.58
16	5.812	7.962	9.312	11.912	15.338	19.37	23.54	26.30	32.00
17	6.408	8.672	10.085	12.792	16.338	20.49	24.77	27.59	33.41
18	7.015	9.390	10.865	13.675	17.338	21.60	25.99	28.87	34.80
19	7.633	10.117	11.651	14.562	18.338	22.72	27.20	30.14	36.19
20	8.260	10.851	12.443	15.452	19.337	23.83	28.41	31.41	37.57
22	9.542	12.338	14.041	17.240	21.337	26.04	30.81	33.92	40.29
24	10.856	13.848	15.659	19.037	23.337	28.24	33.20	36.42	42.98
26	12.198	15.379	17.292	20.843	25.336	30.43	35.56	38.89	45.64
28	13.565	16.928	18.939	22.657	27.336	32.62	37.92	41.34	48.28
30	14.953	18.493	20.599	24.478	29.336	34.80	40.26	43.77	50.89
40	22.164	26.509	29.051	33.660	39.335	45.62	51.80	55.76	63.69
50	27.707	34.764	37.689	42.942	49.335	56.33	63.17	67.50	76.15
60	37.485	43.188	46.459	52.294	59.335	66.98	74.40	79.08	88.38

15 cases were found in the analysis where the Mahalanobis distance was greater than 23.21. The researcher took into account the Cook's distance value before opting to eliminate the 15 cases in order to ascertain whether those occurrences had an unwarranted influence on the outcomes (Pallant, 2011). Cook's distance values greater than one are classified as probability problems (Tabachnick & Fidell, 2013). Table 4.3 value of Cook's distance showed that the value was 0.038, which less than 1. Since there were no serious problems, the 15 cases were retained (Pallant, 2011).

Table 3: Cook's distance value

	Min	Max	Mean	Std. Deviation	N
Cook's distance value	0.000	0.038	0.003	0.006	380

Multicollinearity

Based on the independent variable, multicollinearity can be detected using the tolerance value and the variance inflation factor (VIF) (Hair et al., 2020). Based on the data produced by the SPSS, Table 4.4 results demonstrate that all two independent variables maintained VIF values of less than 10 and tolerance values more than 0.10. The results did not deviate from the criteria established by Tabachnick and Fidell (2013) and Sekaran and Bougie (2011). Based on the tolerance and VIF values, it was consequently presumed that the multicollinearity assumption was not violated in the current study.

Table 4: Multicollinearity

Variable	Tolerance	VIF
Service Quality	0.235	4.257
Content Quality	0.261	3.826
System Quality	0.222	4.500
Social Influence	0.307	3.259
Facilitating Condition	0.294	3.399
Hedonic Motivation	0.411	2.433
Habit	0.519	1.928
Price Value	0.447	2.238
Personal Innovativeness	0.442	2.261
Perceived Satisfaction	0.324	3.088

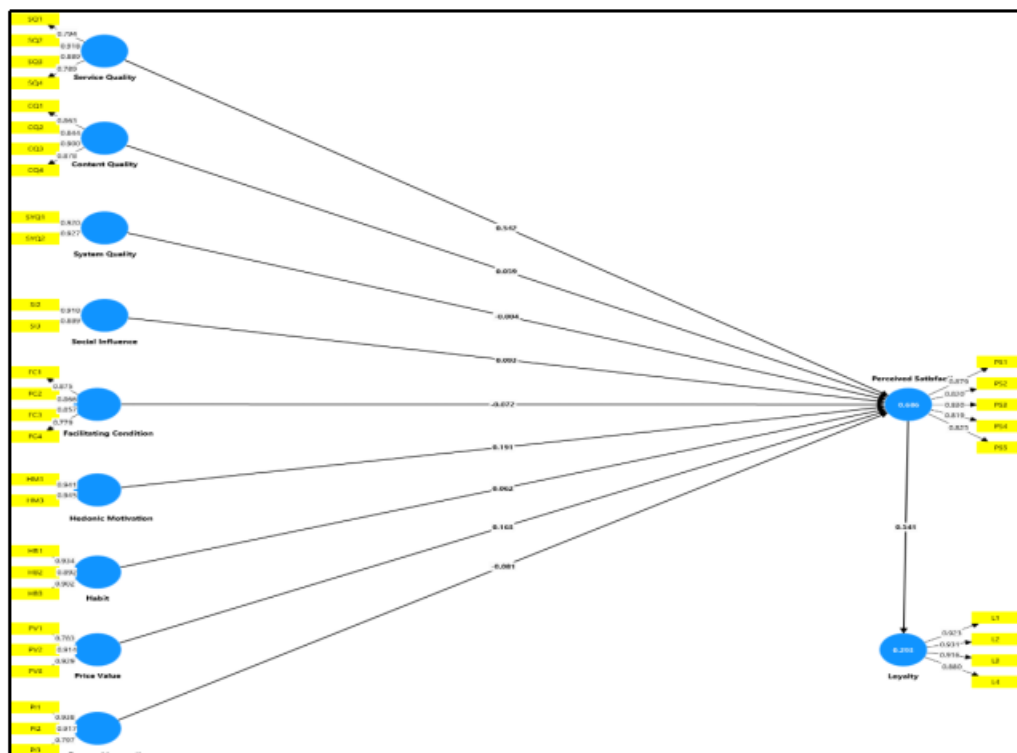
The Assessment of Measurement Model

In the current investigation, 11 underlying constructs were explored. All of these constructs were evaluated through a reflective approach, which assumed that the construct was the cause of the differences in the indicators, such as four items for service quality, content quality, system quality, facilitating conditions and loyalty. While, three items for social influence, hedonic motivation, habit, price value, personal innovativeness and five items for perceived satisfaction. The measurement model evaluated indicator reliability, internal consistency, convergent validity, and discriminant validity.

- i. Indicator Reliability
 - a. Outer Loading
- ii. Internal Consistency
 - a. Composite Reliability
- iii. Convergent Validity
 - a. AVE
- iv. Discriminant Validity
 - a. Fornell-Larckel
 - b. Cross Loading
 - c. HTMT

The measurement model is depicted in Figure 2. In this study, the measurement model comprised predicting service quality, content quality, system quality, social influence, facilitating condition, hedonic motivation, habit, price value and personal innovativeness on perceived satisfaction with educational AR applications. Next, measurement model also comprised predicting perceived satisfaction on loyalty in the context of educational AR applications.

Figure 2 : Measurement model



Indicator Reliability

Outer Loading

Upon verifying the internal consistency reliability of each indicator, the next step is to assess the reliability of the indicator itself. As depicted in Figure 4.1, in the measurement model, the factor loading for each item should be positive and exceed 0.60 (Hair et al., 2016). Four items were removed because to achieve the requirement in this study. The items that were deleted were the variables of system quality, social influence and hedonic motivation (SYQ3, SYQ4, SI1 and HM2).

Table 3: Outer loading

Construct	Items	Outer Loading	Construct	Items	Outer Loading
Service Quality	SQ1	0.794	Habit	HB1	0.934
	SQ2	0.918		HB2	0.892
	SQ3	0.889		HB3	0.902
	SQ4	0.789	Price Value	PV1	0.783
Content Quality	CQ1	0.863		PV2	0.914
	CQ2	0.844		PV3	0.929
	CQ3	0.900	Personal Innovativeness	PI1	0.938
	CQ4	0.878		PI2	0.917
System Quality	SYQ1	0.920		PI3	0.797
	SYQ2	0.927	Perceived Satisfaction	PS1	0.879
Social Influence	SI2	0.918		PS2	0.820
	SI3	0.889		PS3	0.830
Facilitating Condition	FC1	0.875		PS4	0.819
	FC2	0.866		PS5	0.825
	FC3	0.857	Loyalty	L1	0.923
	FC4	0.779		L2	0.931
Hedonic Motivation	HM1	0.941		L3	0.916
	HM3	0.945		L4	0.880

Construct Cross Validated Redundancy (Q²)

The application of the blindfolding technique facilitates the estimation of Stone-Geisser's Q² value, which is employed to assess the predictive relevance of a model (Hair et al., 2017). This resampling methodology involves the systematic omission of data values from an indicator to determine the significance of a measurement model comprising dependent constructs (Hair et al., 2017). The blindfolding technique is efficacious in predicting the significance of a measurement model containing dependent constructs (Hair et al., 2017). The omission distance (D) determines the specific data values that are eliminated, with a higher Q² value indicating superior predictive relevance. The Q² value for all was calculated with

an omission distance of $D = 10$, suggesting that the model possesses adequate predictive relevance since all the construct Q^2 value exceeds zero (Table 4).

Table 4 : Q^2 value

Construct	Q^2
Perceived Satisfaction	0.669
Loyalty	0.410

Goodness of Fit of The Model (GOF)

To evaluate the appropriateness of the PLS-SEM model, the standardized root mean square residual (SRMR) index is calculated (Henseler, 2017; Hair et al., 2017). The SRMR is considered the most recommended metric for this purpose. The specification model goodness-of-fit (SRMR) is a measure that quantifies the discrepancy between empirical and theoretical covariance matrices. A lower SRMR value indicates a higher level of agreement between the model and the data. The criterion for model fit is that if the SRMR value is <0.10 , the model is considered to have good suitability between the model and the data (Ringle et al., 2015). In the current study, the SRMR value was 0.112, indicating that the model demonstrated a not good fit.

Table 5: Model Fit

Standardized Root Mean Square Residual (SRMR)	
Model Fit	0.112

Research Objective 1 and 2: Path Analysis and Research Hypothesis

H1: *System quality positively influences consumer satisfaction with educational AR applications.*

H2: *Content quality positively influences consumer satisfaction with educational AR applications.*

H3: *Service quality positively influences consumer satisfaction with educational AR applications.*

H4: *Social influence positively influences consumer satisfaction with educational AR applications.*

H5: *Facilitating conditions positively influence consumer satisfaction with educational AR applications.*

H6: *Hedonic motivation positively influences consumer satisfaction with educational AR applications.*

H7: *Habit positively influences consumer satisfaction with educational AR applications.*

H8: *Price value positively influences consumer satisfaction with educational AR applications.*

H9: *Personal Innovativeness Positively Influences Consumer Satisfaction with Educational AR Applications.*

H10: *Consumer satisfaction positively influences consumer loyalty toward educational*

To evaluate the significance level of the path coefficients in the structural model with PLS, the bootstrapping technique was used. The bootstrapping procedure in Table 4.17 shows the T values, and P values of the determinant's significance levels. The results indicated that several hypotheses' relationships between the predictors and perceived satisfaction or loyalty in the context of educational AR applications revealed a significance level of 0.05 for p value, 1.64 for t value utilising the bootstrapping results using one tail (Hair et al., 2017; Ramayah et al., 2018).

First, H1 was supported ($\beta = 0.542$, $t = 9.588$, $p < 0.001$), indicating that service quality positively influences perceived satisfaction. H2, which suggested that content quality influences perceived satisfaction was not supported ($\beta = 0.059$, $t = 1.045$, $p = 0.148$), as the p-value greater than 0.05. Similarly, H3 on system quality's influence was also not supported ($\beta = -0.004$, $t = 0.079$, $p = .469$), suggesting no significant influence between them. In contrast, H4, which examined the role of social influence was supported ($\beta = 0.093$, $t = 1.894$, $p = 0.029$), indicating a social influence gave positive influence on perceived satisfaction. While, H5 which examined facilitating conditions was not supported ($\beta = -0.072$, $t = 1.267$, $p = 0.103$), suggesting that facilitating conditions did not significantly influence on perceived satisfaction.

Next, H6 which was predicting a positive influence of hedonic motivation, was supported ($\beta = 0.191$, $t = 4.128$, $p < 0.001$), highlighting the role of hedonic motivation in enhancing satisfaction. H7, which were habit influences perceived satisfaction, was not supported ($\beta = 0.062$, $t = 1.612$, $p = 0.054$), as the p-value was greater than 0.05. H8 on price value was supported ($\beta = 0.163$, $t = 3.909$, $p < 0.001$), showing that price value plays a positive influence role in consumer satisfaction.

H9 not supported ($\beta = -0.081$, $t = 1.873$, $p = 0.031$) since the negative beta coefficient suggests a negative relationship, indicating that personal innovativeness negatively influences consumer satisfaction with educational AR applications, though the p-value still statistically significant. A negative beta coefficient in structural equation modelling indicates a negative relationship between two variables: as one increases, the other decreases (Moradi et al., 2023). Finally, H10 was strongly supported ($\beta = 0.541$, $t = 13.848$, $p < 0.001$) since the p-value less than 0.05. Thus, consumer satisfaction positively influences consumer loyalty toward educational.

Out of the ten hypotheses tested, six were supported (H1, H4, H6, H8, and H10), while four were not supported (H2, H3, H5, H7 and H9). Thus, service quality, hedonic motivation, price value and social influence are significant influence consumers satisfaction in educational AR applications. However, personal innovativeness is statistically significant but give negative influence towards consumer satisfaction with educational AR applications. While, perceived satisfaction in educational AR applications significant enhance loyalty consumers. In contrast, content quality, system quality, facilitating conditions, and habit were not found to have a significant impact in this model.

Table 6: Hypotheses testing results.

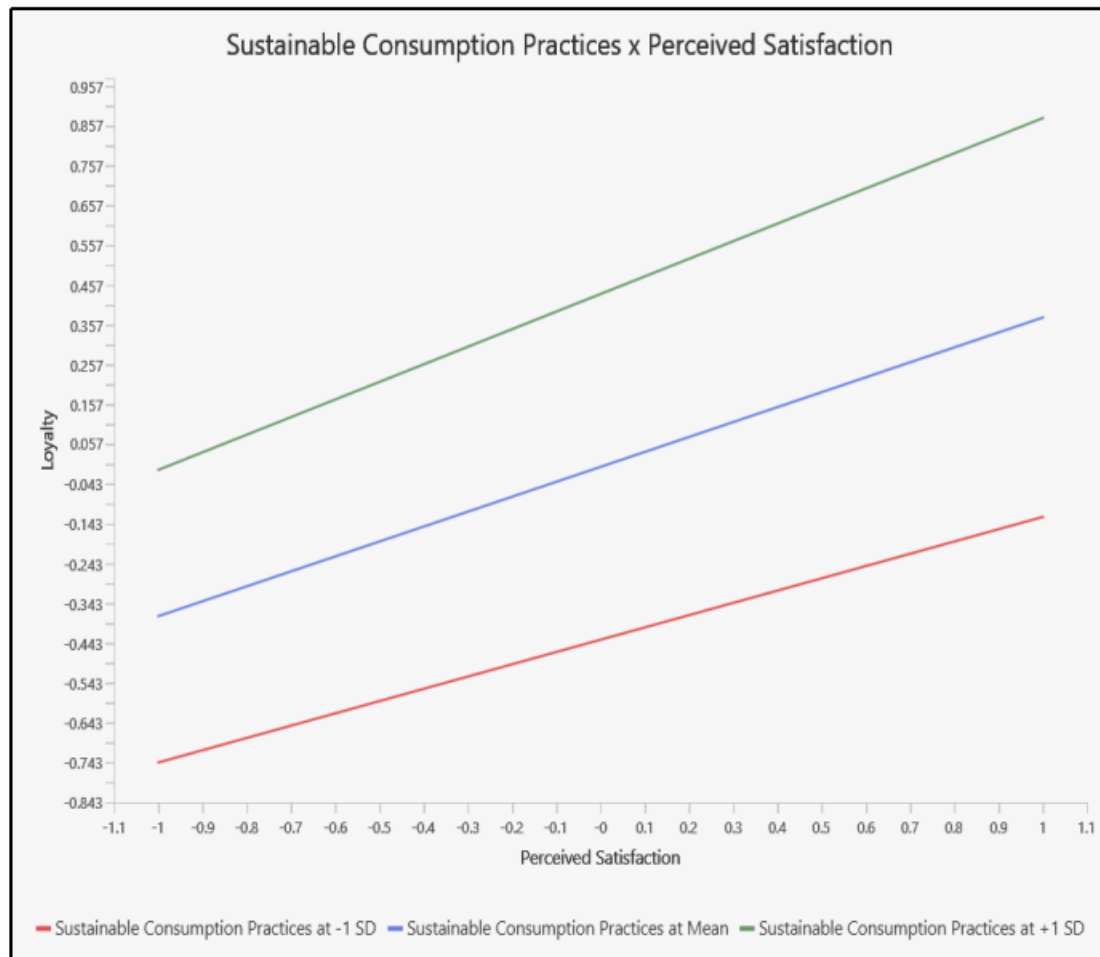
	Hypotheses	Beta	Standard deviation	T statistics	P values	Result
H1	Service Quality → Perceived Satisfaction	0.542	0.057	9.588	0.000	Supported
H2	Content Quality → Perceived Satisfaction	0.059	0.056	1.045	0.148	Not Supported
H3	System Quality → Perceived Satisfaction	-0.004	0.048	0.079	0.469	Not Supported
H4	Social Influence → Perceived Satisfaction	0.093	0.049	1.894	0.029	Supported
H5	Facilitating Condition → Perceived Satisfaction	-0.072	0.057	1.267	0.103	Not Supported
H6	Hedonic Motivation → Perceived Satisfaction	0.191	0.046	4.128	0.000	Supported
H7	Habit → Perceived Satisfaction	0.062	0.038	1.612	0.054	Not Supported
H8	Price Value → Perceived Satisfaction	0.163	0.042	3.909	0.000	Supported
H9	Personal Innovativeness → Perceived Satisfaction	-0.081	0.043	1.873	0.031	Not Supported
H10	Perceived Satisfaction → Loyalty	0.541	0.039	13.848	0.000	Supported

Table 7: Result Moderation Analysis

	Hypotheses	Beta	Standard deviation	T statistics	P values	Result
H11	Sustainable Consumption Practices x Perceived Satisfaction → Loyalty	0.067	0.016	4.049	0.000	Supported

Table 7 showed that H11 ($\beta = 0.067$, $t = 4.049$, $p = 0.000$) was supported in this study since the p-value was less than 0.05. It indicates that sustainable consumption practices significantly moderate the relationship between consumer satisfaction and loyalty toward educational AR applications.

Figure 3: Graph of moderation effect of SCP between on the relationships between consumer satisfaction and loyalty



As shown in Figure 3, when SCP is high (+1 SD), the link between satisfaction and loyalty becomes stronger (green line). When SCP is low (-1 SD), the relationship is still positive but weaker (red line). It showed that consumers who practice more sustainable consumption are more likely to remain loyal when they are satisfied on educational AR applications.

Summary of Hypotheses Results

The results of the hypotheses tested in the present study are summed up in Table 8. The results indicated that 6 hypotheses were supported, and 5 hypotheses were not supported.

Table 8: Summary of results of hypotheses

Hypotheses	Result
H1: System quality positively influences consumer satisfaction with educational AR applications.	Supported
H2: Content quality positively influences consumer satisfaction with educational AR applications.	Not Supported
H3: Service quality positively influences consumer satisfaction with educational AR applications.	Not Supported
H4: Social influence positively influences consumer satisfaction with educational AR applications.	Supported
H5: Facilitating conditions positively influence consumer satisfaction with educational AR applications.	Not Supported
H6: Hedonic motivation positively influences consumer satisfaction with educational AR applications.	Supported
H7: Habit positively influences consumer satisfaction with educational AR applications.	Not Supported
H8: Price value positively influences consumer satisfaction with educational AR applications.	Supported
H9: Personal Innovativeness Positively Influences Consumer Satisfaction with Educational AR Applications.	Not Supported
H10: Consumer satisfaction positively influences consumer loyalty toward educational	Supported
H11: Sustainable Consumption Practices (SCP) Moderate the Relationship Between Consumer Satisfaction and Loyalty Toward Educational AR Applications.	Supported

Discussion

This study examined the determinants of user satisfaction and loyalty toward educational augmented reality (AR) applications among young adults by integrating UTAUT3, the Information Systems Success Model (ISSM), Expectation-Confirmation Theory (ECT), and Sustainable Consumption Practices (SCP). The findings provide nuanced insights into how technological, experiential, and value-driven factors shape post-adoption behavior in educational AR contexts.

The results indicate that service quality emerged as the strongest predictor of user satisfaction. This finding underscores the importance of reliable technical support, responsiveness, and system assistance in sustaining positive user experiences with educational AR applications. Consistent with DeLone and McLean (2003) and Petter et al. (2008), high service quality

reduces user frustration and enhances confidence in technology use, particularly in immersive learning environments where technical disruptions can significantly hinder engagement.

Hedonic motivation was also found to significantly influence satisfaction, highlighting the critical role of enjoyment and intrinsic pleasure in AR-based learning. This finding aligns with prior studies suggesting that immersive and enjoyable learning experiences enhance students' emotional responses and satisfaction (Hamari et al., 2016). In the context of AR, interactive visuals and engaging simulations appear to transform learning into a more enjoyable activity, thereby strengthening satisfaction.

Similarly, price value demonstrated a significant positive effect on satisfaction. This suggests that students evaluate educational AR applications based on a perceived balance between the benefits received and the costs incurred, including monetary, time, and cognitive effort. When AR applications are perceived as cost-effective and beneficial to learning outcomes, satisfaction levels increase, supporting previous findings in digital learning and technology adoption research (Zhou et al., 2020).

Social influence was another significant predictor of satisfaction, indicating that encouragement from peers, lecturers, or academic institutions plays an important role in shaping students' perceptions of AR applications. This result supports the UTAUT3 framework and suggests that social endorsement contributes to confidence and reassurance in adopting new educational technologies (Venkatesh et al., 2012).

In contrast, content quality, system quality, facilitating conditions, habit, and personal innovativeness did not show significant positive effects on satisfaction in this study. The non-significant effect of content quality and system quality may be attributed to students' baseline expectations; as technologically proficient users, young adults may perceive high-quality content and stable systems as minimum requirements rather than satisfaction-enhancing features. When these expectations are met but not exceeded, their impact on satisfaction becomes less salient.

Similarly, the non-significant influence of facilitating conditions suggests that access to devices, internet connectivity, and technical infrastructure may already be sufficiently established in higher education contexts, reducing their explanatory power. The lack of a significant relationship between habit and satisfaction implies that repeated use alone does not guarantee positive emotional evaluation unless accompanied by meaningful and engaging experiences.

Interestingly, personal innovativeness showed a negative relationship with satisfaction, despite being statistically significant. This suggests that highly innovative users may possess higher expectations toward AR applications. When these expectations are not fully met, dissatisfaction may arise, resulting in a negative evaluation. This finding echoes prior research indicating that early adopters and highly innovative users tend to be more critical of technological limitations (Yi et al., 2006).

Consistent with Expectation-Confirmation Theory, user satisfaction strongly predicted loyalty, confirming that students who are satisfied with their AR learning experience are more likely to continue using the application. Loyalty in this study reflects behavioral intention to continue use, rather than attitudinal or word-of-mouth dimensions, aligning with the operationalization of loyalty in the measurement model.

Importantly, the moderation analysis revealed that Sustainable Consumption Practices (SCP) significantly strengthened the relationship between satisfaction and loyalty. This finding indicates that students who value ethical, responsible, and environmentally conscious digital practices are more likely to translate satisfaction into continued usage. The result highlights the growing relevance of sustainability values in shaping digital learning behavior and supports prior literature linking sustainability consciousness to long-term user commitment (White et al., 2019).

Overall, these findings suggest that satisfaction and loyalty toward educational AR applications are not driven solely by technical performance but by a combination of service support, enjoyment, perceived value, social endorsement, and sustainability-oriented values.

In addition to the supported hypotheses, several constructs were found to have no significant positive effect on user satisfaction, offering important insights for both theory and practice. The non-significant relationship between content quality and satisfaction suggests that rich or accurate content alone is insufficient to enhance satisfaction among young adult users. From a marketing perspective, this implies that content quality may function as a basic expectation or hygiene factor, rather than a differentiating attribute. Educational AR providers should therefore avoid overemphasizing content richness in promotional messages and instead focus on how content is delivered through engaging and value-adding experiences.

Similarly, the absence of a significant effect of system quality indicates that technical stability, usability, and system performance are perceived as minimum standards by technologically proficient users. While system reliability remains essential, it no longer serves as a compelling marketing proposition. This finding suggests that system quality should be communicated as a supporting feature rather than a core value proposition in marketing strategies for educational AR applications.

The non-significant influence of facilitating conditions further reinforces this argument. Access to devices, internet connectivity, and institutional support are increasingly normalized within higher education environments. As such, highlighting infrastructure readiness may have limited impact on satisfaction or continued usage. For practitioners, this suggests that marketing efforts should move beyond operational readiness and instead emphasize experiential and emotional benefits.

The lack of a significant relationship between habit and satisfaction indicates that repeated usage does not automatically translate into positive user evaluation. From a marketing standpoint, this finding implies that retention strategies based solely on frequency of use may be ineffective unless they are accompanied by meaningful engagement, enjoyment, and perceived value.

Interestingly, personal innovativeness demonstrated a negative relationship with satisfaction. This suggests that highly innovative users may hold elevated expectations toward educational AR applications and become more critical when these expectations are not fully met. For marketers and developers, this highlights a potential risk in targeting highly innovative users without continuously enhancing features and experiences. Positioning strategies should therefore balance innovation messaging with realistic value delivery to avoid expectation-performance gaps.

Overall, the rejected hypotheses provide valuable managerial insights, indicating that satisfaction and loyalty toward educational AR applications are driven less by technical adequacy and more by experiential, social, and value-based factors.

Implication

This study provides several important theoretical contributions to the understanding of Augmented Reality (AR) application adoption and post-adoption behavior in higher education.

First, by integrating the Unified Theory of Acceptance and Use of Technology 3 (UTAUT3) (Venkatesh et al., 2012), the Information Systems Success Model (ISSM) (DeLone & McLean, 2003), and the concept of Sustainable Consumption Practices (SCP) (Peattie & Peattie, 2009), this research offers a more comprehensive theoretical framework for explaining user experiences in AR-based educational environments. Previous studies have often relied on a single theoretical perspective, either focusing on technology adoption or system quality dimensions, without connecting these perspectives to sustainability considerations (Dwivedi et al., 2020). This integrated approach enriches the literature by bridging technology acceptance, information system quality, and sustainable digital engagement.

Second, the findings that UTAUT3 and ISSM constructs significantly influence satisfaction, which in turn drives loyalty, extend the theoretical understanding of how both adoption-related and system-related factors shape post-adoption behavior. In educational AR contexts, satisfaction is not only determined by performance expectancy and effort expectancy but also by system-related attributes such as content quality, system reliability, and service support (Petter et al., 2008; Al-Emran et al., 2018). This highlights the need for multidimensional models that capture both technological and experiential determinants of satisfaction.

Third, by introducing SCP as a moderating variable, this study expands the theoretical discourse on sustainability in digital environments. The results indicate that user loyalty is not solely a function of satisfaction but is also shaped by broader values, such as environmental consciousness, ethical awareness, and responsible technology usage (White et al., 2019; Kumar et al., 2021). This theoretical advancement emphasizes that loyalty in digital learning environments should be examined not only through individual gratifications but also through users' alignment with sustainability values.

Fourth, this study contributes to the loyalty literature by reinforcing the notion that loyalty encompasses both behavioral and attitudinal dimensions (Dick & Basu, 1994; Oliver, 1999). In the case of educational AR, behavioral loyalty is reflected in continued use and repeated engagement with the application, while attitudinal loyalty manifests in users' willingness to recommend the application and support its long-term development. The integration of sustainability considerations further suggests that attitudinal loyalty may evolve into a value-driven commitment, where users remain engaged with applications that align with their ethical and environmental priorities.

Finally, from a methodological standpoint, the application of Partial Least Squares Structural Equation Modeling (PLS-SEM) demonstrates the suitability of advanced quantitative techniques for testing complex models with multiple constructs and moderating effects (Hair et al., 2019). This methodological contribution provides guidance for future researchers investigating multidimensional frameworks in emerging educational technologies.

Collectively, these implications reinforce the idea that adoption and loyalty toward educational AR applications cannot be fully understood through traditional acceptance theories alone. Instead, they require a more holistic framework that accounts for technological, experiential, and sustainability dimensions, thereby enriching both technology adoption and sustainability literature.

Conclusion

Although this study advances the understanding of user satisfaction and loyalty toward educational AR applications, several opportunities remain for future research.

First, this study focused on young adults in higher education (aged 18–34). While this demographic represents a significant user base for AR applications, future research could broaden the scope to include other age groups, such as secondary school learners, mature students, or professional learners in lifelong education programs. This would allow for comparative analysis of how generational differences influence satisfaction, loyalty, and sustainable digital practices (Prensky, 2001; Bennett et al., 2008).

Second, this study employed a cross-sectional survey design. Future research should adopt longitudinal approaches to better capture the evolution of satisfaction and loyalty over time. Such designs would provide deeper insights into how initial adoption behaviors transition into long-term commitment and whether sustainability values become more salient as users gain experience with AR technologies (Oliver, 1999; Bhattacharjee, 2001).

Third, while this study integrated UTAUT3, ISSM, and SCP, future research could incorporate additional theoretical perspectives. For example, Self-Determination Theory (SDT) may provide insights into intrinsic motivation in AR learning (Deci & Ryan, 2000), while Flow Theory could explain immersive engagement in AR environments (Csikszentmihalyi, 1990). Combining such perspectives could yield richer explanations of user behavior in digital learning contexts.

Fourth, this study examined AR applications primarily from a student-user perspective. Future research should also investigate the role of educators and institutional stakeholders, as their attitudes, readiness, and digital competencies may significantly affect both adoption and long-term use of AR applications (Kirkwood & Price, 2014). Including multiple stakeholder perspectives would enhance the comprehensiveness of future models.

Fifth, while the study demonstrated the moderating role of Sustainable Consumption Practices, additional cultural and contextual factors could be examined. For instance, future research may explore how cultural values, national policies, or institutional strategies around

sustainability influence the relationship between satisfaction and loyalty (Hofstede, 2001; Kumar et al., 2021). Comparative studies across different countries or educational systems would provide valuable cross-cultural insights.

Finally, methodological advancements could strengthen future investigations. The use of mixed-methods research, combining quantitative techniques such as PLS-SEM with qualitative approaches like interviews or focus groups, may uncover nuanced user perceptions that surveys alone cannot capture. Additionally, incorporating experimental designs to test different AR features (e.g., gamification, personalization, eco-friendly design) would provide practical evidence for developers and educators.

In summary, future research should expand the scope of demographics, adopt longitudinal and multi-stakeholder designs, integrate additional theoretical frameworks, and consider cross-cultural and methodological innovations. Such directions will deepen the scholarly understanding of educational AR applications and support the development of more effective, sustainable, and user-centered digital learning environments.

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