Applied Information System and Management (AISM)
Volume 8, (1) 2025, p. 159–168
P-ISSN: 2621-2536; E-ISSN: 2621-2544; DOI: 10.15408/aism.v8i1.45738

Evaluation of E-Learning Usability Based on ISO 25010 with Hofstede's Cultural Dimensions as Moderation: A PLS-SEM Study in Higher Education

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***Abstract*—Although e-learning has rapidly advanced in higher education, many platforms still fall short of meeting user needs due to a lack of integration between usability and cultural dimensions. This study explores how usability influences user satisfaction with e-learning platforms, with cultural dimensions based on Hofstede's model examined as moderating variables. Usability Quality (QiU) is assessed using the ISO/IEC 25010 framework, which includes five key elements: effectiveness, efficiency, user satisfaction, risk avoidance, and contextual relevance. A total of 384 students from private universities in Bali participated in the study, representing a diverse range of academic disciplines. Using SmartPLS and Partial Least Squares Structural Equation Modeling (PLS-SEM), the analysis revealed that usability has a significant effect on user satisfaction (T=7.528, β=0.270), and cultural variables also play a substantial role (T=21.094, β=0.704). Although the moderating effect of culture was statistically significant (T=2.379, β=0.042), its impact was relatively modest compared to the direct effect of usability. Among the usability components, efficiency emerged as the most influential factor. Regarding cultural dimensions, individualism versus collectivism was found to have the strongest effect. These findings emphasize the importance of designing e-learning systems that are both usability-driven and culturally sensitive, ensuring alignment with user expectations and the educational context.**

***Index Terms* —E-learning, usability (QiU) ISO/IEC 25010, user satisfaction, hofstede's culture, PLS-SEM.**

Received: 8 April 2025; Revised: 25 May 2025; Accepted: 31 May 2025.
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I. INTRODUCTION

In today's digital age, e-learning has become a fundamental element of higher education, providing a level of flexibility that traditional classroom settings often lack. However, the effectiveness of online learning is not solely determined by the availability of technology, but also by how user-friendly it is and how well it adapts to cultural contexts [1], [2], [3]. Usability factors such as simplicity of use, operational efficiency, and user satisfaction are crucial to the success of e-learning systems, highlighting the need to develop models that can identify the key drivers of student satisfaction [4], [5]. Perceived ease of use and perceived usefulness have been shown to significantly influence users' attitudes toward adopting a system [6]. A low level of usability negatively impacts users' perceptions of comfort and ease of adapting to the system [7].

Prior studies have emphasized that usability plays a crucial role in enhancing student engagement and learning effectiveness; however, there remains a gap in evaluating e-learning usability across diverse cultural settings [8], [9]. Moreover, with increasing demands for personalized content and varying user expectations, e-learning systems require deeper usability assessments that align with users' cultural preferences and interaction patterns [10].

While usability in e-learning has been widely studied, most previous research has focused either on technical quality as defined by ISO/IEC 25010 or on cultural influence through Hofstede's framework. Very few have attempted to integrate both in a unified evaluation model. As a result, the usability and cultural dimensions are often addressed separately, overlooking the potential combined effect they may have on user satisfaction and system effectiveness [8], [9], [11]. To date, there is still no comprehensive evaluation model that combines the ISO/IEC 25010 quality-in-use standard with cultural dimensions in assessing e-learning systems. Additionally, although ISO/IEC 25010 provides robust metrics for assessing software usability, its relevance to cross-cultural user experience has not been thoroughly explored in the literature [8], [12]. This gap highlights the need for a more holistic approach that bridges usability evaluation with cultural sensitivity especially in multicultural contexts such as Indonesia, and more specifically, Bali.

To evaluate e-learning usability, The ISO/IEC 25010 standard plays a crucial role in evaluating software quality assessment is particularly important, as it enables developers to measure and improve software quality [12], [13], [14]. The ISO/IEC 25010 framework categorizes software quality evaluation into two core models: Product Quality and Quality in Use. The Product Quality model evaluates technical components including functionality, performance, compatibility, user-friendliness, reliability, security, maintainability, and transferability throughout the development phase. In contrast The Quality in Use model emphasizes the experience of end-users, targeting user-centric metrics like effectiveness, efficiency, satisfaction, risk mitigation, and contextual coverage. This approach enables a comprehensive evaluation from both technical and user perception perspectives [8].

This research systematically employs the Quality-in-Use (QiU) framework outlined in ISO/IEC 25010, which assesses software usability through five essential dimensions: effectiveness, efficiency, user satisfaction, risk mitigation, and contextual relevance [8], [15]. Unlike traditional usability models that focus primarily on technical functionality, the QiU model emphasizes user experience and real-world system interaction. By applying the QiU model, e-learning developers can systematically measure and enhance the quality of learning platforms to better align with user expectations [12].

User interfaces tailored to match the cultural preferences of specific regions, particularly when guided by Hofstede's framework in the Arab context, have demonstrated a strong positive impact on usability and user experience [11]. Furthermore, Hofstede's cultural dimensions have demonstrated significant direct, moderating, and mediating effects within technology acceptance models (TAM) [16]. TAM has been widely applied in studies on e-learning and academic technology adoption, serving as a foundational approach for measuring user satisfaction. Enhancements to the Technology Acceptance Model (TAM) are designed to gain deeper insight into how students' ability to self-regulate and their enthusiasm for technology impact their willingness to adopt e-learning platforms [17].

In integrated frameworks, user satisfaction (SF) functions as a core mediator that connects perceived usefulness (PU) and perceived ease of use (PEOU) with behavioral intention to use (BIU). The adaptability of the Technology Acceptance Model (TAM) enables the incorporation of relevant external factors, enhancing its utility as a comprehensive approach to assessing user satisfaction in e-learning environments [18].

This research places a particular emphasis on assessing usability through a cultural perspective by applying the Quality in Use (QiU) framework as defined in ISO/IEC 25010. The QiU framework outlines five fundamental dimensions effectiveness, efficiency, user satisfaction, risk mitigation, and contextual appropriateness all of which prioritize the user's experience and interaction. The assessment is conducted within the context of e-learning implementation in private universities in Bali, where cultural traits necessitate a user-focused and culturally responsive evaluation approach.

Drawing on Hofstede's cultural dimensions, this study investigates the moderating effects of Power Distance, Individualism–Collectivism, Uncertainty Avoidance, and Long-Term Orientation on the relationship between usability and user satisfaction. In addition, the local cultural concept of Tri Hita Karana is considered as a supporting context, although the cultural analysis in this study is limited to Hofstede's framework and does not explore other cultural models. This approach aims to identify which cultural dimensions most significantly influence user satisfaction in e-learning adoption.

This study is grounded in a blend of key conceptual models, including usability as defined by the ISO/IEC 25010 QiU standard, user satisfaction from the TAM, and Hofstede's cultural dimensions. Collectively, these frameworks support the study's core aim: identifying the factors that affect user satisfaction and the continued adoption of e-learning systems within higher education contexts.

Therefore, this study has three primary objectives. First, it aims to examine the influence of e-learning system usability on user satisfaction and cultural factors in evaluating the e-learning environment, using the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach. Second, it seeks to explore how cultural dimensions act as moderating variables either strengthening or weakening the relationship between usability and satisfaction. Third, the study investigates which specific usability elements have the most significant impact on user satisfaction by analyzing the effects of each usability metric, and identifies which of Hofstede's cultural dimensions meaningfully shape users' perceptions across various academic disciplines.

This study applies a survey-based approach to evaluate user perceptions of system usability without deeply analyzing users' interaction behavior within the e-learning platform. It does not focus on pedagogical effectiveness or instructional strategies, but rather emphasizes user interface (UI/UX) design and user-system interaction in digital learning environments. To achieve these goals, this research applies PLS-SEM as the primary analytical technique, supported by SmartPLS software. PLS-SEM is a variance-based statistical approach suitable for exploratory research, especially in models with multiple constructs and indicators, small sample sizes, or non-normally distributed data [19]. In digital education research, the PLS-SEM method has been employed to analyze learner satisfaction in Moodle-based environments and to investigate the effects of digital learning infrastructures on institutional performance through the IS-Impact framework [20].

SmartPLS is utilized to test the relationships between variables such as system quality, service, and learning content on student satisfaction in e-learning. The analysis follows two major stages: measurement model evaluation (outer model) to

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assess construct validity and reliability, and structural model evaluation (inner model) to examine variable relationships, cultural moderation effects, and the significance of cultural dimensions in user satisfaction with e-learning. This approach offers flexibility and precision in identifying which usability indicators most significantly affect satisfaction in online learning environments.

The main contribution of this study lies in presenting an evaluative approach that integrates international usability standards with cultural frameworks. This integration offers practical guidance for developers aiming to design e-learning platforms that are not only inclusive and effective but also culturally relevant and contextually appropriate for local users.

II. Related Work

This research is based on the recognition that the effectiveness of e-learning software is influenced not just by its technical functionality, but also by how well it aligns with the cultural background of its users. The following literature review outlines the theories, methodologies, and key findings from previous studies that support this research particularly those related to cultural integration and the application of the model emphasizes real-world system usability and user experience standards from ISO and IEC (25010 series) in e-learning systems. Previous studies on culture-based e-learning have covered several key aspects, including culturally-driven design and usability, culturally-based online learning evaluation, technology adoption and acceptance in cultural contexts, engagement, inclusivity, and interculturalism, as well as global studies and cultural theories in e-learning, as shown in the taxonomy analysis of prior research in Table 1.

Table 1.
Taxonomy: The Influence of Culture on E-Learning Systems and User Experience

Category	Focus	Citation
Culture-Based Design & Usability	Culturally Aligned UI/UX Preferences and Online Learning Design	[11], [21], [22], [23]
Culturally-Based Online Learning Evaluation	Measurement of UX, effectiveness, and culturally inclusive instructional design.	[24], [25], [26]
Technology Adoption & Acceptance in Cultural Contexts	Cultural factors influencing technology acceptance	[27], [28], [29]
Engagement, Inclusivity & Interculturalism	Cultural sensitivity's effect on user engagement	[30], [31]
Global Studies & Cultural Theories in E-Learning	Global trends, theoretical frameworks, and cross-cultural learning behavior	[32], [33]

Based on Table 1, cultural taxonomy in e-learning indicates that cultural context significantly shapes system design, assessment methods, and user experiences. Numerous prior studies have highlighted the substantial role that culture plays in shaping the design and implementation of online learning systems. Many of these works emphasize that local cultural values significantly influence how user interfaces, system features, and instructional methods are structured to ensure relevance and comfort for users. When e-learning platforms are designed in alignment with the cultural norms and values of their users, the results often include improved satisfaction, usability, and even learning effectiveness [11], [21], [22], [23].

Several researchers have also attempted to evaluate user experiences in e-learning environments using tools that take cultural factors into account such as cross-cultural questionnaires and cultural inclusivity scales [24], [26]. These instruments help reveal how social context shapes individuals' interactions with technology. One study [25], for instance, underscores that the success of a digital system is not determined solely by its technical capabilities, but also by how well it aligns with the values and norms of its user community. Culture has also been shown to influence how people perceive and adopt technology. For example, attitudes toward perceived usefulness and ease of use can vary greatly depending on cultural background [27], [28], [29]. Existing research has further demonstrated that when local cultural elements are considered in the design of e-learning systems, user engagement tends to increase. This effect is especially pronounced in cultural settings with strong social norms or defined gender roleskuat [30], [31]. In global contexts such as Massive Open Online Courses (MOOCs), studies have found that culture influences learning styles, participation patterns, and how users interact with content. These findings [32], [33] reinforce the importance of culturally adaptive learning platforms that are accessible and effective across diverse populations.

1). ISO/IEC 25010 Standard for Evaluating Software Quality

A more advanced standard within the SQuaRE (Systems and Software Quality Requirements and Evaluation) series was developed as a refinement of ISO/IEC 9126. This updated framework presents a detailed structure for assessing software quality through well defined characteristics and sub characteristics. One of its key improvements is the greater focus on quality-in-use dimensions, which are vital for measuring user interaction and experience with software applications [8], [9]. Figure 1 shows the overall structure of ISO/IEC 25010.

Figure 1 presents the framework of the ISO/IEC 25010 standard, which is divided into two principal components: the product quality model and the quality in use model. These two models encompass a set of specific attributes intended to assess different dimensions of software quality. The product quality model evaluates eight key attributes: functional adequacy, performance efficiency, system compatibility, user-friendliness, reliability, security, ease of maintenance, and portability. On the other hand, the quality in use model addresses five user-centered aspects: effectiveness, operational efficiency, user satisfaction, risk mitigation, and contextual adaptability [34].

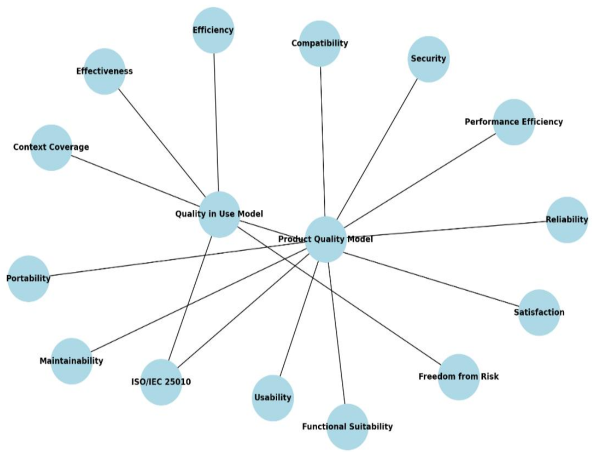

Fig. 1. ISO/IEC 25010 standard architecture [34].

2). How Cultural Factors Shape the Adoption and Utilization of Technology

Cultural factors play a significant role in shaping how individuals accept and interact with technology across various dimensions. User interface (UI) design preferences, for example, are shaped by Hofstede's cultural dimensions, where culturally adapted designs improve user satisfaction and interaction effectiveness [11]. Hofstede emphasized the importance of cultural measurement tools in developing more effective and contextually relevant technologies [35]. Cultural adaptation in e-learning enhances both effectiveness and relevance, with the validation of Hofstede's theoretical framework reinforcing the need to integrate cultural values into instructional design. This ensures that learning systems align more closely with user characteristics and remain effective across various cultural contexts [35].

Previous studies have emphasized the important role of culture in the design and acceptance of e-learning systems, and several have developed culturally informed measurement tools [24], [26]. However, most of these studies have addressed cultural and usability aspects separately, without integrating them into a unified evaluation framework. In addition, many rely on non-standard instruments, making it difficult to compare results across different contexts.

To date, no study has comprehensively integrated the ISO/IEC 25010 standard particularly the "quality in use" dimension with Hofstede's cultural dimensions in evaluating e-learning systems, especially within the context of Indonesia and, more specifically, Bali. This is a critical gap, given that local cultural values such as collectivism and respect for hierarchy strongly influence how users interact with technology [29].

This study seeks to fill that gap by combining the international ISO/IEC 25010 standard with Hofstede's cultural framework into a single, integrated evaluation model. Using the PLS-SEM approach, this research not only assesses the technical usability of e-learning platforms, but also examines how users' cultural backgrounds moderate the relationship between usability and user satisfaction.

The study is focused on the higher education context in Indonesia, with particular emphasis on the cultural characteristics of Bali. This culturally grounded focus contributes to the development of an evaluation model that is both relevant to local users and adaptable to broader multicultural environments. Ultimately, the research aims to provide a more holistic framework for designing inclusive, culturally responsive e-learning systems.

III. Research Method

A quantitative research method was utilized in this investigation to assess e-learning usability from a cultural perspective, drawing upon the Quality in Use (QiU) criteria specified in ISO/IEC 25010. The focus of this study centers on examining how Hofstede's cultural dimensions impact students' interactions with e-learning systems in private universities throughout Bali. Data collection was carried out via an online survey distributed to currently enrolled students who actively engage with e-learning tools. To capture a broad and representative range of participants, a stratified random sampling method was implemented. The responses were processed using statistical analysis to explore correlations between cultural attributes and perceived usability of the platforms. The overall research design and workflow is illustrated in Fig. 2.

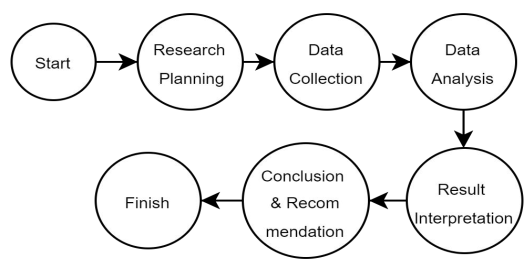

Fig. 2. Flow of the study implementation.

A. Study Planning

The initial phase of this study involved a detailed literature analysis to uncover connections among ISO/IEC 25010, Hofstede's cultural dimensions, and e-learning implementation. Based on the conceptual findings, hypotheses were developed to examine how cultural contexts influence the usability of digital learning systems. A structured questionnaire was designed using a five-point Likert scale, targeting five core usability criteria: effectiveness, efficiency, satisfaction, risk avoidance, and contextual alignment. To ensure balanced representation across disciplines, a stratified random sampling technique was utilized.

B. Data Collection

The questionnaire comprised two main sections: one focused on evaluating e-learning usability based on ISO/IEC 25010, and the other addressed cultural dimensions as proposed by Hofstede, including contrasts between individualism and collectivism, levels of power distance, and uncertainty avoidance. The survey was distributed through university email and WhatsApp following formal approval from institutional authorities, with a response window of 2 to 4 weeks. A pilot test with 30 student participants was conducted to ensure the instrument's validity and reliability prior to the full-scale distribution. The full-scale data collection targeted 384 respondents, based on Cochran's formula for representativeness.

C. Data Handling and Statistical Techniques

The survey results were examined through a combination of descriptive statistical methods, reliability assessment, and Partial Least Squares Structural Equation Modeling (PLS-SEM). The analytical procedure involved the following steps:

- Descriptive Statistics Ensured data completeness and readiness for PLS-SEM analysis.
- Reliability and Validity Testing via Measurement Model (SEM-PLS) Ensured that questionnaire items accurately measured usability and cultural factors.
- Partial Least Squares-based Structural Equation Modeling (PLS-SEM). Tested relationships between cultural dimensions and usability factors to understand how cultural background shapes e-learning experiences.

D. Conclusion and Recommendations

A majority of earlier research has not directly evaluated the usability of e-learning systems based on the ISO 25010 criteria, which include aspects like user effectiveness, operational efficiency, overall satisfaction, risk avoidance, and contextual relevance. These are critical in ensuring optimal e-learning use across diverse cultural backgrounds. Therefore, this study is significant in addressing that gap through an integrated approach: 1) Evaluating e-learning usability using ISO 25010, 2) Investigating how it relates to user satisfaction through TAM, and 3) Positioning Hofstede's cultural indicators as influencing variables in the usability satisfaction dynamic.

This provides a more extensive evaluation of e-learning outcomes and emphasizes the role of culture in user experience, contributing to the development of more adaptive, inclusive, and high-quality e-learning systems. Limitations of this study include: limited to hofstede's culture dimensions (other cultural models were not considered), perception based data (data was collected via user perception surveys which may involve subjective bias), focused only on academic context (results are based on student experiences at private universities in Bali and may not generalize to other sectors), and no real behavioral e-learning data used (the study did not include real-time user interaction data from e-learning systems, relying solely on survey responses).

IV. Result

This research utilizes a stratified random sampling technique, ensuring proportional representation from various academic fields within three leading private universities in Bali. The sample size is determined using Cochran's formula, ensuring that the distribution of respondents accurately represents the proportion of students in each academic discipline, namely Science and Technology (Saintek), Social Sciences and Humanities (Soshum), and Health and Professional Studies.

In total, the study includes 384 respondents, consisting of 40 from Science and Technology, 315 from Social Sciences and Humanities, and 29 from Health and Professional Studies. The stratified random sampling technique ensures balanced representation across all academic disciplines, while cochran's formula determines the optimal sample size. This approach enables the study to produce more valid results in analyzing e-learning usability, user satisfaction, and the influence of cultural factors on digital learning.

A. Descriptive Statistics

Descriptive analysis aims to confirm that the dataset is accurate, free from missing values, and suitable for subsequent processing through PLS-SEM techniques. This was carried out by identifying missing values, evaluating data tendencies through mean and median scores, and measuring answer variability using standard deviation (SD) [19], [36]. The initial step in descriptive analysis focused on understanding respondent characteristics based on the survey results. Using SmartPLS, the analysis included reviewing average values, frequencies, and response distributions for each indicator variable. These results provide a preliminary overview of user perceptions for each construct being studied, prior to conducting validity and reliability testing in the measurement model. Table 2 illustrates the outcomes derived from the descriptive analysis.

Table 2.
Descriptive Statistics Results

Name	Mean	Median	Standard deviation	Scale min	Scale max
U.EF	4.190	4.000	0.762	1.000	5.000
U.EFF	4.206	4.000	0.805	1.000	5.000
U.SAT	4.052	4.000	0.858	1.000	5.000
U.FRR	4.094	4.000	0.821	2.000	5.000
U.CC	4.271	4.000	0.774	2.000	5.000
S.PU	4.013	4.000	0.789	2.000	5.000
S.PEOU	4.174	4.000	0.766	2.000	5.000
S.ATU	3.914	4.000	0.807	2.000	5.000
S.BIU	3.945	4.000	0.829	1.000	5.000
C.PD	3.505	3.000	1.094	1.000	5.000
C.IC	3.911	4.000	0.868	2.000	5.000
C.UA	3.904	4.000	0.862	1.000	5.000
C.LTO	3.891	4.000	0.877	1.000	5.000
C.MF	3.924	4.000	0.920	1.000	5.000

The evaluation results indicated that no missing values were found, allowing the entire dataset to be used in the study. To offer a preliminary insight into how respondents perceived each construct within the PLS-SEM framework, a descriptive analysis was performed. Refer to Table 1 for the summarized results., most indicators had mean values above 4.0 (e.g., U.CC=4.271 and U.EFF=4.206), with a median of 4.000 and standard deviations below 1.0, indicating positive responses and consistent answers. Mean values above 3.0 and standard deviations below 1.0 are generally considered indicators of a well-distributed dataset and positive perceptions [19]. Only C.PD (Power Distance) showed a higher standard deviation (1.094), reflecting greater variation in responses.

This descriptive implication indicates that the majority of respondents hold a positive perception of usability, satisfaction, and cultural dimensions in e-learning, thereby supporting the continuation of the measurement model analysis.

B. Outer Model (Measurement Model)

To examine the associations among the underlying variables in the proposed model, this study employed the PLS-SEM technique. These relationships are illustrated in Fig. 3, this model represents the structural design of the study, illustrating the relationships between three primary constructs: Usability (*X*) as the independent variable, Satisfaction (*Y*) as the outcome variable and incorporates culture as a moderating factor. Its purpose is to examine the extent to which the usability of an e-learning platform influences user satisfaction, while also exploring how cultural elements shape or alter that influence.

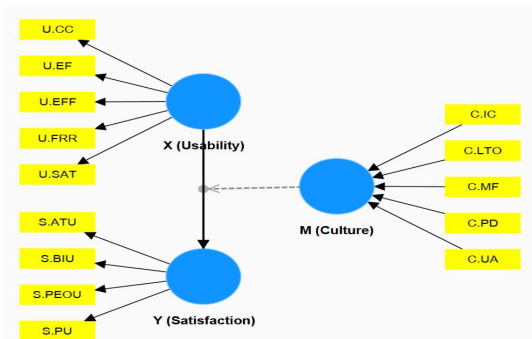

Fig. 3. Path diagram (PLS-SEM structural model).

Based on Fig. 3, which presents the Path Diagram (PLS-SEM Structural Model), both usability (X) and satisfaction variable (Y) is classified as a reflective construct, where its observable indicators are considered outcomes that stem from the latent concept, typically illustrated with directional arrows from the construct toward the indicators. The concept of system usability consists of five primary indicators derived from the ISO/IEC 25010 software quality standard: U.CC (Context Coverage), U.EF (Efficiency), U.EFF (Effectiveness), U.FRR (Freedom from Risk), and U.SAT (Satisfaction). In a reflective model, these indicators are seen as manifestations of the usability construct as a whole, implying that any change in the construct would be reflected across all indicators simultaneously [19]. This construct represents the system's ability to be used effectively and safely across various user contexts [37]. The satisfaction variable (Y) is assessed using four distinct indicators adapted from the Technology Acceptance Model (TAM), namely: user attitude (S.ATU), intention to use (S.BIU), ease of use perception (S.PEOU), and perceived system usefulness (SP.U). This variable illustrates how pleased users are with the system and their likelihood of continuing to engage with it over time [17], [18].

Meanwhile, Culture (M) is constructed as a formative construct, measured using the five cultural dimensions proposed by Hofstede: Individualism vs Collectivism (C.IC), Long-Term Orientation (C.LTO), Masculinity vs Femininity (C.MF), Power Distance (C.PD), and Uncertainty Avoidance (C.UA). In a formative measurement approach, these dimensions collectively form the overall cultural construct; a change in one dimension does not necessarily affect the others, and each indicator uniquely contributes to shaping the cultural construct [19], [36].

In PLS-SEM, the outer model evaluates how effectively the indicators capture the underlying constructs, following the principles of measurement theory [19]. In evaluating the outer model within PLS-SEM, three main steps are performed to ensure measurement quality: construct validity, construct reliability, and factor loading examination.

Construct validity testing ensures that indicators accurately measure their respective constructs. This is evaluated through convergent validity (AVE > 0.50), cross loading, and the Heterotrait-Monotrait Ratio (HTMT < 0.90) [19], [38]. Next, construct reliability is assessed to measure the internal consistency among indicators using Cronbach's Alpha values were ≥ 0.70, while composite reliability (CR) scores > 0.70, and rho_A (≥ 0.70) [19]. Additionally, factor loading checks are performed to ensure that each indicator has a loading value above 0.708, indicating a strong contribution to its respective construct [19]. Once the three conditions are fulfilled, the model can be deemed both valid and reliable, allowing researchers to proceed with inner model (structural model) analysis to examine the connections among latent constructs.

Discriminant validity testing is a critical step in assessment of the measurement model. Discriminant accuracy refers to how clearly a group of indicators identifies its own construct while staying distinct from others within the model [19]. This means that an indicator should correlate more strongly with its designated construct than with other constructs. Based on the cross loading results, most indicators exhibited the highest loading on their intended construct, indicating that discriminant validity was largely met. However, one indicator, S.PEOU, showed a loading of 0.853 on Usability and 0.841 on Satisfaction, which violates the discriminant validity assumption. Therefore, the S.PEOU indicator should be removed, and the outer model should be revised accordingly.

Table 3.
Findings from the Reliability and Validity Assessment

Construct	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
X (Usability)	0.872	0.876	0.907	0.662
Y (Satisfaction)	0.848	0.849	0.908	0.767

Table 3 outlines the outcomes of the construct measurement, revealing that the model under review possesses robust consistency and measurement soundness. The Cronbach's Alpha values for Usability (0.872) and Satisfaction (0.848) are well above the 0.70 benchmark, signifying strong internal coherence [17]. Moreover, composite reliability (ρ_a and ρ_c) values also surpassed the 0.70 threshold, reinforcing the consistency of the constructs. From the perspective of convergent assessment, the Average Variance Extracted (AVE) for Usability (0.662) and Satisfaction (0.767) exceeded the standard cutoff point of 0.50. This implies that each factor explains more variance than what would be attributed to measurement error. Given these findings, the model can be considered dependable and suitable for advancing to the following phase of the evaluation.

The subsequent analysis involves conducting the HTMT (Heterotrait-Monotrait Ratio of Correlations) procedure, which is used to assess the degree of construct distinctiveness within the PLS-SEM (Partial Least Squares Structural Equation Modeling) framework. HTMT value between X (Usability) and Y (Satisfaction) is 0.926, while the HTMT values between the interaction term *M* (Culture) × *X* (Usability) and other constructs remain below 0.90. According to the HTMT criterion, values ≤ 0.85 are preferred for conservative models, and values ≤ 0.90 are acceptable in exploratory research [38]. Furthermore, several studies suggest that in exploratory contexts, HTMT values up to 1.00 may still be acceptable if supported by strong theoretical justification and the absence of multicollinearity or construct overlap [39]. Therefore, the HTMT value of 0.926 between X and Y is considered acceptable, especially since it is supported by multicollinearity testing using VIF (Variance Inflation Factor).

The primary purpose of the VIF test is to ensure that indicators within a construct are not excessively collinear, which could compromise the stability and accuracy of coefficient estimates. VIF scores under 3.3 suggest that multicollinearity is not a concern within the model. Values between 3.3 and 5.0 suggest potential concerns and should be further examined with theoretical justification. VIF values above 5.0 signal high multicollinearity, requiring the removal or combination of indicators [19]. Based on the VIF results generated using SmartPLS, all VIF values fall below 3.3, with the highest value recorded for C.IC (2.750) and the lowest for C.PD (1.387). The VIF value for the interaction term *M* × *X* is 1.000, confirming no multicollinearity issues across the indicators in the outer model. Every item provides a distinct reflection of the construct it is intended to measure. To conclude, the degree of convergence was also evaluated by examining the outer loadings, which indicate the extent to which each item aligns with the concept it is designed to capture. Higher outer loadings reflect stronger convergent validity, with values ≥ 0.70 considered acceptable [19].

Table 4.
Outer Loadings

Indicators and Constructs	Outer Loadings	T values	P values
C.IC→ M (Culture)	0.911	54.221	0.000
C.LTO → M (Culture)	0.851	27.433	0.000
C.MF → M (Culture)	0.777	23.510	0.000
C.PD → M (Culture)	0.583	12.012	0.000
C.UA → M (Culture)	0.819	29.983	0.000
S.ATU ←Y (Satisfaction)	0.861	38.924	0.000
S.BIU ← Y (Satisfaction)	0.886	64.745	0.000
S.PU ← Y (Satisfaction)	0.881	67.810	0.000
U.CC ←X (Usability)	0.799	26.957	0.000
U.EF ← X (Usability)	0.850	44.277	0.000
U.EFF ← X (Usability)	0.812	33.294	0.000
U.FRR ← X (Usability)	0.756	23.690	0.000
U.SAT ← X (Usability)	0.848	51.682	0.000

Based on the outer loadings results in Table 4, all indicators demonstrate a significant contribution to their respective constructs, with loading values ≥ 0.70 and p-values ≤ 0.05, indicating strong convergent validity. Therefore, the model used in this study satisfies the required criteria for PLS-SEM analysis, in line with established methodological standards.

The results of the measurement model (outer model) analysis indicate that all indicators are both valid and reliable, with outer loading values exceeding 0.7, Average Variance Extracted (AVE) values above 0.5, and Composite Reliability scores greater than 0.7. This suggests that constructs such as effectiveness, efficiency, satisfaction, and cultural dimensions can be measured consistently and accurately.

C. Inner Model (Structural Model) Using PLS-SEM

When applying Partial Least Squares Structural Equation Modeling (PLS-SEM), the assessment of the structural or inner model involves multiple procedures. These include analyzing the path coefficients, calculating f-squared (f^2) values to measure effect size, determining R-squared (R^2) values for evaluating the model's predictive accuracy, and using the Standardized Root Mean Square Residual (SRMR) to assess model fit [19]. Path coefficient analysis specifically helps determine how strong and statistically significant the relationships are among latent constructs within the framework. To interpret the results, standard benchmarks such as the path coefficient (β), t-statistic, and p-value are used—where significance is established if the p-value ≤ 0.05 and t-value ≥ 1.96 [19].

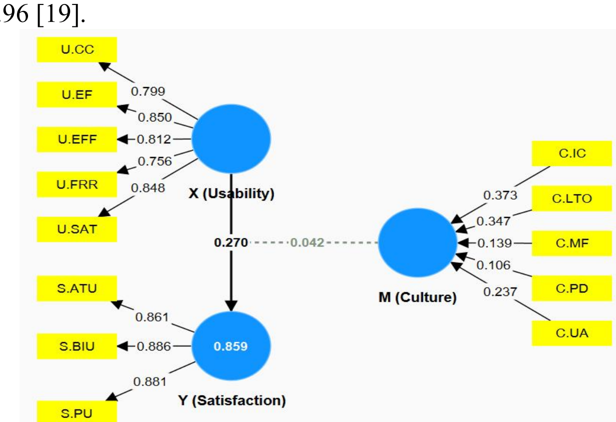

Fig. 4. Structural model (PLS-SEM).

Following the assessment of the structural model shown in Fig. 4, the subsequent phase involves quantitatively examining how strongly the constructs are linked, which is reflected in the values of the path coefficients. Detailed analysis results are presented in Table 5, which contains the path coefficients for each relationship within the model.

Table 5
Analysis of Path Coefficients in the Structural Model

Relationship	Path Coefficient (β)	T-Value	P-Value	Conclusion
Culture → Satisfaction	0.704	21.094	0.000	Significant
Usability → Satisfaction	0.270	7.528	0.000	Significant
Culture x X Usability → Satisfaction	0.042	2.379	0.017	Significant

Path coefficient calculation based on Table 5 shows that the research model exhibits strong predictive power ($R^2 = 0.859$), significant variable relationships (f^2 Usability → Satisfaction = 0.198), and an acceptable model fit (SRMR= 0.052). According to the standards established in [19] the model is appropriate for hypothesis interpretation and further analysis to gain deeper insights into variable relationships.

The results of the structural model (inner model) analysis indicate that usability has a significant positive effect on user satisfaction ($t > 1.96$; $p < 0.05$). Moreover, the cultural moderationparticularly the dimension of Individualism versus Collectivism (C .IC) was found to strengthen this relationship.

D. Research Findings and Discussion

1) Assessing the Importance of Interconnections Among Constructs Within the PLS-SEM Framework.

In the context of Partial Least Squares Structural Equation Modeling (PLS-SEM), the strength of connections between latent constructs is assessed through path coefficients. As shown in Table 5, each relationship among the variables demonstrates statistically meaningful results [20], with T-values meeting or exceeding 1.96 and P-values at or below 0.05. Usability (X) significantly influences user satisfaction (Y) with T = 7.528 and P = 0.000, indicating that higher usability in an e-learning system leads to higher satisfaction. The findings from this analysis align with earlier studies, suggesting that a similar pattern or outcome has been observed in prior investigations quality-in-use approach encompassing usability, effectiveness, and satisfaction can be effectively used to evaluate software quality from the user's perspective [8]. Furthermore, these findings also align with the assertion that cultural factors influence e-learning usability, emphasizing the importance of incorporating cultural elements into e-learning design to create a more positive and user-centered experience [40].

Culture (M) also has a significant impact on satisfaction (Y) with T = 21.094 and P = 0.000, suggesting the importance of cultural factors in determining user satisfaction. The moderating effect of culture (M) on the Usability→Satisfaction relationship is also statistically significant (T = 2.379, P = 0.017), While the path coefficient is relatively low (β = 0.042), this suggests that the influence is less pronounced compared to the direct impact of usability. Thus, while culture contributes to the relationship, its influence is less dominant.

2) Cultural Moderation of the Usability–Satisfaction Relationship.

Table 5 illustrates that cultural factors (M) play a meaningful role in altering the strength of the association between Usability and Satisfaction in the context of e-learning. This is supported by the T-statistic for M (Culture) → Y (Satisfaction) = 21.094 (P = 0.000) and for the interaction term M × X → Y = 2.379 (P = 0.017), both exceeding the threshold of significance ($T > 1.96$, $P < 0.05$) [20]. The findings suggest that various cultural traits namely Power Distance, the spectrum of Individualism and Collectivism, Uncertainty Avoidance, and Long-Term Orientation affect how strongly usability correlates with user satisfaction. Prior studies have also confirmed that Power Distance and Individualism are key cultural elements that shape user preferences for interface design in e-learning platforms, ultimately impacting satisfaction and user engagement [21].

3) The Significant Influence of Usability Factors and Cultural Dimensions on User Satisfaction.

In this study, the usability construct (*X*) comprises several indicators that contribute to user satisfaction (*Y*). To identify the most influential factor, an outer loading analysis was conducted using SmartPLS. As shown in Table 4, efficiency (U.EF) recorded the highest loading score (0.850), followed by satisfaction (U.SAT) at 0.848, effectiveness (U.EFF) at 0.812, context coverage (U.CC) at 0.799, and freedom from risk (U.FRR) at 0.756. These values indicate that efficiency (U.EF) is the most dominant usability factor affecting user satisfaction. A loading value ≥ 0.70 reflects strong convergent validity, suggesting that these indicators reliably represent their corresponding constructs [19].

Based on the results presented in Table 4, the most influential cultural dimension moderating the relationship between usability and user satisfaction is individualism vs. collectivism (C.IC), with the highest loading score of 0.911. This finding aligns with previous research showing that users from collectivist cultures tend to value social engagement in online learning environments, while those from individualist cultures are more concerned with how efficiently and effectively the system performs [27]. This study further emphasizes that the individualism dimension plays the most significant role in shaping user satisfaction with e-learning systems [41]. In addition, these results reinforce earlier findings that cultural differences particularly in terms of individualism and collectivism are key factors influencing how usability affects user satisfaction [19].

V. CONCLUSIONS

Based This study found that the easier and more efficient an e-learning system is to use, the more satisfied users tend to be. Cultural values especially whether someone leans more toward individualism or collectivism also play a role in shaping how users perceive and experience the system. By combining ISO 25010 usability standards with Hofstede's cultural dimensions, this research provides a more complete picture of user satisfaction in digital learning.

However, there are some limitations. The study only used Hofstede's cultural model and didn't explore local cultural values like Tri Hita Karana. The data relied solely on users' perceptions through surveys and didn't include actual system usage data. The research was also limited to students in Bali and conducted at a single point in time, so it doesn't reflect changes over time or in different settings.

Future research could expand this model by including local cultural insights, real user behavior data, and a longer-term approach. For developers and educational institutions, these findings highlight the need to design e-learning systems that are not only user-friendly but also culturally relevant—helping users feel more connected, comfortable, and satisfied with their learning experience.systems.

ACKNOWLEDGMENT

The authors would like to express their gratitude to Universitas Amikom Yogyakarta for the support and facilities provided throughout the course of this research. Special thanks are extended to the respondents, particularly students from private universities in Bali, for their valuable time and participation in the survey. The authors also appreciate the constructive feedback from academic advisors and colleagues, which greatly contributed to the refinement of this paper.

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