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Utilizing Mobile Applications for 21st-Century Learning and Digital Preservation of Balinese Script

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Abstract: Balinese Script and other local languages are facing extinction as their use has been increasingly replaced by national languages, which are simpler and more practical. To preserve this local wisdom, Bali province has implemented governor regulations promoting various efforts, including compulsory Balinese language subjects (covering Balinese Script) in schools from primary to high school and requiring institution nameplates to be written in Balinese Script alongside other languages. Despite these efforts, there is still a gap in the technological support for preserving the script. This collaborative study, a joint effort between language and computer science, explores the technological side of these preservation initiatives. The study demonstrates the advantages of using a proposed mobile application for 21st-century learning of Balinese Script. The application offers paperless material, aligning with green and sustainable learning practices, and improves the efficiency of acquiring knowledge related to transliteration and translation from Latin text input. This approach supports real-time learning and makes the process of learning Balinese Script more accessible, effective, and efficient for a broader audience. The integration of technology in this context is considered a significant contribution to the preservation of Balinese Script and serves as a model for other local language preservation efforts in the digital age.

Keywords: Mobile Application, 21st-Century Learning, Digital Preservation, Balinese Script

INTRODUCTION

This study is a crucial contribution to the urgent research in technology for information data on various forms of local wisdom in Indonesia (Indonesian Ministry of Education, Culture, Research and Technology, 2024). One of those various forms of local wisdom is the Balinese Script used in Bali, which enriches local culture and supports tourism. Like other local languages or scripts, Balinese Script, as an Abugida (Verhoeven & Perfetti, 2022; Pandey & Padakannaya, 2023), faces an extinction signal since its use has already been replaced by the national language, which is simpler and more practical. This condition raises concerns over its knowledge preservation, including its transliteration knowledge (Mammadzada, 2023; Erawati, Mulyawan, & Sulibra, 2024). Bali province has already had governor regulations, to anticipate this extinction signalment through many efforts in Bali, including conducting compulsory local content subject Balinese language (covering Balinese Script) from primary to high school, requiring institution's name plate to be written in Balinese Script along with different languages, requiring local, national, and international event using the Balinese language along with different languages, requiring local, national, and international event using the Balinese language along with different languages, requiring public places announcement, like airport, using the Balinese language along with different languages, etc. For the greater impact of preservation, regulations and other supports, such as technological support in 21st-century learning, were needed.

The 21st-century learning (Herlinawati et al., 2024; Jumriani & Prasetyo, 2022) is related to technology-based learning to improve students' digital literacy skills. Indonesia is moving forward to 21st-century learning. This study proposes specific Balinese Script learning mobile applications as a preparation and a technological product

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for digital preservation based on the background problem described previously. The advantage of using this proposed Information Technology application for 21st-century learning of Balinese Script, including paperless material to conduct green-and-sustainable-oriented learning and efficiency to grab knowledge in real-time related to the transliteration and translation aspects from Latin text input. That effort was considered the main contribution to this research area.

In this study, there are several aspects related to the utilization of mobile applications for 21st-century learning and digital preservation of Balinese Script, namely: 1) the compliance with the standard rules (Anom et al., 2013) of transliteration for both Latin input to Balinese Script output and vice versa (Indrawan et al., 2023; Dewi et al., 2023); 2) the additional translation for the related Latin text input; and 3) the compliance with the Unicode of Balinese Script for the computer font (Indrawan et al., 2022; Le, 2021) that was used by the mobile application to render Balinese Script output in its scriptio-continua style (Widiarti & Pulungan, 2020; Butskhrikidze, 2021).

The standard rules for the transliteration process are regulated by the Balinese Language, Script, and Literature Advisory Agency, which is the Bali Province government agency that carries out guidance and formulates programs for the maintenance, study, development, and preservation of the Balinese Language, Script, and Literature. They involve rules for basic syllables (akśara wreṣāstra), vowels, semi-vowels, adopted syllables (akśara ṣwalalita), sound killers (pangangge tengenan), holy symbols, numerals, punctuations, ligatures, and other presentation issues (Indrawan, Paramarta, Nurhayata, & Sariyasa, 2021; Indrawan et al., 2023; Paramarta, Indrawan, & Rai, 2024). The translation process depends on the content in the mobile application database, which is in the Indonesian language that came from the dictionary book (Anom et al., 2013). Additional English translation in that database was the other significant contribution of this research to create awareness among international users.

Regarding compliance with the Unicode of Balinese Script, mobile applications use the computer font Noto Serif Balinese to display Balinese Script. Other Unicode-compliant Balinese computer fonts have different styles of shapes, including Noto Sans Balinese, Kadiri, Pustaka Bali, and Vimala. The last three fonts are under the GitHub repository.

This paper was organized into several sections, namely Section 1 described the problem background and supporting previous research; Section 2 conveyed the method to handle the challenge of the source of knowledge to be accommodated by the mobile application to provide that knowledge in a better way; Section 3 covered the analysis of the previous section; and finally, Section 4 consisted of some important conclusion points.

METHOD

Utilizing mobile applications for 21st-century learning and digital preservation of Balinese Script in this study exposes the method to handle the challenges that exist in the source of knowledge, in the form of the dictionary book (Anom et al., 2013), to be accommodated by mobile applications (Indrawan et al., 2023; Dewi et al., 2023). That method was conducted to represent the knowledge better in mobile applications. Figure 1 shows a sample of the source of knowledge consisting of imaginary dashed-line rectangles. Each complete dashed-line rectangle consists of a base word with related derivative words. An incomplete dashed-line rectangle means other related words are on the other page or column.

Other challenges, which were the focus of this study, included the aspect of spelling, pasang pageh (terminology in the Balinese language for any transliteration exception from the standard rules), homonyms, meaningful stand-alone base words and dependent base forms (kind of root words that must have a suffix or a prefix to be meaningful), derivative words, nasal prefix, combined word (phrase), and connotative phrases. Those challenges were related to the problem identification stage of Figure 2 and continued in the literature study on how the utilized mobile applications were developed to accommodate them.

Based on this stage, the transliteration algorithm of the applications was designed using the Finite-State Machine (FSM) method (Raj, Kalpana, & Singh, 2020; Sajini, Suja, Gilbert Raj, Kowsalyadevi, & Maria, 2023), which has less computational power than some other models of computation, and the number of states limits its memory. An FSM is a mathematical model of computation consisting of a finite number of states, transitions between those states, and actions associated with those transitions. It is used to represent and control execution flow in systems with a limited set of conditions or behaviors. FSMs are known for their efficiency and compactness, especially in VLSI design, where state assignment is crucial for optimizing power consumption and area. The method's simplicity and reduced computational complexity make it suitable for embedded systems or mobile devices with limited resources.

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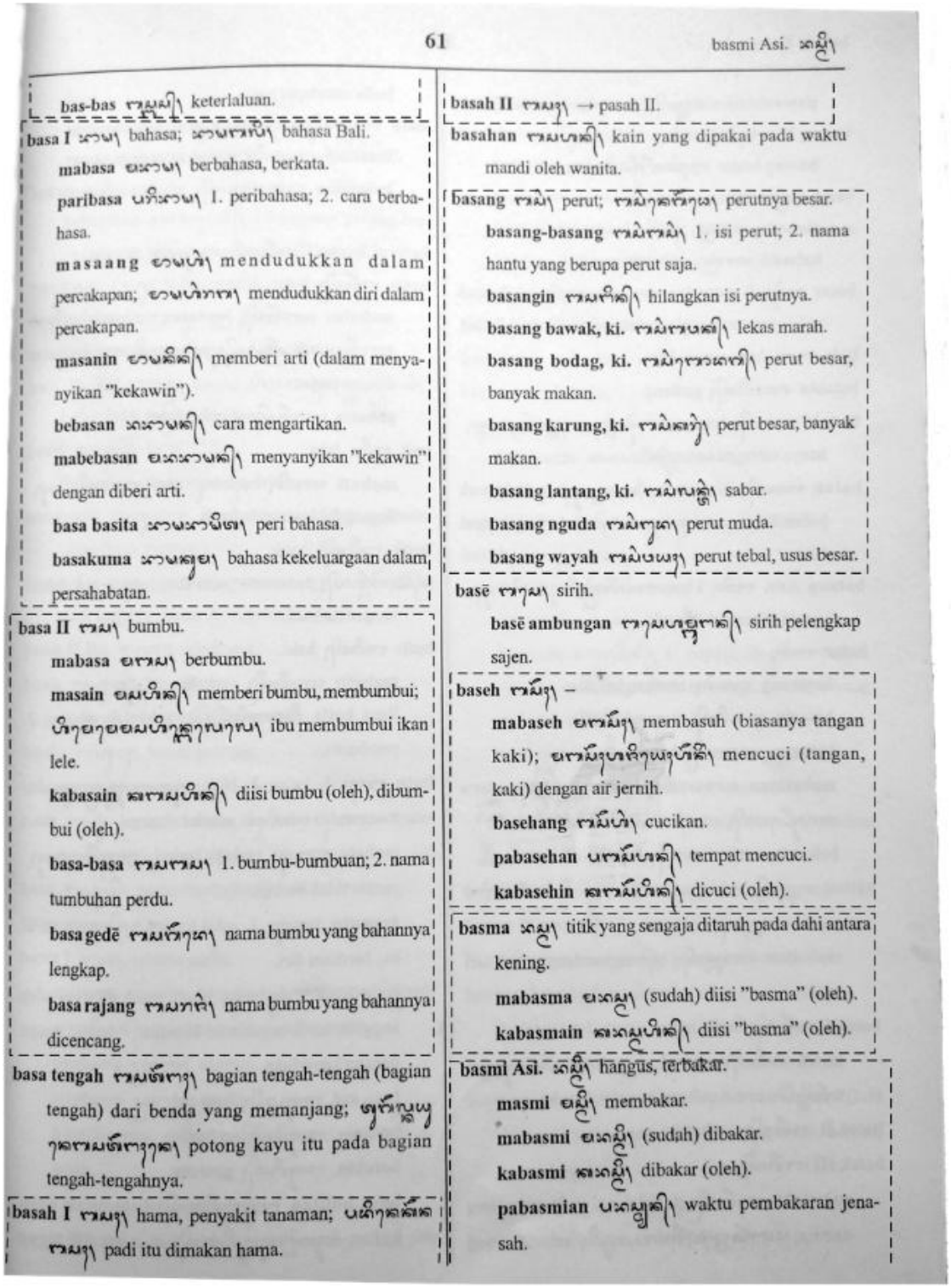

61 basmi Asi.

bas-bas keterlaluan.

basa I bahasa; bahasa Bali.
mabasa berbahasa, berkata.
paribasa 1. peribahasa; 2. cara berbahasa.
masaang mendudukkan dalam percakapan; mendudukkan diri dalam percakapan.
masanin memberi arti (dalam menyanyikan "kekawin").
bebasan cara mengartikan.
mabebasan menyanyikan "kekawin" dengan diberi arti.
basa basita peri bahasa.
basakuma bahasa kekeluargaan dalam persahabatan.

basa II bumbu.
mabasa berbumbu.
masain memberi bumbu, membumbui; ibu membumbui ikan lele.
kabasain diisi bumbu (oleh), dibumbui (oleh).
basa-basa 1. bumbu-bumbuan; 2. nama tumbuhan perdu.
basa gedē nama bumbu yang bahannya lengkap.
basa rajang nama bumbu yang bahannya dicencang.

basa tengah bagian tengah-tengah (bagian tengah) dari benda yang memanjang; potong kayu itu pada bagian tengah-tengahnya.

basah I hama, penyakit tanaman; padi itu dimakan hama.

basah II → pasah II.

basahan kain yang dipakai pada waktu mandi oleh wanita.

basang perut; perutnya besar.
basang-basang 1. isi perut; 2. nama hantu yang berupa perut saja.
basangin hilangkan isi perutnya.
basang bawak, ki. lekas marah.
basang bodag, ki. perut besar, banyak makan.
basang karung, ki. perut besar, banyak makan.
basang lantang, ki. sabar.
basang nguda perut muda.
basang wayah perut tebal, usus besar.

basē sirih.
basē ambungan sirih pelengkap sajen.

baseh –
mabaseh membasuh (biasanya tangan kaki); mencuci (tangan, kaki) dengan air jernih.
basehang cucikan.
pabasehan tempat mencuci.
kabasehin dicuci (oleh).

basma titik yang sengaja ditaruh pada dahi antara kening.
mabasma (sudah) diisi "basma" (oleh).
kabasmain diisi "basma" (oleh).

basmi Asi. hangus, terbakar.
masmi membakar.
mabasmi (sudah) dibakar.
kabasmi dibakar (oleh).
pabasmian waktu pembakaran jenasah.

Fig. 1 Sample of the source of knowledge

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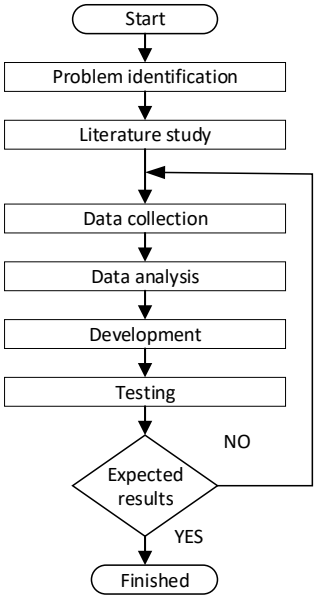

Fig. 2 Research stages

So far, from that FSM model utilization, there is no study to solve the problem in the Balinese Script transliteration area. This research addresses the gap using that model. To the author's knowledge, this study has never been conducted yet and is considered the main contribution of this research.

The data collection stage was related to digitizing sources of knowledge and transforming them according to the needs of the applications. The data analysis should be the stage where the previous challenges, the algorithm, and data collection are analyzed and synchronized for the seamless process of the next stages of development and testing.

The iteration process of the research stages was unavoidable since the previous stages started from the data collection stage, which needed to be improved because many exceptions from standard transliteration rules existed and needed to be accommodated.

Figure 3a shows examples of Balinese Script and its Latin text in the Balinese-Indonesian dictionary with Balinese Script as the ground truth for validation for the developed FSM model of Balinese Script conversion. Figure 3b shows Balinese Script glyphs and their Unicode (https://unicode.org/charts/PDF/U1B00.pdf). Figure 4 shows the FSM's state-transition example during transliteration to the Balinese Script. Table 1 shows more possible state transitions at the state-transition table, as the gray row represents the state transition example in Figure 4, each for (1) current state "A" with its next state "ke" (gray row of section No. 3); (2) current state "ke" with its next state is "h" (gray row of section No. 2); and (3) current state "h" without its next state that indicates the end of the transliteration process (gray row of section No. 4).

Several aspects related to the state-transition example, i.e.: a) Database searching for special words from the Latin text input was conducted. Words were identified from the Latin text input by the space separation. Figure 4 shows an example of a Balinese word "Akeh" (many) for simplicity; b) If the word "Akeh" has a special word flag in the database's table (represented by value *1* of column "special" from the return record with column "word" value equal to "akeh"), then that word is replaced with a pre-defined special word or Balinese Script code (represented by the value of column "sword") for the proper transliteration by using the FSM-based method to the Balinese Script. Noted that in this example, the word "Akeh" has no special word flag (represented by value *0* of column "special") and it would be replaced by the same word "akeh" of column "sword". Noted that the word "Akeh" and "akeh" would be transliterated the same since the uppercase letter has no difference in the process (case-insensitive transliteration); c) The FSM's current state or next state of the Latin text input (modified or not by the existing special words) contains various letter combinations that must comply with the standard transliteration rules. Figure 4 shows an example of a current state "A" with its next state "ke". Next, continue to a current state "ke" with its next state is "h"; d) A current state "A" should be converted as a Balinese Script code "ha", i.e. a consonant "h" with its inheritance sound "a" ([a], before being transliterated to the Balinese Script "ᬳ" (Unicode U+1B33). Its next state "ke" ([ke]) should be converted the same as a Balinese Script code "ke" before transliterated to the Balinese Script "ᬓᬾ", which is a combination of two Balinese Script glyphs, i.e., (1) basic syllable "ka" ("ᬓ", U+1B13); and (2) vowel sign *taling* "e" ("ᬾ", U+1B62). Next, continue to a current

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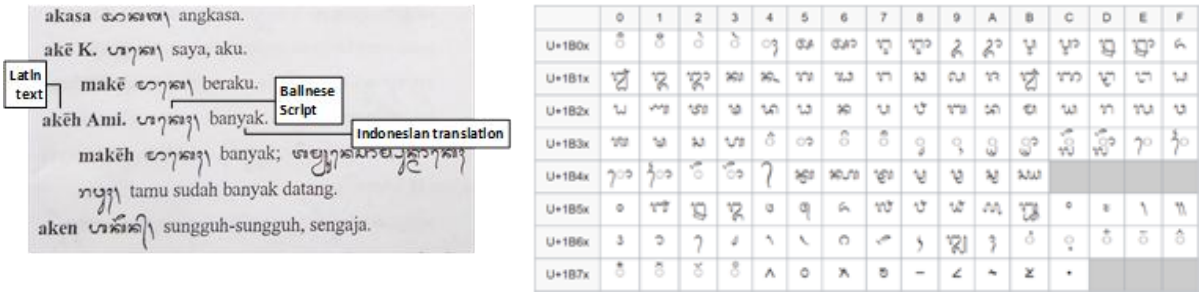
state “ke” with its next state sound-killer “h” (IPA: [h]) should be converted the same as a Balinese Script code “h” before being transliterated to the Balinese Script *bisah* “ᭃ” (U+1B04). So, all together combined, the word “Akeh” should be converted as a Balinese Script code “hakeh” ([hakeh]) before being transliterated to Balinese Script “ᬳᬲᬓᬵᬲ᭄”. Noted that this is a case-insensitive transliteration process, as described previously; and e) The output result is the Balinese Script code that was displayed to the Balinese Script by the Noto Serif Balinese font with its dedicated Balinese Script Unicode.



(a) (b)

Fig. 3 Balinese Script: (a) Examples from the Balinese-Indonesian dictionary; (b) Unicode

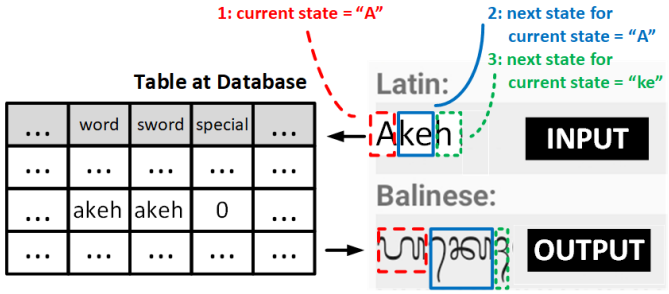


Fig. 4 The state-transition example

Table 1. State transition table of the FSM model in converting Balinese Script

No.	Current State[1]	Input	Next State	Output
1	substr(*in*[*i*], *j*, k_1) = syl_1	*j*+1 + k_2-1 < *in.length* AND (substr(*in*[*i*], *j*+1, k_2) = syl_2 OR substr(*in*[*i*], *j*+1, k_2) = cvs_1 OR substr(*in*[*i*], *j*+1, k_2) = vow_1 OR substr(*in*[*i*], *j*+1, k_2) = csk_1 OR substr(*in*[*i*], *j*+1, k_2) = num_1 OR substr(*in*[*i*], *j*+1, k_2) = pun_1 OR substr(*in*[*i*], *j*+1, k_2) = nl_1)	substr(*in*[*i*], *j*+1, k_2)	*out* = *out* . *conv*(substr(*in*[*i*], *j*, k_1))
		j+1 + k_2-1 ≥ *in.length*		*out* = *out* . *conv*(substr(*in*[*i*], *j*, k_1))
2	substr(*in*[*i*], *j*, k_1) = cvs_1	*j*+1 + k_2-1 < *in.length* AND (substr(*in*[*i*], *j*+1, k_2) = syl_1 OR substr(*in*[*i*], *j*+1, k_2) = cvs_2 OR substr(*in*[*i*], *j*+1, k_2) = vow_1 OR substr(*in*[*i*], *j*+1, k_2) = csk_1 OR substr(*in*[*i*], *j*+1, k_2) = num_1 OR substr(*in*[*i*], *j*+1, k_2) = pun_1 OR substr(*in*[*i*], *j*+1, k_2) = nl_1)	substr(*in*[*i*], *j*+1, k_2)	*out* = *out* . *conv*(substr(*in*[*i*], *j*, k_1))
		j+1 + k_2-1 ≥ *in.length*		*out* = *out* . *conv*(substr(*in*[*i*], *j*, k_1))
3	substr(*in*[*i*], *j*, k_1) = vow_1	*j*+1 + k_2-1 < *in.length* AND (substr(*in*[*i*], *j*+1, k_2) = syl_1 OR substr(*in*[*i*], *j*+1, k_2) = cvs_1 OR substr(*in*[*i*], *j*+1, k_2) = vow_2 OR substr(*in*[*i*], *j*+1, k_2) = sk_1 OR substr(*in*[*i*], *j*+1, k_2) = num_1 OR substr(*in*[*i*], *j*+1, k_2) = pun_1 OR substr(*in*[*i*], *j*+1, k_2) = nl_1)	substr(*in*[*i*], *j*+1, k_2)	*out* = *out* . *conv*(substr(*in*[*i*], *j*, k_1))
		j+1 + k_2-1 ≥ *in.length*		*out* = *out* . *conv*(substr(*in*[*i*], *j*, k_1))
4	substr(*in*[*i*], *j*, k_1) = csk_1	*j*+1 + k_2-1 < *in.length* AND (substr(*in*[*i*], *j*+1, k_2) = syl_1 OR substr(*in*[*i*], *j*+1, k_2) = cvs_1 OR substr(*in*[*i*], *j*+1, k_2) = vow_1 OR substr(*in*[*i*], *j*+1, k_2) = csk_2 OR substr(*in*[*i*], *j*+1, k_2) = num_1 OR substr(*in*[*i*], *j*+1, k_2) = pun_1 OR substr(*in*[*i*], *j*+1, k_2) = nl_1)	substr(*in*[*i*], *j*+1, k_2)	*out* = *out* . *conv*(substr(*in*[*i*], *j*, k_1))
		j+1 ≥ *in.length*		*out* = *out* . *conv*(substr(*in*[*i*], *j*, k_1))
5	substr(*in*[*i*], *j*, 1) = num_1	*j*+1 + k_2-1 < *in.length* AND (substr(*in*[*i*], *j*+1, k_2) = syl_1 OR substr(*in*[*i*], *j*+1, k_2) = cvs_1 OR substr(*in*[*i*], *j*+1, k_2) = vow_1 OR substr(*in*[*i*], *j*+1, k_2) = csk_1 OR substr(*in*[*i*], *j*+1, k_2) = num_2 OR substr(*in*[*i*], *j*+1, k_2) = pun_1 OR substr(*in*[*i*], *j*+1, k_2) = nl_1)	substr(*in*[*i*], *j*+1, k_2)	*out* = *out* . *conv*(substr(*in*[*i*], *j*, 1))

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		j+1 ≥ *in.length*		*out* = *out* . *conv*(substr(*in*[*i*], *j*, 1))
6	substr(*in*[*i*], *j*, 1) = pun_1	j+1 + k_2-1 < *in.length* AND (substr(*in*[*i*], j+1, k_2) = syl_1 OR substr(*in*[*i*], j+1, k_2) = cvs_1 OR substr(*in*[*i*], j+1, k_2) = vow_1 OR substr(*in*[*i*], j+1, k_2) = csk_1 OR substr(*in*[*i*], j+1, k_2) = num_1 OR substr(*in*[*i*], j+1, k_2) = pun_2 OR substr(*in*[*i*], j+1, k_2) = nl_1)	substr(*in*[*i*], j+1, k_2)	*out* = *out* . *conv*(substr(*in*[*i*], *j*, 1))
		j+1 ≥ *in.length*		*out* = *out* . *conv*(substr(*in*[*i*], *j*, 1))
7	substr(*in*[*i*], *j*, 1) = nl_1	j+1 + k_2-1 < *in.length* AND (substr(*in*[*i*], j+1, k_2) = syl_1 OR substr(*in*[*i*], j+1, k_2) = cvs_1 OR substr(*in*[*i*], j+1, k_2) = vow_1 OR substr(*in*[*i*], j+1, k_2) = csk_1 OR substr(*in*[*i*], j+1, k_2) = num_1 OR substr(*in*[*i*], j+1, k_2) = pun_1 OR substr(*in*[*i*], j+1, k_2) = nl_2)	substr(*in*[*i*], j+1, k_2)	*out* = *out* . *conv*(substr(*in*[*i*], *j*, 1))
		j+1 ≥ *in.length*		*out* = *out* . *conv*(substr(*in*[*i*], *j*, 1))

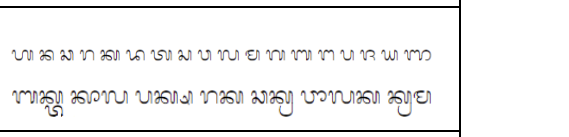
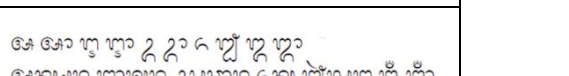
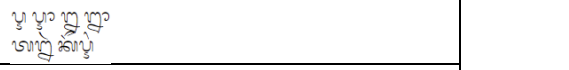
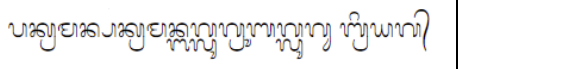
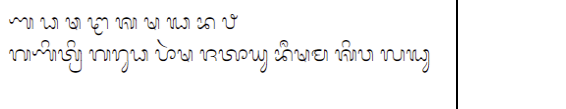
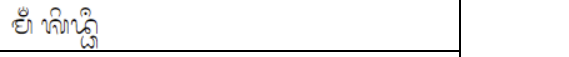
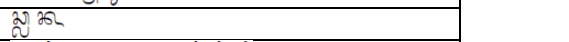
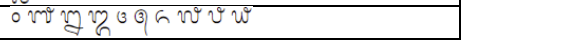
[1] Current State may consist of a syllable (***syl***), a combination of consonant and dependent vowel sign (***cvs***), vowel (***vow***), consonant (***csk***), numeric (***num***), punctuation (***pun***), or new line (***nl***).

The implementation was done on the mobile application installed on an 8 GB RAM targeted mobile device with a hardware platform of 8-core CPU (2 ARM Cortex-A76 @2.05 GHz and 6 ARM Cortex-A55 @2.05 GHz) and 64-bit Android 13 Operating System. That mobile application was developed with the cross-platform Flutter framework. The web server was constructed by Apache, the database server MySQL, and the programming language PHP, combined with JavaScript.

RESULT

Refer to the Balinese Alphabet document, Table 2 shows the representative testing cases and results that comply with the standard transliteration rules (Anom et al., 2013).

Table 2. Testing Cases

No.	Category with examples (in English translation for transliterated words in the next column)	Case (in Balinese or Indonesian syllables, phrases, or words)	Result
1	Basic syllables and examples. Bring Time Force “Bigger brother” Disc “A non-priest” Member	ha na ca ra ka da ta sa wa la ma ga ba nga pa ja ya nya Bakta Kala Paksa Raka Cakra Walaka Krama	
2	Vowel signs examples. Sold House Nine Wood Yam “Musical instrument” Giant “Should be” Two	Kādep Jĕro Siya Kayu Sēla Angklung Daitya Patūt Dwī	
3	Independent vowels and examples. Alphabet “God’s name” Ceremony One “A Javanese King” “One holy letter” “Symbol of God”	a ā i ī u ū ē ai o au Akśara Iswara Upacāra Eka Airlangga Ong OM	
4	Illegal combination of syllable-vowel signs and examples. Also “Eat a lot”	rĕ rö lĕ lö Talĕr Kĕrĕng	
5	Semi-vowel examples. Mr. Raman Membership Stupid “Naive Rubag” Laughter	Pak Raman Pakraman Baglug Rubag lugu Briag	
6	Akśara swalalita and examples. Chain “Big eagle” “Arjuna's alias” “A bird in Ramayana” Decree “God’s name” “Low tone in singing”	na dha tha ta sa śa gha bha pha Ganitri Garudha Partha Jatayu Bhiśama Siwa Laghu	
7	Sound-killer examples. “Musical instrument” Pig Mind Ear Ship	Cēngcēng Bangkung Manah Karna Kapal	
8	Miscellaneous signs examples. “Holy letter” Perfect	Mang Siddham	
9	Holy symbol Ongkara examples. “May God bless you.” “May peace be everywhere.”	Om Swastiastu Om Santi, Santi, Santi, Om	
10	Miscellaneous syllables.	cha kha	
11	The digits.	0 1 2 3 4 5 6 7 8 9	

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12	Punctuations.	, . < .0. > >> : "	[illegible]
13	Some variation of usages. Combination of independence-vowel a kara with vowel signs Pairing of pa kapal with suku or suku ilut Romanization of the inherent sound: Real real Usage of pangangge akśara: Side "Thank you" Warrior Wife "Books of Vedha" Primary Religion "A village's name"	i u ē o ĕ ö pu phu Sekala sekalĕ Samping Sukśma Kśatria Strī Smerti Utama Dharma Tamblang	[illegible]
14	Ligatures.	hā nā cā rā kā dā tā sā wā lā mā gā pā yā nā dhā thā tā şā śā ghā bhā	[illegible]
15	Abbreviation examples. Regional Development Bank Bali Be Pe De Bali Ba Pe Da Bali Ba Pa Da Bali	Bank Pembangunan Daerah Bali Bē, Pē, Dē, Bali Ba, Pe, Da, Bali Ba, Pa, Da, Bali	[illegible]
16	Word boundaries and line break rules. Many of those letters, 47, i.e.: vowels, 14, consonants, 33, those vowels also become vowel signs, and have two sounds, each is called: sound hrĕswa and dīrgha.	Akeh akśaranē, 47, luir ipun: akśara suara, 14, akśara wianjana, 33, akśara suara punika talĕr dados pangangge suara, tur madrĕwe suara kakalih, kawāśtanin: suara hrĕswa miwah dīrgha.	[illegible]

All examples can be seen in Figure 1 and their use in mobile applications (Indrawan et al., 2023; Dewi et al., 2023), as shown in Figure 5 and Figure 6. The application accommodated several aspects of the source of knowledge from the dictionary book, including providing English translation information that did not exist in the dictionary book and was considered a significant contribution to this research.

Related to the aspect of spelling, Latin text writing is based on the improved Balinese language spelling which is following the decree of the Indonesian Ministry of Education and Culture No. 070/U/1974 (Anom et al., 2013), with the exception on writing "ē" (IPA: [e]) (Ramli, Jamil, & Ardi, 2020; Trinh, Nguyen, & Le, 2022) and "e" [ə] were differentiated by diacritic sign. The examples are shown by the words "basē" (betel) and "baseh" (with the prefix "ma" meaning to wash hands and/or feet, see the next dependent base form).

On the aspect of pasang pageh, which happened to loan words from the Kawi language (Old Javanese language and Sansekerta), the example is the word "basa" (language, with the Roman numerals I). This example has its Balinese Script writing or transliteration from Latin text that does not follow the standard rules as does by the word "basa" (seasoning, with the Roman numerals II).

Related to meaningful stand-alone base words and dependent base forms, the examples of the base word are "basa," "basah," "basang" (stomach), "basē," "basma" (A specific material that is intentionally placed on a point area of the forehead between the eyebrows), and "basmi" (burned). An example of the base form is the word "baseh".

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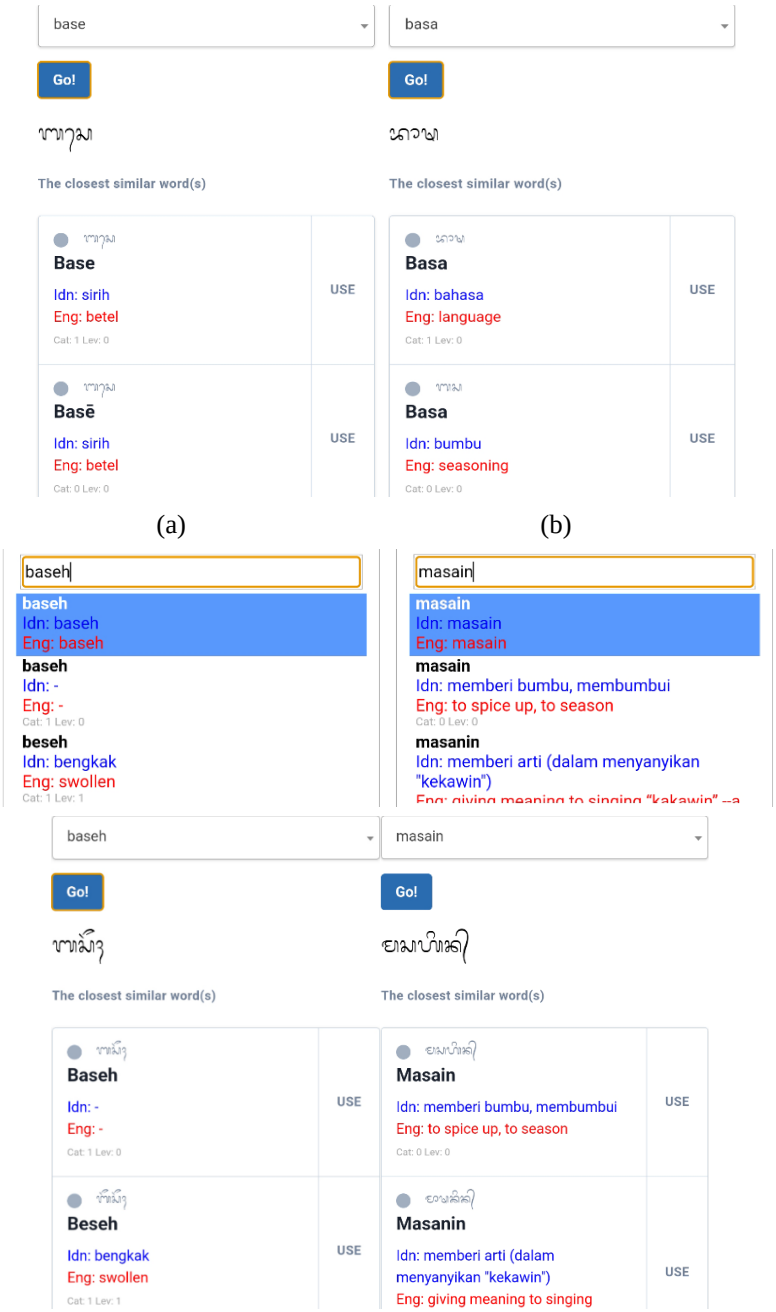

Fig. 5 ToAksara application screenshots for aspects: a) spelling; b) pasang pageh and homonym; c) homonym; and d) nasal prefix of an affixed word

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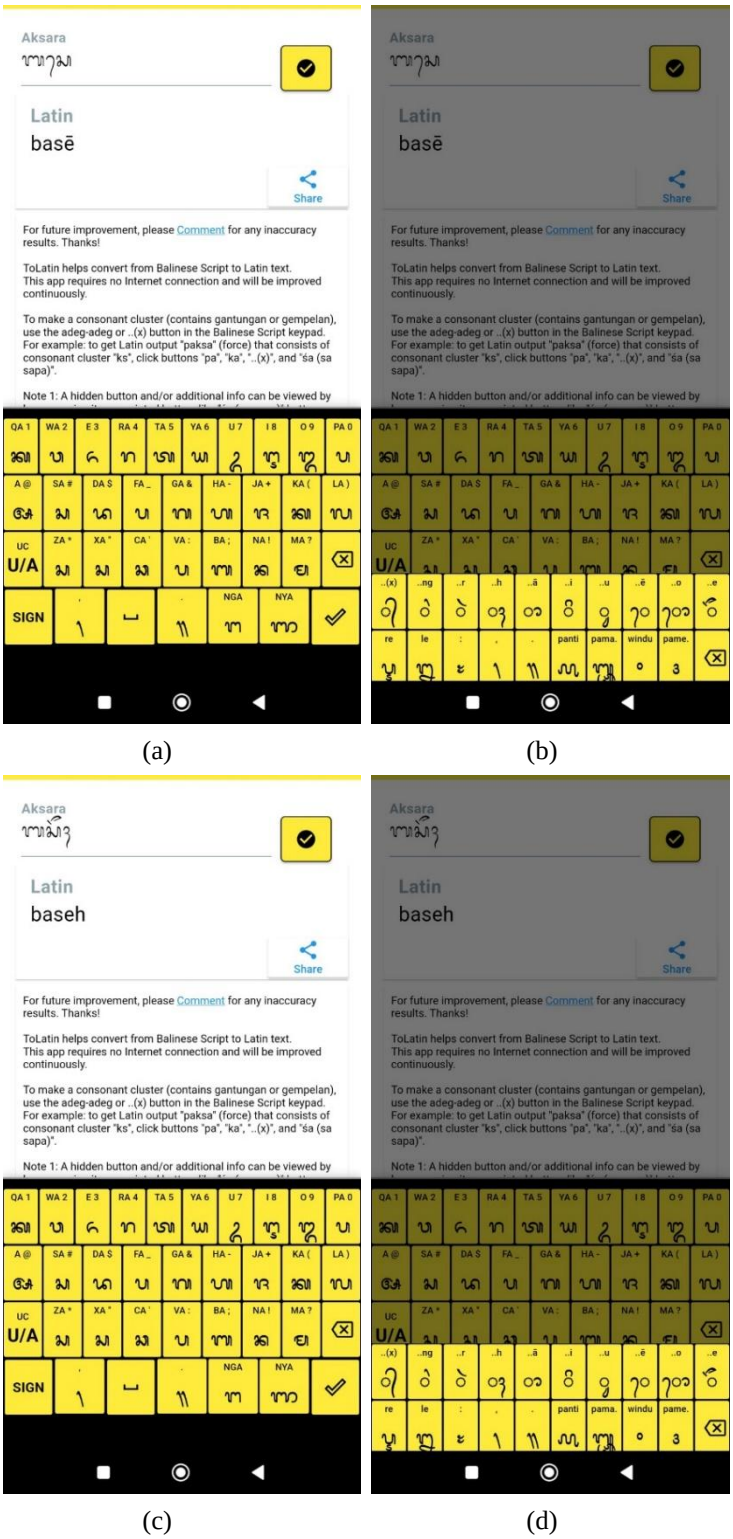

Fig. 6 ToLatin application screenshots for spelling aspect: a) output “ē” with a diacritic sign; b) output “ē” using input sign taling “ᬾ᭄”; c) output “e” without a diacritic sign; and d) output “e” using input sign pepet “

In the Balinese language, a derived word could be in one of three forms: an affixed word, a repeated word, or a compound word (a combination of two or more words with a single meaning). Examples of affixed words are “masaang (sit in the conversation),” “masanin” (giving meaning to singing “kakawin” - a kind of Balinese poetry),

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and “masain” (to spice up, to season). The first two examples come from the base word “basa” (I), and the last example comes from the base word “basa” (II). Examples of repeated words are the word “basa-basa” (1. condiments; 2. the name of the herbaceous plant) and “basang-basang” (1. stomach contents; 2. the name of the ghost in the form of a stomach only). The first example comes from the base word “basa” (II), which means the plural version of that base word, and the last example comes from the base word “basang,” which has a different meaning from its base word and is treated as a separate lemma (Ifada, Rachman, Syauqy, Wahyuni, & Pawitra, 2023). An example of a compound word is the word “basa gedē” (the name of the seasoning whose ingredients are complete), which comes from the base word “basa” (II). This example is treated as a sublemma, and the meaning refers to its first word as a lemma.

Affixed words lead to the other aspect, namely nasal prefixes in the construction of words with allomorph (Saddhono, Ermanto, Susanto, Istanti, & Sukmono, 2023) or nasal consonants “m,” “n,” “ng,” and “ny.” The examples are the same as the examples of affixed words.

Related to a combined word (phrase), it is treated as a sublemma of a lemma of the core word, whether it has an idiomatic meaning or not. Examples of compound words are “basa rajang” and “basang bodag”. The first example comes from the base word “basa” (II), and the last example comes from the base word “basang.”

A connotation phrase does not have a denotative meaning and is treated as a sublemma. An example is the word “basang bawak” (irritable), which comes from the base word “basang”.

Based on all previous challenges that exist on the source of knowledge, which is in the form of the dictionary book, and how the mobile applications accommodate them, the utilized mobile applications in this study was also introduced to high-school teachers at Undiksha‘s community service event series, one of them at SMKN 2 Tejakula, Buleleng, Bali, Indonesia. The purpose was to get ideas from related stakeholders on how 21st-century learning can be conducted from this technological approach.

DISCUSSIONS

The results of this study highlight the successful accommodation of several aspects of Balinese language and script in mobile applications, addressing the gap in available resources for digital preservation and learning. As demonstrated in Figure 1, 5, and 6, the mobile application provided a useful platform for improving the accessibility and understanding of Balinese language elements not found in traditional dictionary books. This is a significant contribution, as it extends the functionality of the dictionary by offering English translations and other important linguistic features, which were not previously available.

In terms of spelling, the study adhered to the improved Balinese language spelling system as prescribed by the Indonesian Ministry of Education and Culture (No. 070/U/1974) (Anom et al., 2013). However, it was noted that certain spelling conventions, such as differentiating between the characters “ē” and “e,” required special attention due to their distinct diacritic markings, as exemplified by the words “basē” (betel) and “baseh” (to wash hands/feet). These distinctions, while important for accuracy, posed challenges in ensuring consistency across the digital platform. The balancing of standardized spelling and linguistic nuances is a critical consideration for the future development of the mobile application.

Moreover, the study discussed the complexities of accommodating loanwords from Kawi (Old Javanese) and Sanskrit, as seen with the word “basa,” which has multiple meanings and varying transliterations depending on context. This issue is compounded by the need to handle dependent base forms, as demonstrated in examples such as "baseh" (a base form of “basa”). The ability to represent these variations accurately in a mobile application is a testament to the potential of digital tools to preserve and enhance regional linguistic resources.

Additionally, the study identified the role of affixed, repeated, and compound words in the Balinese language, with specific examples such as “masaang,” “masanin,” and “masain.” These forms showcase how the mobile application effectively handles complex word constructions, including nasal prefixes and compound words, by treating them as sublemmas or providing context-specific meanings. The mobile application also accommodated phrases with idiomatic meanings, like “basang bawak,” ensuring the full range of linguistic expression was captured.

The successful use of the mobile application in a community service event at SMKN 2 Tejakula further demonstrates its practical application in real-world settings. The event served as a platform for engaging with stakeholders and receiving valuable feedback on how technology can enhance 21st-century learning. This aspect of the study underscores the importance of collaboration with educators to refine the application and ensure its relevance and effectiveness in educational contexts.

CONCLUSION

Utilizing mobile applications for 21st-century learning and digital preservation of Balinese Script in this study exposed several compliance aspects to the standard rules of transliteration and the Unicode of Balinese Script of the computer font used by the mobile applications. Several challenging accommodations of the knowledge from the source to the mobile application were also discussed, and these accommodations were made to provide the

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representation of the knowledge in a better way in the mobile application. The enhancement of those mobile applications would be the future work, including adding user accounts to provide more personal learning experiences, like history, statistics, et cetera.

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