❏   490

Usability evaluation of ToAksara as Balinese script learning mobile application

**Gede Indrawan[1,2], Sariyasa[2,3], Luh Joni Erawati Dewi[2,4], Made Santo Gitakarma[1],
I Made Agus Oka Gunawan[5], Putu Ade Pranata[2]**

[1]Department of Electronic Systems Engineering Technology, Engineering and Vocational Faculty, Universitas Pendidikan Ganesha, Singaraja, Indonesia
[2]Department of Computer Science, Postgraduate Program, Universitas Pendidikan Ganesha, Singaraja, Indonesia
[3]Department of Mathematics Education, Faculty of Mathematics and Natural Sciences, Universitas Pendidikan Ganesha, Singaraja, Indonesia
[4]Department of Software Engineering Technology, Engineering and Vocational Faculty, Universitas Pendidikan Ganesha, Singaraja, Indonesia
[5]Department of Information System, Faculty of Science and Technology, Universitas Tabanan, Tabanan, Indonesia

Article Info

ABSTRACT

ToAksara application transliterates Latin text into Balinese script and has been used in high school teaching and learning activities in Buleleng Regency, Bali, Indonesia. This application was expected to provide comfort and satisfaction for students while learning the Balinese language and script. To measure the comfort and satisfaction level, a usability evaluation was carried out that focused on the application's end user. This research used a combination of concurrent think-aloud (CTA) and user experience questionnaire (UEQ) to evaluate ToAksara. In CTA, data collection involved nine respondents given a task scenario and expressing their problems or input. In UEQ, data collection involved 385 respondents who chose the value closest to their impression of 26 statements. Based on the analysis results, CTA produced several recommendations for improving the application regarding navigation, functionality, and errors. Based on the analysis, the user satisfaction results showed that all aspects were included in the excellent category. The aspects of attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty each produced a value of 2.144, 2.220, 2.385, 2.345, 2.139, and 2.101. The excellent category shows that ToAksara was included in the range of the top 10% of products compared to the UEQ benchmark.

Corresponding Author:

Sariyasa
Department of Computer Science, Postgraduate Program, Universitas Pendidikan Ganesha
St. Udayana 11, Singaraja, Bali 81116, Indonesia
Email: sariyasa@mobilecomputing.id

1.   INTRODUCTION

The Government has preserved the Balinese language and script by issuing regional regulations that include learning the Balinese language and script in the school curriculum [1]. In addition, another approach taken to help preserve Balinese culture, especially the Balinese language and script, is the currently developing technological approach. Several technological innovations have been produced from research; one of the technological innovations produced is the Balinese script transliteration application [2]. This application was developed using two transliteration models, namely transliteration of Latin text into Balinese script [3] and transliteration of Balinese script into Latin text [4]. ToAksara application (ToAksara, in short

for the subsequent references) was a product result of research implementing a transliteration model for Latin text into Balinese script [5], as shown in Figure 1. Figure 1(a) shows an empty input-output with a simple user guide on the ToAksara application, Figure 1(b) shows a Latin input that generates similarity-ranking-based words with their Indonesian and English translations, and Figure 1(c) shows the Balinese script output related to the Latin input, and its similarity-ranking-based words that were generated upon pressing the "Go!" button. The transliteration state-of-the-art included the handling algorithm of the Balinese script as Abugida [6] that used a mathematical model of a finite-state machine [7]–[10] and utilized unicode font [11], [12] to render Balinese script, including its non-alphanumeric glyphs [13], on the application output. As one of the applications developed for technology-based cultural preservation, this application supports learning activities at the high school level in Buleleng Regency, Bali, Indonesia.
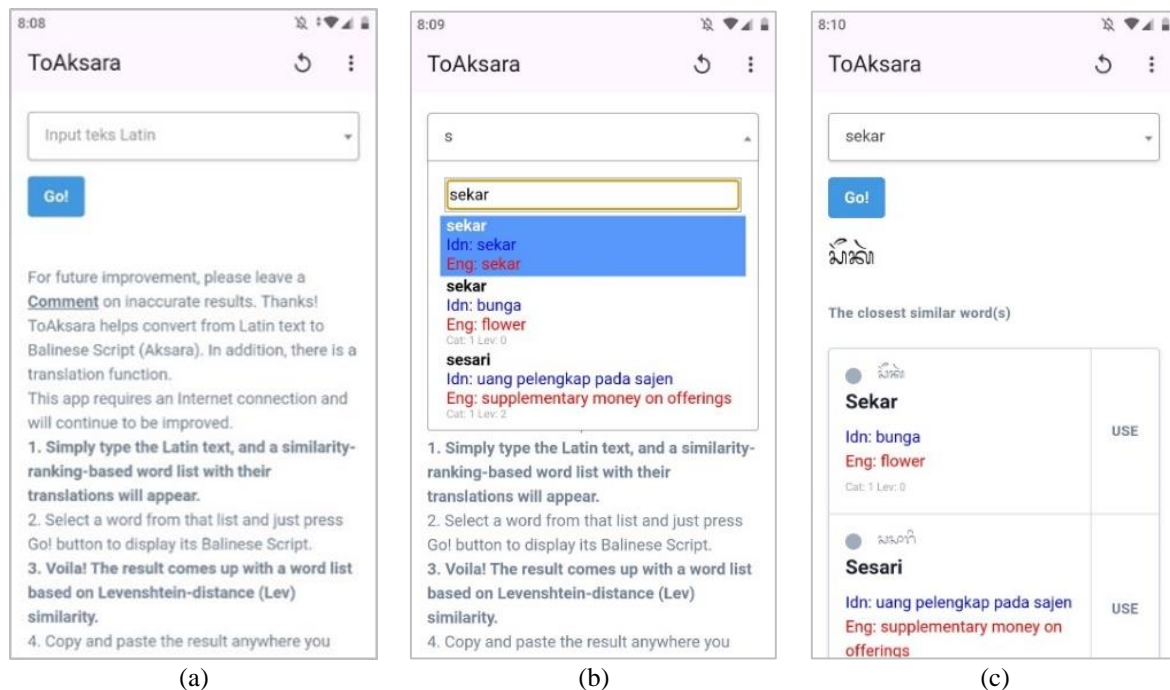

Figure 1. ToAksara application with (a) empty input-output, (b) Latin input, and (c) Balinese script output

Using ToAksara in learning activities was expected to realize effective and efficient ubiquitous learning activities for the Balinese language and script. This goal was expected to be achieved when students feel comfortable and satisfied using the application in their learning activities. To measure this, an evaluation was carried out involving students who use the application, so that it was known how comfortable and satisfied users were in using ToAksara for further development. Usability evaluation is one system evaluation method that focuses on evaluating how well users can learn and use the system and how satisfied users are with the process in the system [14]. The usability evaluation methods are categorized into inspection, testing, and inquiry [15]. The inquiry [16] and testing methods [17] involve users in the evaluation process, so in this research, both methods were used to observe users and their responses when using ToAksara.

The testing method was used to observe users when using ToAksara [15], while the inquiry method was used to measure user satisfaction with the application [18], [19]. Evaluation techniques used in usability testing include remote testing, coaching, question-asking protocol, and think-aloud [20]. Think-aloud has several advantages, including being cheap, strong, flexible, reliable, and easy to use [21], [22]. Research conducted using think-aloud has succeeded in finding user problems, such as obstacles experienced when carrying out an action or task, interface problems, and system functionality that does not work [23]. Based on the evaluation stage, think-aloud can be divided into concurrent think-aloud (CTA) and retrospective think-aloud (RTA) [23], [24]. The CTA technique is carried out when respondents are interacting with the system [25], [26], while RTA is carried out when respondents have finished interacting with the system [27]. The CTA technique is better than RTA in detecting usability problems because users will directly express their opinions using the system [22], [28]. The CTA technique also saves evaluation time because the evaluation process does not require video replays and is analyzed together with respondents [29], [30]. A user

experience questionnaire (UEQ) is one type of questionnaire from the inquiry method that can be used to measure user satisfaction [15], [31]. UEQ can provide an overview of the usability aspect of user experience [32]. UEQ has six aspects of user experience, with 26 statement items to measure user satisfaction [33], [34]. The application of UEQ usually takes 3-5 minutes to read and complete the questionnaire [32], [35].

Based on the literature review, this research conducted a user-based evaluation of ToAksara as a Balinese language and script learning application at the high school level in Buleleng Regency, Bali, Indonesia. The evaluation used CTA and UEQ. Evaluation using CTA produced problems and recommendations according to those expressed by users when using ToAksara. The user satisfaction value on each aspect produced using UEQ was compared with the benchmark on the UEQ data analysis tool to obtain the categories achieved from each aspect of the user experience of ToAksara. The final results of this research were expected to produce recommendations for researchers and education stakeholders in making policies for the further development of ToAksara to support the preservation of the Balinese language and script through increasingly effective and efficient technology-based learning activities.

In the paper, we described the research background and provided related literature reviews in section 1. The research method was presented in section 2, which explained the related flowchart and the stages. In section 3, detailed results of the discussion and analysis of the evaluation results were provided. The conclusion in section 4 concludes several important points of this research.

2. METHOD

As shown in Figure 2, this research was conducted in four stages: preparation, planning, data collection, and results and analysis. The preparation stage was carried out by identifying existing problems, and then a literature review was conducted on the results of the problem identification. At the planning stage, respondents were selected, and research instruments were designed. This research used instruments related to the task scenarios carried out by respondents and UEQs with additional questions. Data collection was carried out using the resulting instruments, where the data collection results were then analyzed to produce the final evaluation results of ToAksara.
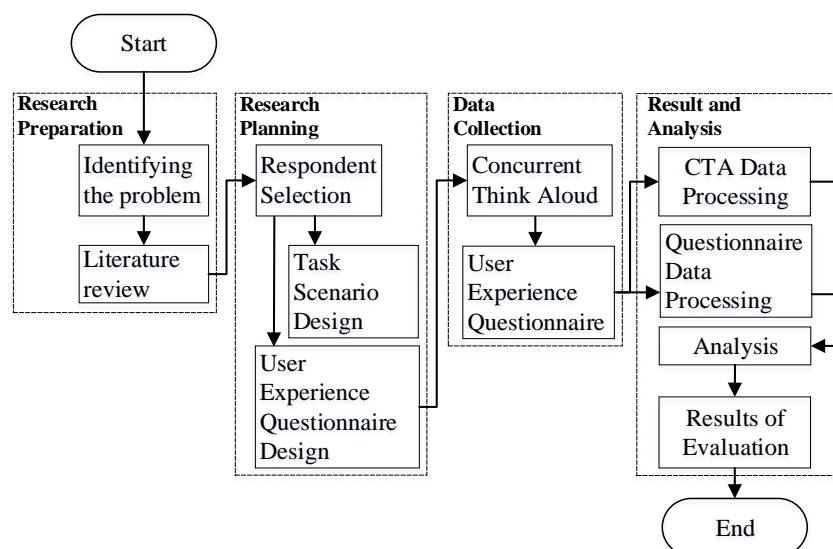
Figure 2. Research method

2.1. Research preparation

In the preparation stage, direct observation and identification of problems were carried out with the research subjects to obtain an initial picture of users of ToAksara, namely high school students in Buleleng Regency, Bali, Indonesia. Furthermore, a literature review was conducted on user-based application evaluation according to the results of problem identification. The preparation stage resulted in formulating the problem being researched, which is related to evaluating ToAksara using CTA and UEQ on high school students in Buleleng Regency, Bali, Indonesia.

2.2. Research planning

Based on the basic education data (DAPODIK) application [36], it was known that there are 10,278 active students in the 2024/2025 academic year, divided into nine sub-districts in Buleleng Regency. User evaluations using think-aloud in previous research showed that the number of respondents required was manageable. Sarasmayana *et al.* [37] used five students as respondents, and Pratama *et al.* [38] used 10 respondents. Respondents in this research were randomly selected from high schools in nine sub-districts in Buleleng Regency. So, in this research, nine respondents who worked on the task scenario for the CTA evaluation were selected. As for the user experience evaluation, the number of respondents was determined using the Slovin formula [39] with a confidence coefficient of 95%. So, by using the Slovin formula as in (1), the number of samples from the population that would be respondents to fill out the UEQ was 385.

$$n = \frac{N}{1+Ne^2} = \frac{10,278}{1+10,278(0.05^2)} = 385.0159 \tag{1}$$

At this stage, the instrument used for data collection was also designed. Respondents interacted with the application in CTA according to the task scenario as shown in Table 1, which explains the tasks that ToAksara users must carry out. The questionnaire used has six aspects of user experience as shown in Figure 3 and 26 statement items as shown in Table 2 that respondents must fill in [40]. The statements in each UEQ item consist of a pair of terms with opposite meanings, such as slow-fast and complicated-easy. The aspects and statement items were then arranged into a questionnaire. This research questionnaire used the Indonesian version to make it easier for respondents [33] (its English was provided in this paper for understandability). The questionnaire also included additional questions to help respondents provide assessment results on the UEQ.

Table 1. Task scenario

| Task code	Task scenario
T01	Please transliterate the word "*sekar*" (flower).
T02	Next, please copy the transliteration results.
T03	Please choose the most similar word from the transliteration results of the word "*sekar*".
T04	Please delete the results of the word transliteration that you did.
T05	Please transliterate 2 Balinese words.
T06	Please transliterate 3 Balinese words.
T07	Add feedback for future application development.
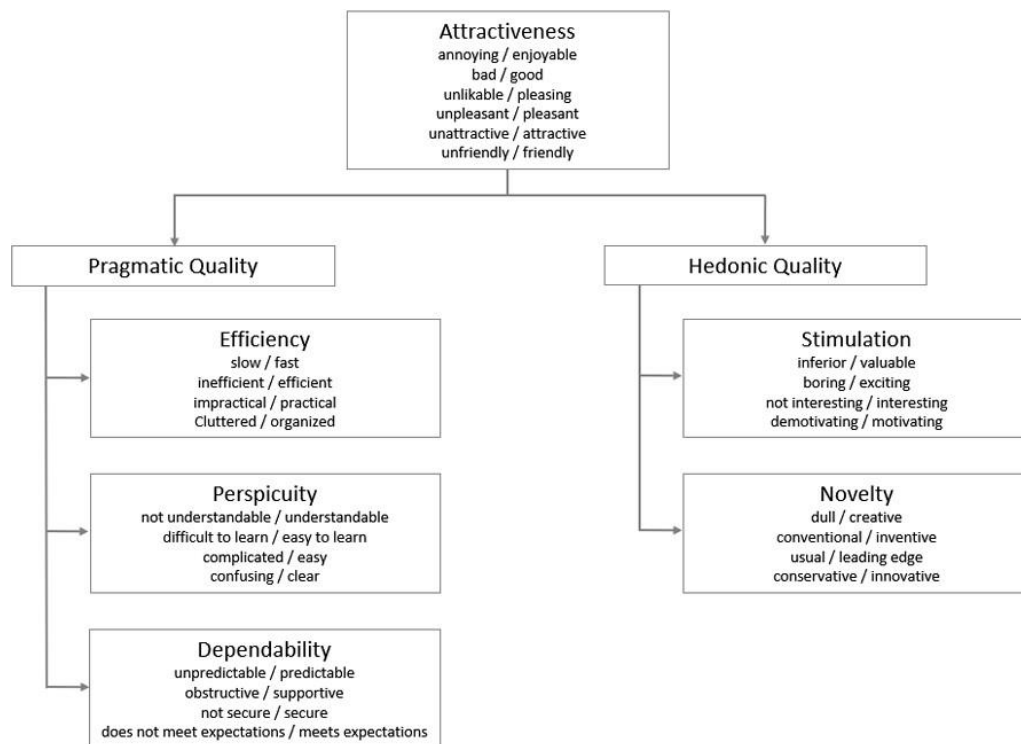
Figure 3. Aspects and statement items in UEQ

Table 2. User experience questionnaire with additional statements

Pernyataan tambahan (Additional statement)	Butir pernyataan (Item)	1 2 3 4 5 6 7	Butir pernyataan (Item)	
Produk ini terlihat menyenangkan (This product looks enjoyable)	menyusahkan (annoying)	o o o o o o o	menyenangkan (enjoyable)	1
Produk ini dapat dipahami (This product is understandable)	tak dapat dipahami (not understandable)	o o o o o o o	dapat dipahami (understandable)	2
Produk ini dirancang secara kreatif (This product is creatively designed)	kreatif (creative)	o o o o o o o	monoton (dull)	3
Produk ini mudah dipelajari (This product is easy to learn)	mudah dipelajari (easy to learn)	o o o o o o o	sulit dipelajari (difficult to learn)	4
Produk ini bermanfaat (This product is valuable)	bermanfaat (valuable)	o o o o o o o	kurang bermanfaat (inferior)	5
Produk ini mengasyikkan (This product is exciting)	membosankan (boring)	o o o o o o o	mengasyikkan (exciting)	6
Produk ini menarik (This product is interesting)	tidak menarik (not interesting)	o o o o o o o	menarik (interesting)	7
Interaksi dengan produk ini dapat diprediksi (Interactions with this product are predictable)	tak dapat diprediksi (unpredictable)	o o o o o o o	dapat diprediksi (predictable)	8
Dengan produk ini, saya melakukan tugas saya dengan cepat (With this product, I do my task fast)	cepat (fast)	o o o o o o o	lambat (slow)	9
Produk ini berdaya cipta (This product has an inventive design)	berdaya cipta (inventive)	o o o o o o o	konvensional (conventional)	10
Interaksi dengan produk ini mendukung penyelesaian tugas saya (Interaction with this product is supportive in completing tasks)	menghalangi (obstructive)	o o o o o o o	mendukung (supportive)	11
Produk ini terlihat bagus (This product looks good)	baik (good)	o o o o o o o	buruk (bad)	12
Produk ini rumit (This product is complicated)	rumit (complicated)	o o o o o o o	sederhana (easy)	13
Produk ini terlihat menggembirakan (This product looks pleasing)	tidak disukai (unlikable)	o o o o o o o	menggembirakan (pleasing)	14
Produk ini menggunakan teknologi terdepan (This product uses leading edge technology)	lazim (usual)	o o o o o o o	terdepan (leading edge)	15
Produk ini terlihat nyaman (This product looks pleasant)	tidak nyaman (unpleasant)	o o o o o o o	nyaman (pleasant)	16
Interaksi dengan produk ini aman (Interaction with this product is secure)	aman (secure)	o o o o o o o	tidak aman (not secure)	17
Produk ini memotivasi (This product is motivating)	memotivasi (motivating)	o o o o o o o	tidak memotivasi (demotivating)	18
Interaksi dengan produk ini memenuhi ekspektasi saya (Interaction with product meets my expectations)	memenuhi ekspektasi (meet expectations)	o o o o o o o	tidak memenuhi ekspektasi (does not meet expectations)	19
Dengan produk ini, saya melakukan tugas saya dengan efisien (With this product, I do my task efficiently)	tidak efisien (inefficient)	o o o o o o o	efisien (efficient)	20
Produk ini membingungkan (This product is confusing)	jelas (clear)	o o o o o o o	membingungkan (confusing)	21
Dengan produk ini, saya melakukan tugas saya dengan praktis (With this product, I do my job practically)	tidak praktis (impractical)	o o o o o o o	praktis (practical)	22
Dengan produk ini, saya melakukan tugas saya dengan terorganisasi (With this product, I do my tasks in an organized)	terorganisasi (organized)	o o o o o o o	berantakan (cluttered)	23
Produk ini terlihat atraktif (This product looks attractive)	atraktif (attractive)	o o o o o o o	tidak atraktif (unattractive)	24
Produk ini terlihat ramah pengguna (This product is user friendly)	ramah pengguna (friendly)	o o o o o o o	tidak ramah pengguna (unfriendly)	25
Produk ini inovatif (This product is innovative)	konservatif (conservative)	o o o o o o o	inovatif (innovative)	26

2.3. Data collection

The initial data collection stage was conducted on nine respondents who worked on the task scenario. In CTA, the data collection process was carried out on respondents during task completion. In data collection using this technique, respondents were given directions to tell as clearly as possible what they thought when they carried out the stages to complete the requested task. The data collection process was carried out by recording all problems or suggestions expressed by respondents for further processing of each respondent's recording results.

Data collection on UEQ was done by filling out a questionnaire. Table 3 is an example of a questionnaire on 3 statement items. A respondent chose statement items by selecting the circle closest to their impression. Table 3 shows that a respondent rated the product as more "*menyenangkan*" (enjoyable), "*dapat dipahami*" (understandable), and "*kreatif*" (creative).

2.4. Results and analysis

Evaluation with CTA produced qualitative data in the form of application problems/suggestions expressed by each respondent. Respondents' problems/suggestions were summarized to obtain conclusions from the problems/suggestions of all respondents. The processing of the values of each aspect of user experience was carried out using UEQ data analysis. UEQ analysis was carried out by calculating the average value for each aspect. The UEQ results were then benchmarked by comparing the values of each aspect with the product data set available in the UEQ data analysis tool. Benchmark testing describes the relative quality of a product compared to other products. The values for the benchmark range in each category are shown in Table 4 [34].

Table 3. Example of questionnaire completion (in Indonesian language with English translation)

Pernyataan tambahan (Additional statement)	*Butir pernyataan* (Item)	1	2	3	4	5	6	7	*Butir pernyataan* (Item)	
Produk ini terlihat menyenangkan (This product looks enjoyable)	*menyusahkan* (annoying)	o	o	o	o	x	o	o	*menyenangkan* (enjoyable)	1
Produk ini dapat dipahami (This product is understandable)	*tak dapat dipahami* (not understandable)	o	o	o	o	o	x	o	*dapat dipahami* (understandable)	2
Produk ini dirancang secara kreatif (This product is creatively designed)	*kreatif* (creative)	o	x	o	o	o	o	o	*monoton* (dull)	3

Table 4. Benchmark ranges in the UEQ data analysis tool

Aspect	Category				
	Excellent	Good	Above average	Below average	Bad
Attractiveness	≥1.75	≥1.52 <1.75	≥1.17 <1.52	≥0.7 <1.17	<0.7
Perspicuity	≥1.9	≥1.56 <1.9	≥1.08 <1.56	≥0.64 <1.08	<0.64
Efficiency	≥1.78	≥1.47 <1.78	≥0.98 <1.47	≥0.54 <0.98	<0.54
Dependability	≥1.65	≥1.48 <1.65	≥1.14 <1.48	≥0.78 <1.14	<0.78
Stimulation	≥1.55	≥1.31 <1.55	≥0.99 <1.31	≥0.5 <0.99	<0.5
Novelty	≥1.4	≥1.05 <1.4	≥0.71 <1.05	≥0.3 <0.71	<0.3

3. RESULTS AND DISCUSSION

3.1. Evaluation results

Evaluation with CTA produces qualitative data in the form of problems and suggestions for application development. Based on the think-aloud process carried out by each respondent, a list of problems and suggestions from ToAksara was produced, which can be seen in Table 5. The list of problems and suggestions was then analyzed to determine the application's features or aspects that needed improvement. Suggestions from respondents were also analyzed so that the improvements made were based on the needs expressed by users.

Table 5. Concurrent think-aloud results

Respondent	Problems	Suggestions
R01	The button for transliteration is not clear.	The "Go" label can be customized, or the transliteration can appear automatically without pressing a button.
R02	There are transliteration errors, such as in the word "*punia*" (donation).	It is necessary to check the application code for its transliteration algorithm.
R03	The closest similar word needs fixing, such as transliteration of "*sekar*" (flower), where closest similar word shown as "*sesari*" (supplementary money on offerings)	The application code needs improvement.
R04	There are no problems.	The label on the transliteration button needs to be adjusted to make its function clear.
R05	There are no problems. Application is suitable and easy to use.	There are no suggestions.
R06	It is difficult to find tools to copy the transliteration results.	A button or functionality is needed to make it easier for users to copy transliteration results.
R07	There are no problems.	Need a feature for a complete dictionary of Balinese script and language to perfect the application.
R08	Access to provide feedback is less clear.	We need to clarify buttons to provide input from application.
R09	There are no problems.	A special button is needed to copy transliteration results.

Based on the data obtained from the questionnaire, they were then entered into the UEQ data analysis tools to produce values for each aspect of user experience. In general, the distribution of answers from respondents is shown in Table 6. In this distribution of answers, information was collected from the scores given by respondents, such as scores that lead to negative (1-3), neutral (4), and positive (5-7). This answer distribution table also helps to gain a deeper understanding of ToAksara as perceived by users based on the answers given by respondents.

The overall value of each statement item that the respondents gave was then transformed into positive and negative values ranging from +3 to -3. After being transformed, the data were calculated to find each aspect's average value. The results of the average calculation per item are shown in Figure 4. Next, calculations were carried out to obtain the final average of each aspect of user experience. Table 7 shows the average value of six aspects of user experience that show positive values, which are 2.144 for attractiveness, 2.220 for perspicuity, 2.385 for efficiency, 2.345 for dependability, 2.139 for stimulation, and 2.101 for novelty.

Table 6. Distribution of questionnaire answers

No	Item	1	2	3	4	5	6	7	Aspects
1	annoying/enjoyable	0	0	4	0	43	203	135	Attractiveness
2	not understandable/understandable	0	0	5	3	7	159	211	Perspicuity
3	dull/creative	0	6	1	21	20	214	123	Novelty
4	difficult to learn/easy to learn	4	6	9	0	3	155	208	Perspicuity
5	inferior/valuable	0	0	3	5	12	116	249	Stimulation
6	boring/exciting	0	0	1	25	48	284	27	Stimulation
7	not interesting/interesting	0	0	0	13	20	264	88	Stimulation
8	unpredictable/predictable	0	8	7	10	38	169	153	Dependability
9	slow/fast	0	0	3	6	9	247	120	Efficiency
10	conventional/inventive	0	3	0	13	45	218	106	Novelty
11	obstructive/supportive	0	0	0	14	27	147	197	Dependability
12	bad/good	0	0	0	4	7	199	175	Attractiveness
13	complicated/easy	0	0	0	4	50	277	54	Perspicuity
14	unlikable/pleasing	0	0	4	6	64	260	51	Attractiveness
15	usual/leading edge	0	0	4	27	22	188	144	Novelty
16	unpleasant/pleasant	0	0	4	1	26	227	127	Attractiveness
17	not secure/secure	0	0	5	0	3	195	182	Dependability
18	demotivating/motivating	0	0	4	19	25	234	103	Stimulation
19	does not meet expectations/meets expectations	0	0	2	11	7	147	218	Dependability
20	inefficient/efficient	0	0	0	4	9	144	228	Efficiency
21	confusing/clear	0	0	0	0	63	233	89	Perspicuity
22	impractical/practical	0	0	0	3	21	219	142	Efficiency
23	cluttered/organized	0	3	0	3	9	166	204	Efficiency
24	unattractive/attractive	0	3	0	18	48	224	92	Attractiveness
25	unfriendly/friendly	0	0	0	3	77	176	129	Attractiveness
26	conservative/innovative	0	0	5	27	42	158	153	Novelty

Table 7. Mean value of user experience aspects

UEQ scales (mean and variance)		
Attractiveness	2.144	0.31
Perspicuity	2.220	0.27
Efficiency	2.385	0.24
Dependability	2.345	0.32
Stimulation	2.139	0.32
Novelty	2.101	0.49

3.2. Analysis results

Table 5 shows several problems and suggestions regarding ToAksara. The conclusion data based on the analysis conducted on the problems and suggestions for improving the application's usability can be seen in Table 8. The analysis results produce recommendations for improvements in navigation, functionality, and perspicuity in ToAksara.

The results of the average value of the user experience aspects shown in Table 8 were then processed using the UEQ data analysis tool. In the UEQ data analysis tool, the average value of each aspect has been connected to the data set in the benchmark. The benchmark was a dataset of 18,483 people from 401 studies on various products. The results of this comparison described the relative quality of ToAksara compared to other products [34]. The results of the ToAksara benchmark test are shown in Table 9.

Based on Table 9 and visualized in Figure 5 to show ToAksara's position along with all categories in the UEQ benchmark, all aspects of ToAksara were included in the excellent category. The excellent category

shows that ToAksara was included in the range of the top 10% of products compared to the UEQ benchmark. Based on the interpretation of the values obtained, as shown in Figure 5, it can be seen that the novelty and stimulation aspects had the smallest value, so improvements can be focused on developing or improving applications in these two aspects. In addition to improving ToAksara, further research can analyze the improvements made. Based on previous research, the improvements made showed increased user satisfaction and decreased error rates. Further analysis [41], [42] can also be done by analyzing the relationship between variables in the UEQ used in this research. Relationship analysis can be used as a reference for variables that are interrelated and have a significant influence on increasing satisfaction with the application.
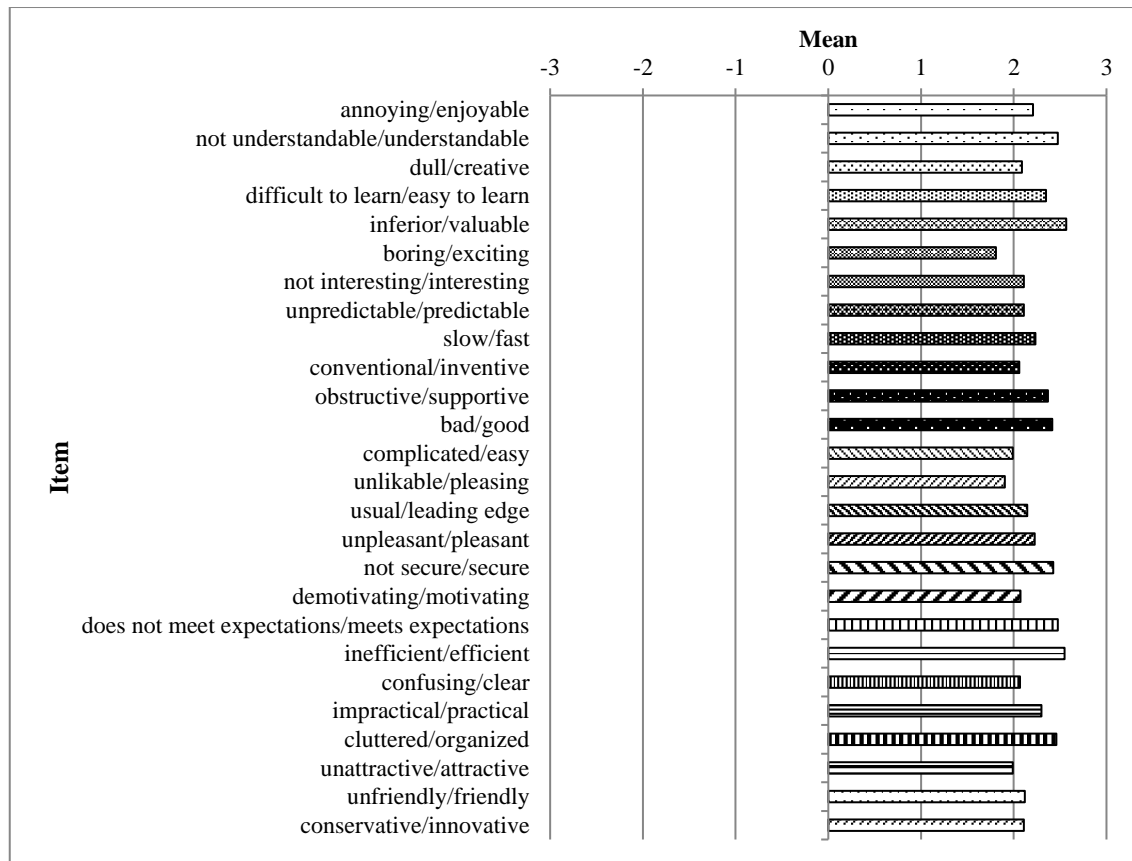

Figure 4. Mean value per item

Table 8. Results of concurrent think-aloud analysis

No	Respondents	Features/Aspects	Recommendation
1	R01, R04, R06, R08, R09	Navigation	Added application navigation on: 1. The transliteration button 2. Copy the transliteration result button 3. Input button for the application
2	R07	Functional	Addition of Balinese script and language dictionary functionality to the application
3	R02, R03	Error	Corrections on: 1. Transliteration error 2. Closest similar word

Table 9. ToAksara benchmark

| Aspect	Mean	Comparison to the benchmark	Interpretation
Attractiveness	2.144	Excellent	In the range of the 10% best results
Perspicuity	2.220	Excellent	In the range of the 10% best results
Efficiency	2.385	Excellent	In the range of the 10% best results
Dependability	2.345	Excellent	In the range of the 10% best results
Stimulation	2.139	Excellent	In the range of the 10% best results
Novelty	2.101	Excellent	In the range of the 10% best results
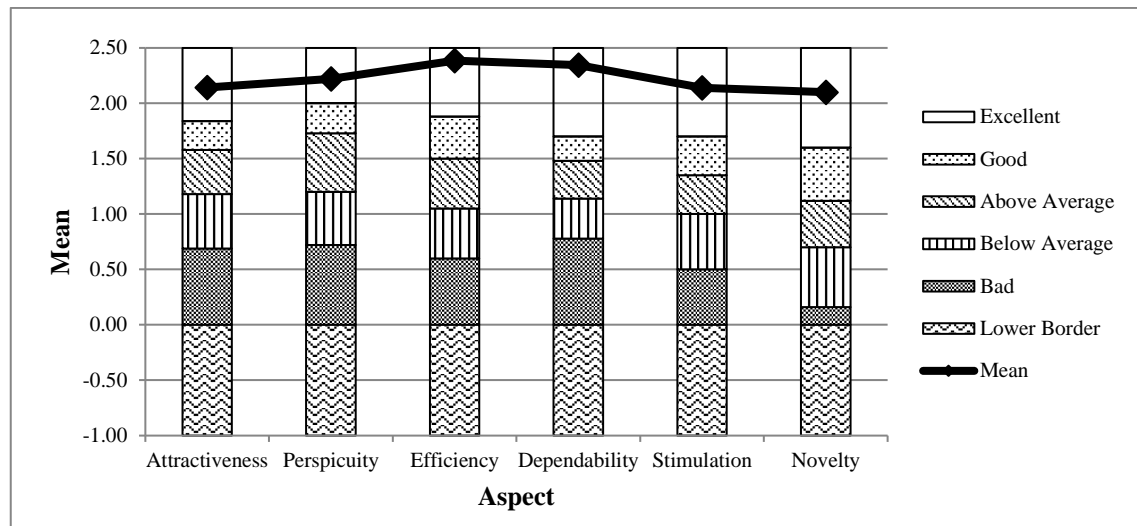
Figure 5. UEQ benchmark

4.   CONCLUSION

The usability evaluation results of ToAksara show that users were satisfied with using this mobile application for Balinese language and script learning. However, continuous improvement can still be done, where CTA produced several recommendations for application improvement. The nine respondents involved in this evaluation provided recommendations on aspects related to navigation, functionality, and errors in the application. The user satisfaction results with ToAksara were successfully analyzed using the UEQ. The instrument used has been adjusted by adding additional questions to explain each aspect asked. User satisfaction on each aspect produced a value of 2.144 for attractiveness, 2.220 for perspicuity, 2.385 for efficiency, 2.345 for dependability, 2.139 for stimulation, and 2.101 for novelty. Based on the analysis, user satisfaction results showed that all aspects were included in the excellent category. The excellent category indicates that ToAksara was included in the range of the top 10% of products compared to the UEQ benchmark. Further research can be conducted by analyzing the improvements made and the relationship between each aspect of UEQ to see its influence on user satisfaction.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Gede Indrawan	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
Sariyasa		✓		✓		✓	✓	✓		✓	✓	✓		
Luh Joni Erawati Dewi		✓	✓	✓		✓	✓			✓	✓		✓	
Made Santo Gitakarma		✓	✓	✓		✓	✓	✓		✓	✓			
I Made Agus Oka Gunawan	✓	✓	✓	✓		✓		✓	✓	✓				
Putu Ade Pranata		✓				✓		✓		✓				

C	:	**C**onceptualization	I	:	**I**nvestigation	Vi	:	**Vi**sualization
M	:	**M**ethodology	R	:	**R**esources	Su	:	**Su**pervision
So	:	**So**ftware	D	:	**D**ata Curation	P	:	**P**roject administration
Va	:	**Va**lidation	O	:	Writing - **O**riginal Draft	Fu	:	**Fu**nding acquisition
Fo	:	**Fo**rmal analysis	E	:	Writing - Review & **E**diting			

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the author's institutional review board or equivalent committee.

DATA AVAILABILITY

The data that support the findings of this study are available on reasonable request from the corresponding author. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

REFERENCES

[1] Bali Government, "Bali Governor Regulation no. 80/2018 on the protection and use of Balinese language, script, and literature and the implementation of Balinese language month (in Indonesian: *Peraturan Gubernur Bali nomor 80 tahun 2018 tentang pelindungan dan penggunaan bahasa, aksara, dan sastra Bali serta penyelenggaraan bulan bahasa Bali*)," *JDIH Pemerintah Provinsi Bali*, 2018. Accessed: Dec. 12, 2024. [Online]. Available: https://jdih.baliprov.go.id/produk-hukum/peraturan/abstrak/24665

[2] I. M. D. R. Mudiarta *et al.*, "Balinese character recognition on mobile application based on Tesseract open source OCR engine," *Journal of Physics: Conference Series*, vol. 1516, no. 1, Apr. 2020, doi: 10.1088/1742-6596/1516/1/012017.

[3] G. Indrawan, C. O. Birawidya, L. J. E. Dewi, K. Agustini, I. G. A. Gunadi, and I. K. Paramarta, "Derivative word conversion method to Balinese script on mobile computing," *ICIC Express Letters*, vol. 17, no. 7, pp. 725–733, 2023, doi: 10.24507/icicel.17.07.725.

[4] L. J. E. Dewi *et al.*, "ToLatin Mobile: a finite state machine-based mobile application for Balinese script to Latin letter conversion (In Indonesian: *ToLatin Mobile: aplikasi mobile konversi aksara Bali ke huruf Latin berbasis finite state machine*)," 000493329, 2023 [Online]. Available: https://go.undiksha.ac.id/EC00202361351

[5] G. Indrawan, L. J. E. Dewi, I. G. A. Gunadi, K. Agustini, and I. K. Paramarta, "The analysis of Noto Serif Balinese font to support computer-assisted transliteration to Balinese script," in *Information and Communication Technology for Competitive Strategies (ICTCS 2021)*, Springer, Singapore, 2023, pp. 571–580, doi: 10.1007/978-981-19-0095-2_54.

[6] A. E. Gnanadesikan, "Towards a typology of phonemic scripts," *Writing Systems Research*, vol. 9, no. 1, pp. 14–35, Jan. 2017, doi: 10.1080/17586801.2017.1308239.

[7] S. Hollos and J. R. Hollos, *Finite automata and regular expressions: problems and solutions*. New York, United States: Abrazol Publishing, 2013.

[8] J. Wang and W. Tepfenhart, *Formal methods in computer science*. New York, United States: Chapman and Hall/CRC, 2019, doi: 10.1201/9780429184185.

[9] M. L. M. Sajini, S. Suja, S. M. G. Raj, S. Kowsalyadevi, and C. Maria, "Finite state machine-based load scheduling algorithm for smart home energy management," *IETE Journal of Research*, vol. 69, no. 10, pp. 7460–7475, Oct. 2023, doi: 10.1080/03772063.2021.2010607.

[10] M. Nadeem, M. Lal, J. Cen, and M. Sharsheer, "AR4FSM: mobile augmented reality application in engineering education for finite-state machine understanding," *Education Sciences*, vol. 12, no. 8, pp. 1-19, Aug. 2022, doi: 10.3390/educsci12080555.

[11] Unicode Consortium, "The unicode® standard: version 16.0 – core specification," *Unicode Consortium*, 2024. Accessed: Dec. 12, 2024. [Online]. Available: https://www.unicode.org/versions/Unicode16.0.0/UnicodeStandard-16.0.pdf

[12] Unicode, "Balinese-range: 1B00–1B7F," *Unicode, Inc.*, 2024. Accessed: Dec. 12, 2024. [Online]. Available: https://unicode.org/charts/PDF/U1B00.pdf

[13] G. Indrawan, I. W. Sutaya, K. U. Ariawan, M. S. Gitakarma, I. G. Nurhayata, and I. K. Paramarta, "A method for non-alphanumeric text processing on transliteration to the Balinese script," *ICIC Express Letters*, vol. 16, no. 7, pp. 687–694, 2022, doi: 10.24507/icicel.16.07.687.

[14] B. Maqbool and S. Herold, "Potential effectiveness and efficiency issues in usability evaluation within digital health: a systematic literature review," *Journal of Systems and Software*, vol. 208, Feb. 2024, doi: 10.1016/j.jss.2023.111881.

[15] S. Gupta, "A comparative study of usability evaluation methods," *International Journal of Computer Trends and Technology*, vol. 22, no. 3, pp. 103–106, Apr. 2015, doi: 10.14445/22312803/IJCTT-V22P121.

[16] A. C. V. D. Berg, S. Giest, and W. Kraaij, "Assessing inclusivity in online platforms through usability evaluation with Google Analytics," *Policy & Internet*, vol. 15, no. 1, pp. 55–77, Mar. 2023, doi: 10.1002/poi3.328.

[17] S. G. Johnson, T. Potrebny, L. Larun, D. Ciliska, and N. R. Olsen, "Usability methods and attributes reported in usability studies of mobile apps for health care education: scoping review," *JMIR Medical Education*, vol. 8, no. 2, Jun. 2022, doi: 10.2196/38259.

[18] N. S. Aziz, N. S. Sulaiman, W. N. I. T. M. Hassan, N. L. Zakaria, and A. Yaacob, "A review of website measurement for website usability evaluation," *Journal of Physics: Conference Series*, vol. 1874, no. 1, May 2021, doi: 10.1088/1742-6596/1874/1/012045.

[19] J. Lu, M. Schmidt, M. Lee, and R. Huang, "Usability research in educational technology: a state-of-the-art systematic review," *Educational technology research and development*, vol. 70, no. 6, pp. 1951–1992, Dec. 2022, doi: 10.1007/s11423-022-10152-6.

[20] M. Hertzum, *Usability testing: A practitioner's guide to evaluating the user experience*. Cham: Springer International Publishing, 2020, doi: 10.1007/978-3-031-02227-2.

[21] K. Ishaq, F. Rosdi, N. A. M. Zin, and A. Abid, "Heuristics and think-aloud method for evaluating the usability of game-based language learning," *International Journal of Advanced Computer Science and Applications*, vol. 12, no. 11, 2021, doi: 10.14569/IJACSA.2021.0121136.

[22] O. Alhadreti, "Comparing two methods of usability testing in Saudi Arabia: concurrent think-aloud vs. co-discovery," *International Journal of Human–Computer Interaction*, vol. 37, no. 2, pp. 118–130, Jan. 2021, doi: 10.1080/10447318.2020.1809152.

[23] M. Prokop, L. Pilař, and I. Tichá, "Impact of think-aloud on eye-tracking: a comparison of concurrent and retrospective think-aloud for research on decision-making in the game environment," *Sensors*, vol. 20, no. 10, pp. 1-21, May 2020, doi: 10.3390/s20102750.

[24] M. Hertzum, "Concurrent or retrospective thinking aloud in usability tests: a meta-analytic review," *ACM Transactions on Computer-Human Interaction*, vol. 31, no. 3, pp. 1–29, Jun. 2024, doi: 10.1145/3665327.

[25] J. Holbrook, C. Stephens, L. J. P. III, S. Bastami, and D. Kiggins, "Learning about routine successful pilot techniques using a cued retrospective think-aloud task," in *22nd International Symposium on Aviation Psychology*, 2023, pp. 1–7. [Online]. Available: https://corescholar.libraries.wright.edu/isap_2023/54

[26] M. P. Jaya, G. R. Dantes, and M. Candiasa, "Analysis of Jejak Bali virtual class using usability testing, including concurrent think aloud techniques and performance measurement techniques," *Journal of Physics: Conference Series*, vol. 1810, no. 1, Mar. 2021, doi: 10.1088/1742-6596/1810/1/012010.

[27] M. Fan *et al.*, "Older adults' concurrent and retrospective think-aloud verbalizations for identifying user experience problems of VR games," *Interacting with Computers*, vol. 34, no. 4, pp. 99–115, Feb. 2022, doi: 10.1093/iwc/iwac039.

[28] I. M. S. Sandhiyasa, I. G. A. Gunadi, and G. Indrawan, "The evaluation of the academic progress information system SIsKA-NG mobile based on heuristic and user experience," *International Journal of Modern Education and Computer Science*, vol. 14, no. 2, pp. 55–64, Apr. 2022, doi: 10.5815/ijmecs.2022.02.05.

[29] L. W. P. Peute, N. F. de Keizer, and M. W. M. Jaspers, "The value of retrospective and concurrent think aloud in formative usability testing of a physician data query tool," *Journal of Biomedical Informatics*, vol. 55, pp. 1–10, Jun. 2015, doi: 10.1016/j.jbi.2015.02.006.

[30] S. McDonald, H. M. Edwards, and T. Zhao, "Exploring think-alouds in usability testing: an international survey," *IEEE Transactions on Professional Communication*, vol. 55, no. 1, pp. 2–19, Mar. 2012, doi: 10.1109/TPC.2011.2182569.

[31] M. Schrepp, J. Kollmorgen, and J. Thomaschewski, "A comparison of SUS, UMUX-LITE, and UEQ-S," *Journal of User Experience*, vol. 18, no. 2, pp. 86–104, 2023.

[32] H. Santoso, M. Schrepp, R. Y. Kartono Isal, A. Yudha Utom, and B. Priyogi, "Measuring the user experience," *The Journal of Educators Online*, vol. 13, no. 1, Jan. 2016, doi: 10.9743/JEO.2016.1.5.

[33] M. A. Kushendriawan, H. B. Santoso, P. O. H. Putra, and M. Schrepp, "Evaluating user experience of a mobile health application 'Halodoc' using user experience questionnaire and usability testing," *Jurnal Sistem Informasi*, vol. 17, no. 1, pp. 58–71, Apr. 2021, doi: 10.21609/jsi.v17i1.1063.

[34] M. Schrepp, A. Hinderks, and J. Thomaschewski, "Construction of a benchmark for the user experience questionnaire (UEQ)," *International Journal of Interactive Multimedia and Artificial Intelligence*, vol. 4, no. 4, pp. 40-44, 2017, doi: 10.9781/ijimai.2017.445.

[35] A. Hidayat, F. I. Pratama, and J. Nadik, "User experience measurement of ERebana application using user experience questionnaire," in *2022 IEEE 8th International Conference on Computing, Engineering and Design (ICCED)*, Jul. 2022, pp. 1–5, doi: 10.1109/ICCED56140.2022.10010409.

[36] R. Novendra, N. Jalinus, W. Waskito, A. Afriansyah, and A. Rasfira, "User satisfaction analysis f service quality of DAPODIK applications (educational data) using servqual method," *Journal of Applied Engineering and Technological Science (JAETS)*, vol. 3, no. 2, pp. 185–189, Jun. 2022, doi: 10.37385/jaets.v3i2.790.

[37] K. Y. Sarasmayana, L. J. E. Dewi, and I. M. G. Sunarya, "Usability evaluation of the academic information system using the concurrent think-aloud, webuse, and sus methods," *Journal of Computer Networks, Architecture and High Performance Computing*, vol. 6, no. 2, pp. 903–912, Jun. 2024, doi: 10.47709/cnahpc.v6i2.3977.

[38] I. T. Pratama, R. Putri, R. Fernanda, and Sunardi, "The usability analysis of human resource information system (HRIS) using usability scale system and concurrent think aloud," in *2022 International Conference on Informatics, Multimedia, Cyber and Information System (ICIMCIS)*, Nov. 2022, pp. 270–275, doi: 10.1109/ICIMCIS56303.2022.10017542.

[39] J. J. Tejada and J. R. B. Punzalan, "On the misuse of Slovin's formula," *The Philippine Statistician*, vol. 61, no. 1, pp. 129-136, 2012.

[40] M. Schrepp, *User experience questionnaires: how to use questionnaires to measure the user experience of your products?* Amazon Digital Services LLC, 2021.

[41] N. A. Hidayah, N. Hasanati, R. N. Putri, K. F. Musa, Z. Nihayah, and A. Muin, "Analysis using the technology acceptance model (TAM) and DeLone & McLean information system (D&M IS) success model of AIS mobile user acceptance," in *2020 8th International Conference on Cyber and IT Service Management (CITSM)*, Oct. 2020, pp. 1–4, doi: 10.1109/CITSM50537.2020.9268859.

[42] A. S. Al-Adwan, N. Li, A. Al-Adwan, G. A. Abbasi, N. A. Albelbisi, and A. Habibi, "Extending the technology acceptance model (TAM) to predict university students' intentions to use metaverse-based learning platforms," *Education and Information Technologies*, vol. 28, no. 11, pp. 15381–15413, Nov. 2023, doi: 10.1007/s10639-023-11816-3.

BIOGRAPHIES OF AUTHORS

Gede Indrawan ⓘ � SC ◑ is a professor in computer engineering technology. He received his doctoral degree in electrical engineering and informatics from Institut Teknologi Bandung, Indonesia. He is a lecturer in the Electronic Systems Engineering Technology Diploma Program and the Computer Science Graduate Program at Universitas Pendidikan Ganesha, Bali, Indonesia. His research interests include mobile computing, Balinese script computerization, robotics, internet of things (IoT), biometrics, and pattern recognition. He can be contacted at email: gindrawan@undiksha.ac.id or gindrawan@mobilecomputing.id.

Sariyasa ⓘ � SC ◑ is a professor of mathematics. He received his doctoral degree in mathematics from Flinders University, Australia. He is a lecturer in the Mathematics Education Undergraduate Program and the Computer Science Graduate Program at Universitas Pendidikan Ganesha, Bali, Indonesia. His research interests include IT evaluation, finite-state automata, complexity analysis, and numerical computation. He can be contacted at email: sariyasa@undiksha.ac.id or sariyasa@mobilecomputing.id.

Luh Joni Erawati Dewi ⓘ � SC ◑ is an associate professor of informatics at the Department of Software Engineering Technology, Universitas Pendidikan Ganesha, Bali, Indonesia. She received her doctor's degree in educational research and evaluation from Universitas Negeri Jakarta. She is also a lecturer in the Computer Science Graduate Program at Universitas Pendidikan Ganesha. Her research interests include technology for learning, data mining, machine learning, data analytics, various algorithms, and data structures. She can be contacted at email: joni.erawati@undiksha.ac.id or joni.erawati@mobilecomputing.id.

Made Santo Gitakarma ⓘ � SC ◑ is an associate professor of electrical engineering at the Department of Electronic Systems Engineering Technology, Universitas Pendidikan Ganesha, Bali, Indonesia. He received his doctoral degree in computer science from Universitas Gadjah Mada, Indonesia. His research interests include robotics, mobile computing, computer networks, and IoT. He can be contacted at email: santo@undiksha.ac.id or santo@mobilecomputing.id.

I Made Agus Oka Gunawan ⓘ � SC ◑ is an associate professor of computer science at the Department of Information Systems, Universitas Tabanan, Bali, Indonesia. He received his master's degree in computer science from Universitas Pendidikan Ganesha, Bali, Indonesia. His research interests include software engineering and evaluation systems. He can be contacted at email: agusokagunawan@mobilecomputing.id.

Putu Ade Pranata ⓘ � SC ◑ is an information technology teacher at SMK TI Bali Global Badung, Bali, Indonesia. He is a master's student in the computer science study program at Universitas Pendidikan Ganesha, Bali, Indonesia. His research interests include software engineering and evaluation systems. He can be contacted at email: ade.pranata@mobilecomputing.id.