Enhanced System Usability Scale using the Software Quality Standard Approach

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ABSTRACT

The objective of this paper is to improve the current System Usability Scale (SUS) and assess its applicability in the context of Learning Management Systems (LMS). The need to evaluate the usability of systems has become increasingly important in today's market, as it can have a significant impact on the user experience. In light of the COVID-19 pandemic, e-learning has become an essential tool for students, making LMS an appropriate research case study. Through a comprehensive literature review, it was discovered that SUS is the most widely used tool for evaluating system usability. However, SUS fails to satisfy some of the usability criteria outlined in ISO 9126 and ISO 9241-11. Therefore, this paper proposes an enhanced SUS model and its conceptual framework to address these limitations. The proposed model was validated using a case study approach, involving subject matter experts and software testing students, who evaluated the reliability of the enhanced SUS. Additionally, the existing and enhanced SUS models were evaluated based on an LMS case study and the results were used to calculate the enhanced SUS's reliability coefficient using Cronbach's alpha. The validation results show that the enhanced SUS has higher reliability with improved quality coverage compared to the original SUS. The proposed model has the potential to enhance the evaluation of system usability and, consequently, improve user experience.

Keywords-System Usability Scale (SAS); usability; software quality

I. INTRODUCTION

Usability refers to the ease of use and user satisfaction with a system [1]. Usability is also defined as an endeavor to quantify friendliness by measuring certain quantifiable end user attributes, such as users' skill, time to learn, productivity from utilizing the system, and appraisal of user's engagement with the entire system [2]. In the context of Learning Management Systems (LMS), usability is crucial for effective teaching and learning. According to [3], improving the usability of LMS

interfaces can enhance student engagement and the learning outcome. Hence, it is very crucial to evaluate the usability quality of a system or software in order to provide a higher level of user satisfaction [22]. It is very important to maintain the quality of the system as it is very difficult to gain the trust of the user who has had a bad experience using a system with bad quality [4]. There are various methods that can be used in order to measure the usability score of a system [23]. One of the methods is to use the Standardized Usability Questionnaire and calculate the score based on the result. System Usability Scale (SUS) is one such standardized usability questionnaire [5] which is used to evaluate the quality of a product or system [6]. SUS was introduced by John Brooke from Digital Corporation in 1984. Since then, it has become the most widely used standardized usability questionnaire among the researchers and practitioners of usability [7]. SUS consists of ten questions which are directed to measure the usability quality of a system.

According to ISO 9241-11 [8], usability is "the extent to which a product can be used by the specified users to achieve the specified goals with effectiveness, efficiency, and satisfaction in a specified context of use". Based on ISO 9241-11, usability is defined using three criteria which are effectiveness, efficiency, and satisfaction. According to ISO 9126 [9], usability is redefined "as the capability of the software to be understood, learned, used and liked by the user when used under specified conditions". In ISO 9126, usability is defined using five criteria which are understandability, learnability, operability, attractiveness, and usability compliance. The usability criteria defined by ISO 9241-11 and ISO 9126 are shown in Table I.

TABLE I. USABILITY CRITERIA CLASSFICATION

ISO	Usability criteria
ISO 9241-11	Efficiency
	Effectiveness
	Satisfaction
ISO 9126	Understandability
	Learnability
	Operability
	Attractiveness
	Usability compliance

These usability criteria were mapped to the questions in SUS to identify the usability criteria based on ISO 9241-11 and ISO 9126. More than one usability criteria may be mapped for each question. To map the questions and usability criteria, a conceptual model is illustrated. Figure 1 shows the conceptual model. UQ refers to the number of Usability Questions in the SUS. SUS evaluates the satisfaction of the user, the understandability of the user about the system, the learnability of the user about the system, the operability of the system, the usability compliance, and the efficiency of the system. However, SUS does not have any usability questions that evaluate the effectiveness and attractiveness of a system.

II. ENHANCED SYSTEM USABILITY SCALE

An enhanced conceptual model of the SUS and enhanced SUS questionnaire is proposed in this work. The enhanced SUS consists of 19 questions which evaluate 8 usability criteria defined using ISO 9241-11 and ISO 9126.

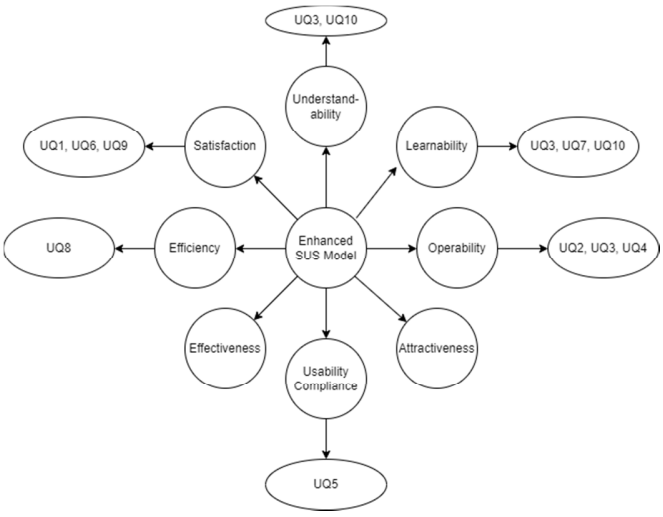

Fig. 1. Conceptual model of usability criteria mapped for each question in SUS.

A. The Proposed Enhanced System Usability Scale Conceptual Model

A conceptual model is proposed for the enhanced SUS. The enhanced model represents the 8 usability criteria based on ISO 9126 and ISO 9241-11. Mapping of the usability criteria and enhanced usability questions are shown in the conceptual model. Figure 2 shows the conceptual model of the usability criteria mapped for each question in the enhanced SUS. It can be seen that there are newly added 9 questions. The red bordered box represents the enhanced usability criteria and the green bordered box represents the newly added usability questions. In Figure 2, UQ14, UQ16, and UQ17 evaluate the attractiveness of the system, UQ11, UQ12, and UQ15 evaluate the effectiveness of the system, UQ5, UQ13, and UQ14 evaluate the usability compliance, and UQ18 and UQ19 evaluate, the efficiency of the system.

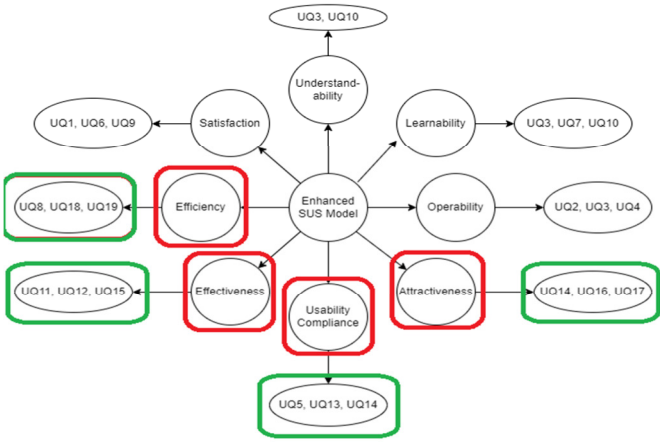

Fig. 2. Conceptual model of usability criteria mapped for each question in the enhanced SUS.

B. The Proposed Enhanced System Usability Scale

SUS is enhanced as the existing SUS does not evaluate the required usability criteria. Hence, the existing SUS has been

enhanced by adding 9 questions. The questions are adapted from the existing standardized usability questionnaire. Table II shows the proposed enhanced SUS. The table also shows the standardized usability questionnaire that is used as a reference.

TABLE II. ENHANCED SYSTEM USABILITY SCALE

No	Questions	Adapted
UQ1	I think that I would like to use this system frequently.	SUS [6, 7]
UQ2	I found the system unnecessarily complex.	SUS [6, 7]
UQ3	I thought the system was easy to use.	SUS [6, 7]
UQ4	I think that I would need the support of a technical person to be able to use this system.	SUS [6, 7]
UQ5	I found the various functions in this system were well integrated.	SUS [6, 7]
UQ6	I thought there was too much inconsistency in this system.	SUS [6, 7]
UQ7	I would imagine that most people would learn to use this system very quickly.	SUS [6, 7]
UQ8	I found the system very awkward to use.	SUS [6, 7]
UQ9	I felt very confident using the system.	SUS [6, 7]
UQ10	I needed to learn a lot of things before I could get going with this system.	SUS [6, 7]
UQ11	Tasks can be performed in a straightforward manner using this software.	SUMI [18]
UQ12	I'm unable to complete my work effectively using this system.	CSUQ [13]
UQ13	I found the interface design of the system follows the usability standards.	Question created based on ISO 9126 definition [9]
UQ14	I found this system does not fulfil the usability standards.	Question created based on ISO 9126 definition [9]
UQ15	I can use it successfully every time	USE [19]
UQ16	I found this system's color and graphical design is not attractive enough.	CSUQ [16]
UQ17	I found this system's user interface is very user friendly.	CSUQ [16]
UQ18	This system responds too slowly to inputs.	SUMI [18]
UQ19	This system helps me to do my job efficiently.	CSUQ [15]

III. METHODOLOGY

Interviews among the Subject Matter Experts (SMEs) were carried out to validate the enhanced SUS. The experts were provided with questions about the understanding of the usability and the enhanced SUS questionnaire. The example of questions that were asked to the SMEs are:

- What is your philosophy on usability?
- Do you think it is important to identify the usability score of a system?
- Do you think it is important to enhance the existing SUS?
- Do you think the enhanced SUS would improve the score and be more reliable compared to the existing SUS?
- Do you think one usability question can be mapped to more than one usability criteria?

Besides that, a survey was conducted among the students who had studied and have knowledge in software verification and validation to validate the reliability and suitability of the questions to evaluate the usability of a system. The data obtained were used to validate the enhanced SUS. After the validation among the SMEs was completed, the data gathered were used to calculate the coefficient reliability using Cronbach's alpha.

IV. VALIDATION

The qualitative method was used to validate the relevancy of usability sub-criteria mapping with the usability questions and the reliability of the usability questions. This method was carried out among three groups of SMEs. The SMEs were Certified Testers Foundation Level (CTFL) academician experts, industrial IT experts, and computer science students studying Software Verification and Validation in UTeM (Figure 3).

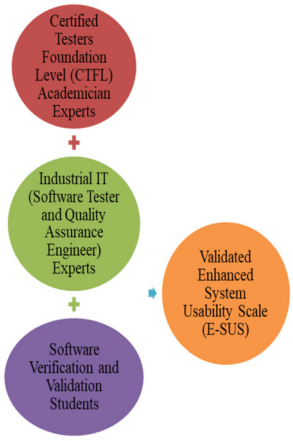

Fig. 3. Flowchart of the summarised validation methods.

V. RESULT

Four IT experts and two academician experts were involved in the validation of the mapped criteria for the usability question in the enhanced SUS. The IT experts were quality assurance engineers with working experience of more than four years. The academician experts were CTFL-certified senior lecturers with working experience of more than 20 years (Table III). Each of the participants involved in this research as the SME was assigned with an ID (Table IV).

TABLE III. VALIDATION EXPERTS SUMMARY

Participants	Quantity
University	
Academician	2
Industrial (IT Experts)	
Quality Assurance (QA) Engineer	4
Total	6

TABLE IV. SME IDs

No	Category	ID
1	Academician 1	AD1
2	Academician 2	AD2
3	QA Engineer 1	QAE1
4	QA Engineer 2	QAE2
5	QA Engineer 3	QAE3
6	QA Engineer 4	QAE4

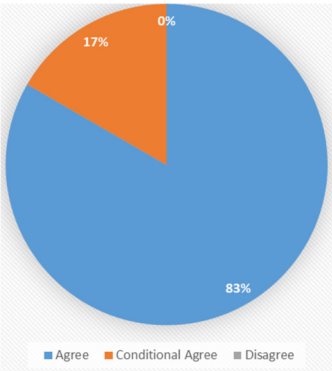

Fig. 4. SMEs agreement regarding enhancing the existing SUS.

Figure 4 shows the total percentage of the SMEs that agreed in enhancing the existing SUS. In overall, 5 out of 6 respondents, agreed to enhance the existing SUS (83%). The remaining SME had conditionally agreed. The SMEs agreed that one usability question can be mapped to more than one usability criteria and think that the enhanced SUS would improve the score and be more reliable compared to the existing SUS. Besides, the SMEs were asked about the philosophy of the usability in a system. Various explanations were given by the SMEs. AD1 emphasized learning through a system. "A system with good usability should have less learning curve and be more usable." User-friendliness is an important aspect of a system. A system must be capable enough to be used by all groups of people. Most importantly, those who doesn't have a technology background. This aspect was emphasized by two SMEs: "A system must be user-friendly to ease the end users because not all of them have technology background. As the LMS will be used by students from different fields of study, it is really important to ensure that the system performs well and is easy to use"[QAE4]. "A good usability criterion of a system is having features that are user friendly. An LMS should be easy to use and learn" [QAE2]. Lastly, time is a vital aspect when the user uses a system. A system with good usability must be able to serve the users without consuming ime. QAE1 epmhasized on this aspect during the validation process: "Usability is a scale to test the usability of a system where it is easy to use or difficult for a user to use the system. User can use lesser time to learn how to use the system and can easily start using a system."

A. *Verification of System Usability Scale Mapping with Usability Criteria*

Based on Figure 5, all the experts have either agreed (4) or strongly agreed (5) with UQ1, UQ2, and UQ5. Meanwhile, two of the experts were neutral (3) to the criteria mapped for UQ3, UQ4, and UQ13, one of the experts rated as neutral (3) UQ6, UQ7, UQ9, UQ10, UQ11, UQ14, UQ15, UQ17, and UQ18 and three of the experts rated neutral UQ8. One expert disagreed (2) with the criteria mapped in UQ4, UQ6, UQ12, UQ14, UQ16, UQ17, UQ18, and UQ19. However, the criteria remained similar for UQ4, UQ6, UQ12, UQ14, UQ16, UQ17, UQ18, and UQ19 as only one SME disagreed with the other five.

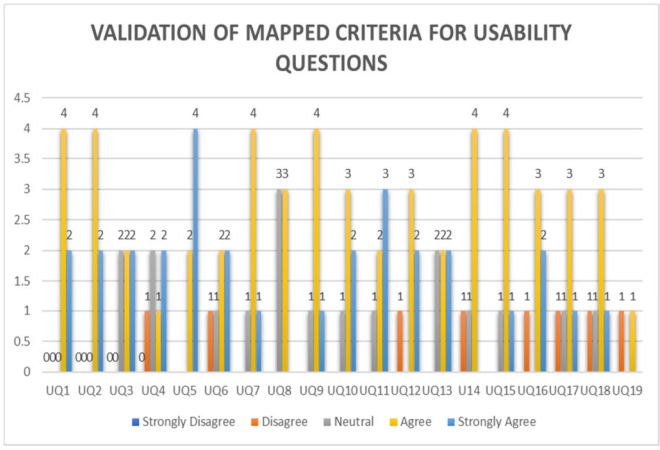

Fig. 5. Chart analysis of the validation of the usability criteria mapped to the usability questions.

B. *Validation of the Reliability of the Usability Questions in Enhanced SUS with SMEs*

The SMEs were asked to evaluate the reliability and suitability of the usability questions in the enhanced SUS. Based on Figure 6, all the experts either agreed (4) or strongly agreed (5) with UQ1, UQ2, UQ3, UQ4, UQ5, UQ6, UQ7, UQ8, UQ9, and UQ10. Meanwhile, two of the experts were neutral (3) to the reliability of the questions for UQ17 and one was neutral (3) to UQ14, UQ15, and UQ19. Moreover, one SME disagreed (2) with the reliability of UQ11, UQ12, UQ13, UQ14, UQ16, and UQ18. However, the usability questions for UQ11, UQ12, UQ13, UQ14, UQ16, and UQ18 were sustained as only one out of six SMEs disagreed with them.

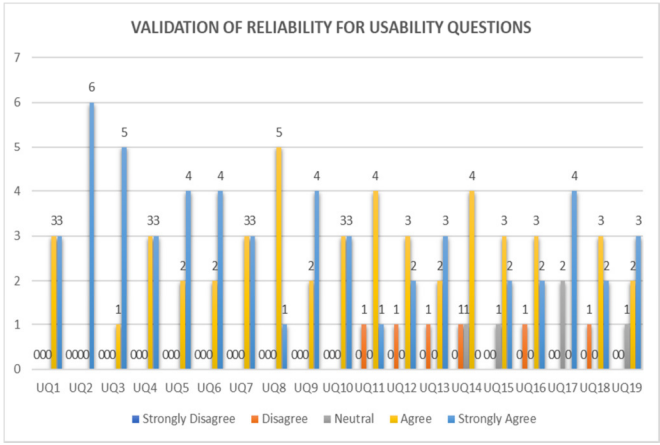

Fig. 6. Chart analysis the validation of the reliability of the usability questions in the enhanced SUS.

C. *Validation of the Reliability of the Usability Questions in Enhanced SUS with Software Verification and Validation Students*

A survey was conducted among a group of 80 students who had studied and have knowledge of software verification and validation. They were asked to evaluate the reliability and suitability of the usability questions in the enhanced SUS.

Table V shows the outcome of the survey. None question was rejected by the respondents as the sum of agree and strongly agree was above 50% for all. The data collected were used to calculate the reliability of the enhanced SUS using the Cronbach's alpha method.

TABLE V. ANALYSIS OF VALIDATING THE RELIABILITY OF THE USABILITY QUESTIONS IN PERCENTAGE (%)

No	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Sum of (4) and (5)
UQ1	1.16%	1.16%	4.65%	30.23%	62.79%	93.02%
UQ2	1.16%	4.65%	1.16%	25.58%	56.98%	82.56%
UQ3	2.33%	3.49%	5.81%	22.10%	66.28%	88.38%
UQ4	4.65%	8.14%	6.98%	23.26%	56.78%	80.04%
UQ5	1.16%	2.33%	8.14%	29.10%	59.30%	88.40%
UQ6	3.49%	8.14%	18.6%	13.95%	55.81%	69.76%
UQ7	1.16%	1.16%	6.98%	27.91%	62.80%	90.71%
UQ8	6.98%	13.95%	15.12%	19.77%	44.19%	63.96%
UQ9	1.16%	2.33%	11.63%	31.40%	53.49%	84.89%
UQ10	2.33%	11.63%	8.14%	20.93%	56.78%	77.71%
UQ11	1.16%	3.49%	6.98%	33.72%	54.65%	88.40%
UQ12	4.65%	11.63%	13.95%	17.44%	52.33%	69.77%
UQ13	2.33%	3.49%	6.98%	32.56%	54.65%	87.21%
UQ14	4.65%	11.63%	13.95%	20.93%	48.84	69.77%
UQ15	1.16%	2.33%	12.79%	32.56%	51.16%	83.72%
UQ16	6.98%	12.79%	16.28%	19.77%	44.19%	63.96%
UQ17	1.16%	1.16%	4.65%	30.23%	62.79%	92.42%
UQ18	2.33%	10.46%	17.44%	18.60%	51.16%	69.76&
UQ19	1.16%	2.33%	11.63%	27.91%	56.98%	84.89%

D. Reliability Test

Reliability can be expressed in terms of stability, equivalence, and consistency [10]. A frequent technique is consistency check, which is also known as Cronbach's alpha coefficient. For estimating the internal consistency, only one test is required as opposed to test-retest for stability and alternate form for equivalence. Cronbach's alpha is a measurement of the squared correlation between the true and the observed scores [11, 12]. To put it another way, the ratio of true score variance to the observed score variance is used to determine dependability. The basic equation for alpha used in the calculation is:

$$a = \frac{n}{n-1}\left(1 - \frac{\sum V_i}{V_{test}}\right) \quad (1)$$

where n is the number of questions, V_i is the variance of scores on each question, and V_{test} is the total variance of the overall scores on the entire test.

The number of questions (items), the variance of the scores upon every item, and the variance of the overall score all play a role in calculating Cronbach's alpha. The alpha value ranges from 0 to 1. If the alpha number is higher than 0.70, the level is considered acceptable. If V_{test} is greater than V_i, then this number will be high. The scores are dispersed due to the huge volatility. Table VI shows the Cronbach's alpha rule of thumb. The Cronbach's alpha reliability coefficient was calculated with the IBM SPSS Statistics software [13].

The enhanced SUS reliability coefficient was calculated based on the result obtained from the SMEs and the survey respondents. The reliability coefficient of SUS is calculated using IBM SPSS Statistics. According to the SPSS analysis, the Cronbach's alpha reliability coefficient for enhanced SUS is 0.954. Figures 7 and 8 show the case processing summary and reliability coefficient recorded from SPSS. We can see in Figure 7 that there are 86 valid cases to process and the total percentage of cases processed is 100%. According to Figure 8, the number of items evaluated is 19 and Cronbach's alpha reliability coefficient is 0.954.

TABLE VI. CRONBACH'S ALPHA RULE OF THUMB

Alpha	Level of consistency
>0.9	Excellent
>0.8	Good
>0.7	Acceptable
>0.6	Questionable
>0.5	Poor
<0.5	Unacceptable

Case Processing Summary

		N	%
Cases	Valid	86	100.0
	Excluded[a]	0	.0
	Total	86	100.0

a. Listwise deletion based on all variables in the procedure.

Fig. 7. Case processing summary of the enhanced SUS.

Reliability Statistics

Cronbach's Alpha	N of Items
.954	19

Fig. 8. Cronbach's alpha reliability coefficient of the enhanced SUS.

E. Comparison of Key Properties

The reliability coefficient of the enhanced SUS is 0.95 and it is greater by 0.03 from the existing SUS. As a result from the validation of the enhanced SUS through SMEs and reliability coefficient, all the proposed usability questions are accepted, and no changes were made to the proposed questionnaire. Table VII shows the comparison of the key properties between SUSU and enhanced SUS.

TABLE VII. COMPARISON OF KEY PROPERTIES

Key Properties	SUS	Enhanced SUS
Number of questions	10	19
License type	Free	Free
Subject of evaluation	Computer software	Computer software
Reliability coefficient	0.92	0.95
Usability criteria coverage	Understandability Learnability Operability Satisfaction Efficiency Usability compliance	Understandability Learnability Operability Satisfaction Efficiency Usability compliance Attractiveness Effectiveness

VI. CONCLUSION

The proposed Enhanced System Usability Scale was validated in this paper in terms of reliability coefficient and the usability criteria that it covers. It is vital to ensure that all the usability criteria are evaluated while validating or evaluating the usability of a system. However, future enhancement can be made by reducing the number of questions as most of the users prefer to spend less time evaluating a system' usability.

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REFERENCES

[1] A. Hafeez, S. Javed, A. B. Murtaza, A. Aziz, S. M. Hassan, and I. Hussain, "A Survey on the Adaption of CMS in Pakistani Universities," *Engineering, Technology & Applied Science Research*, vol. 9, no. 6, pp. 5037–5040, Dec. 2019, https://doi.org/10.48084/etasr.3159.

[2] S. Vairamuthu and S. M. Anouncia, "Reconnoitering Students' Satisfaction of an Online Based Assessment System to Improve Usability using PSO: An Examination into a Problem Solving and Programming Course," *Engineering, Technology & Applied Science Research*, vol. 6, no. 5, pp. 1207–1211, Oct. 2016, https://doi.org/10.48084/etasr.800.

[3] M. Jordan and N. Duckett, "Universities Confront 'Tech Disruption': Perceptions of Student Engagement Online Using Two Learning Management Systems," *The Journal of Public and Professional Sociology*, vol. 10, no. 1, Jan. 2018.

[4] I. Maslov, S. Nikou, and P. Hansen, "Exploring user experience of learning management system," *The International Journal of Information and Learning Technology*, vol. 38, no. 4, pp. 344–363, Jan. 2021, https://doi.org/10.1108/IJILT-03-2021-0046.

[5] ISO/TC 159/SC 4 Ergonomics of human-system interaction Technical Commitee, *ISO 9241-11:1998. Ergonomic requirements for office work with visual display terminals (VDTs) — Part 11: Guidance on usability*. Geneva, Switzerland: ISO, 1998.

[6] J. R. Lewis and J. Sauro, "Revisiting the Factor Structure of the System Usability Scale," *JUX - The Journal of User Experience*, vol. 12, no. 4, pp. 183–192, Aug. 2017.

[7] J. R. Lewis, "The System Usability Scale: Past, Present, and Future," *International Journal of Human–Computer Interaction*, vol. 34, no. 7, pp. 577–590, Jul. 2018, https://doi.org/10.1080/10447318.2018.1455307.

[8] ISO/TC 159/SC 4 Technical Committee, *ISO 9241-11:2018. Ergonomics of human-system interaction*. Geneva, Switzerland: ISO, 2018.

[9] ISO/IEC JTC 1/SC 7 Technical Committee, *ISO/IEC 9126-1:2001. Software engineering — Product quality — Part 1: Quality model*. Geneva, Switzerland: ISO, 2001.

[10] R. Reh, M. L. Mursidi, and N. A. A. Husin, "Reliability analysis for pilot survey in integrated survey management system," in *2011 Malaysian Conference in Software Engineering*, Johor Bahru, Malaysia, Sep. 2011, pp. 220–222, https://doi.org/10.1109/MySEC.2011.6140673.

[11] J. M. Cortina, "What is coefficient alpha? An examination of theory and applications," *Journal of Applied Psychology*, vol. 78, no. 1, pp. 98–104, 1993, https://doi.org/10.1037/0021-9010.78.1.98.

[12] N. Schmitt, "Uses and abuses of coefficient alpha," *Psychological Assessment*, vol. 8, no. 4, pp. 350–353, 1996, https://doi.org/10.1037/1040-3590.8.4.350.

[13] J. R. Lewis, "IBM computer usability satisfaction questionnaires: Psychometric evaluation and instructions for use," *International Journal of Human–Computer Interaction*, vol. 7, no. 1, pp. 57–78, Jan. 1995, https://doi.org/10.1080/10447319509526110.

[14] J. Sauro and J. R. Lewis, "Chapter 8 - Standardized Usability Questionnaires," in *Quantifying the User Experience*, J. Sauro and J. R. Lewis, Eds. Boston, MA, USA: Morgan Kaufmann, 2012, pp. 185–240.

[15] L. Buenaflor, "ISO 9126 Software Quality Characteristics," *Medium*, Sep. 02, 2017. https://medium.com/@leanardbuenaflor/iso-9126-software-quality-characteristics-a25a26e7d046.

[16] Sholiq, R. A. Auda, A. P. Subriadi, A. Tjahyanto, and A. D. Wulandari, "Measuring software quality with usability, efficiency, and portability characteristics," *IOP Conference Series: Earth and Environmental Science*, vol. 704, no. 1, Nov. 2021, Art. no. 012039, https://doi.org/10.1088/1755-1315/704/1/012039.

[17] O. A. Rotaru, S. Vert, R. Vasiu, and D. Andone, "Standardised Questionnaires in Usability Evaluation. Applying Standardised Usability Questionnaires in Digital Products Evaluation," in *Information and Software Technologies*, Cham, 2020, pp. 39–48, https://doi.org/10.1007/978-3-030-59506-7_4.

[18] J. Kirakowski and M. Corbett, "SUMI: the Software Usability Measurement Inventory," *British Journal of Educational Technology*, vol. 24, no. 3, pp. 210–212, 1993, https://doi.org/10.1111/j.1467-8535.1993.tb00076.x.

[19] J. Kirakowski and M. Corbett, "SUMI: the Software Usability Measurement Inventory," *British Journal of Educational Technology*, vol. 24, no. 3, pp. 210–212, 1993, https://doi.org/10.1111/j.1467-8535.1993.tb00076.x.

[20] R. A. Ali and M. R. M. Arshad, "Perspectives of Students' Behavior Towards Mobile Learning (M-learning) in Egypt: an Extension of the UTAUT Model," *Engineering, Technology & Applied Science Research*, vol. 6, no. 4, pp. 1109–1114, Aug. 2016, https://doi.org/10.48084/etasr.710.

[21] M. Hemmati and H. Hosseini, "Effect of IT Application on Project Performance Focusing on the Mediating Role of Organizational Innovation, Knowledge Management and Organizational Capabilities," *Engineering, Technology & Applied Science Research*, vol. 6, no. 6, pp. 1221–1226, Dec. 2016, https://doi.org/10.48084/etasr.769.

[22] N. A. Kamarudin, R. R. Raja Ikram, F. N. Azman, S. S. Syed Ahmad, and D. Bin Zainuddin, "A Study of The Effects of Short-Term AI Coding Course with Gamification Elements on Students' Cognitive Mental Health," *TEM Journal*, vol. 11, no. 4, pp. 1854–1862, Nov. 2022, https://doi.org/10.18421/TEM114-53.

[23] Y. Thamilarasan and R. R. R. Ikram, "MyMUET: A Design of a Mobile based Crowdsourced Assessment for Malaysia University English Test with Non-Synchronous Participant Interaction," *International Journal of Innovative Technology and Exploring Engineering*, vol. 8, no. 11, Sep. 2019, https://doi.org/10.35940/ijitee.K2277.0981119.