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Article

Interdisciplinary and Intercultural Development of an Early Literacy App in Dhuwaya

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Abstract: Phonological awareness is a skill which is crucial in learning to read. In this paper, we report on the challenges encountered while developing a digital application (app) for teaching phonological awareness and early literacy skills in Dhuwaya. Dhuwaya is a Yolŋu language variety spoken in Yirrkala and surrounding areas in East Arnhem Land. Dhuwaya is the first language of the children who attend a bilingual school in which Dhuwaya and English are the languages of instruction. Dhuwaya and English have different phonemic inventories and different alphabets. The Dhuwaya alphabet is based on Roman alphabet symbols and has 31 graphemes (compared to 26 in English). The app was designed to teach children how to segment and blend syllables and phonemes and to identify common words as well as suffixes used in the language. However, the development was not straightforward, and the impact of the linguistic, cultural and educational challenges could not have been predicted. Amongst these was the inherent variation in the language, including glottal stops, the pronunciation of stops, the focus on syllables as a decoding strategy for literacy development and challenges of finding one-syllable words such as those initially used with English-speaking children. Another challenge was identifying culturally appropriate images which the children could relate to and which were not copyrighted. In this paper, we discuss these plus a range of other issues that emerged, identifying how these problems were addressed and resolved by the interdisciplinary and intercultural team.

Keywords: Aboriginal languages; phonological awareness; biliteracy; bilingual; iPad app

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1. Introduction

While the Aboriginal population of Australia is 3.3%, in the Northern Territory it is 30.3% (Australian Bureau of Statistics 2016). Much of the Aboriginal population lives in remote or very remote areas of the Territory, and many children in these contexts grow up learning a language other than English as a first language—either a form of the Traditional Aboriginal Language (TIL) from the country in which they reside or one of the more recently emerged creoles, new mixed languages, such as Gurindji Kriol (Meakins 2013; Meakins et al. 2019) and Light Warlpiri (O'Shannessy 2013, 2015), or a koine such as Dhuwaya (Amery 1985, 1993). For many of these Aboriginal children, their attendance at school is their first serious engagement with English.

There is widespread international recognition of the efficacy of bilingual education for children, including those from minority language backgrounds (Cummins 2000), with previous research finding enhanced cognitive abilities (Thomas and Collier 1997; Garcia 2009), grade level proficiency in both languages (Barnett et al. 2007; Farver et al. 2009) and social advantages, including better intercultural communication and employment opportunities (Morales 2020). Despite this, however, few schools in the Northern Territory offer bilingual programs to their Aboriginal child populations. One school that has

benefited from a bilingual program for over 40 years is Yirrkala School. Situated in East Arnhem Land, this school teaches a 'step' program (see Morales et al. 2018 for further information), introducing oral English in the early years, with literacy taught in the local language, Dhuwaya (see Amery 1993).

One of the challenges in delivering a bilingual program in an Aboriginal language is that there tend to be limited resources, particularly digital resources. While Yirrkala School has quite a collection of resources available for the classroom, it has few resources for developing the children's phonological awareness, an important skill required for learning to read. For this reason, we developed a digital application (app) for iPads. In order to learn to read, children need to recognise that words can be broken down into smaller units (phonemes) and that these units can be represented by different letters (graphemes) of the alphabet. While writing systems differ (and not all are alphabetic), alphabetic systems also vary in terms of the consistency of their phoneme to grapheme correspondences. English is not very consistent, having 26 letters to represent 44 different sounds (e.g., consider the spellings of *lot* and *yacht* or *threw* and *through*). This requires letter knowledge—the ability to identify a sound, name the letter and identify the shape of the letter (Piasta et al. 2016). In addition, children must have phonological awareness. This is the ability to manipulate the sounds in the language and, as Morales (2020) says, to focus on the abstract sound structure of a word as opposed to its meaning. These include segmenting and blending syllables and phonemes as well as manipulating sounds (such as replacing the first sound of a word to make a different word). Phonological awareness and letter knowledge are the skills which are crucially important in acquiring reading skills (Powell and Diamond 2012). In this paper, we document the process of developing the app designed to enhance the phonological awareness skills of Dhuwaya speaking children, discussing a range of challenges which emerged and showing how they were resolved.

2. The Dhuwaya Language

> *Yolŋu speak different languages because of the two Djaŋ'kawu sisters who created land, animals, places as they travelled across the land carrying sacred dilly bags containing all the different languages and handing the clan languages out throughout Arnhem Land. However, nowadays there are many people living together in one place in this community [Yirrkala] so the languages have been mixed up. Dhuwaya is a language made from other clan languages.*
>
> (Ganambarr 1994)

The Aboriginal languages of the Yolŋu Matha[1] or Yolŋu Dhäruk group are spoken throughout Northeast Arnhem Land. They are a cluster of Pama-Nyungan ('suffixing') languages surrounded by non-Pama-Nyungan ('prefixing') languages. There are 40–50 clans, and traditionally, speaking one's own clan language was a significant marker of one's identity. Yolŋu group together many of these clan languages by the word used for *this/here*: Dhuwal Dhuwala Dhay'yi, Dhaŋu Djaŋu and Nhaŋu (& Yan-nhaŋu) (Schebeck 2001). Other clan language clusters identified are Djinaŋ (Waters 1989), Djinba (Waters 1989) and Ritharrŋu (Heath 1980).

Today, young Yolŋu learn to speak one of three Yolŋu varieties as their first language. In the Yirrkala area, and surrounding Laynhapuy homelands, Dhuwaya is widely acquired as shown in Figure 1:

Dhaŋu-Gälpu is the first language of some families in this area, and Dhuwal-Djambarrpuyŋu is the language most young people acquire to the west of Yirrkala and Laynhapuy. In Yirrkala itself, several clan languages are spoken by varying numbers of people; Dhuwaya is a koine language which has resulted from extended contact between speakers of different dialects of Yolŋu Matha. As Morales (2020, p. 16) summarises:

[1] Yolŋu is the word for 'person, Aboriginal person' in many, but not all, of the languages commonly referred to as Yolŋu languages. As reported in Amery (1985), 'The label Yolŋu Matha was also engineered at S.A.L [School of Australian Linguistics] as a cover term for all Yolŋu languages No such label had previously existed. It is now generally accepted throughout the region' (Footnote 18, p. 21).

The processs of koineization tends to involve various processes of simplification (Siegel 1985) and Dhuwaya is indeed somewhat simplified (or, arguably, regularized (see Amery 1993, pp. 53–55)) in comparison to the clan languages (e.g., compare Dhuwaya's four verb conjugation classes to Gumatj's eight and Dhangu's nine).

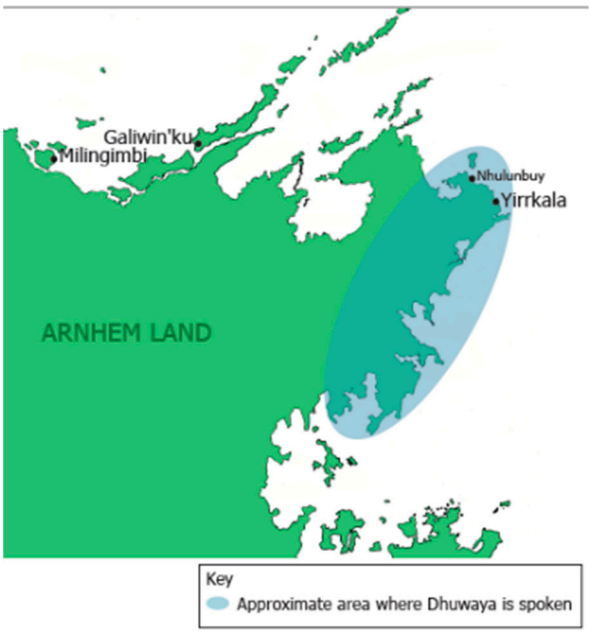


Figure 1. Dhuwaya area.

3. Rationale for the Dhuwaya App Development

The development of the app built upon an earlier project undertaken by Gemma Morales for her PhD (Morales 2020). This involved a 24-level teaching intervention (the Indigenous Languages Early Literacy app) administered on an iPad which taught Dhuwaya syllable and phoneme segmentation, blending and letter knowledge during the last term of the year in 2015. A pretest was administered prior to the intervention, and a post-test twice after it, once immediately following the intervention and again six months later. The project could not be set up formally as an experimental design due to the small number of children attending the school. While the outcomes of the intervention could not demonstrate significant improvements due to the lack of a control group, it did appear to have prompted a moderately successful increase in the children's phonemic awareness skills.

The previous year, a report on the education of Aboriginal children in the Northern Territory (Wilson 2014) commissioned by the Department of Education and Training (NT) argued that all children in the NT should be assessed for phonological awareness and actively taught it in the early years. To this end, a test of phonological awareness was developed by the DET (NT) in English. Given the bilingual context at Yirrkala, it was decided to develop an app for teaching these skills in Dhuwaya since there is considerable evidence that these skills are transferrable to another language (e.g., August and Shanahan 2006; Feinauer et al. 2013), particularly when the writing systems are shared, as in the case of Dhuwaya and English (August and Shanahan 2006).

Several factors contributed to the decision to use an iPad app rather than more traditional approaches to teaching phonological awareness. The children, like children everywhere, are very familiar with modern technology associated with the pervasive use of mobile phones and tend to engage better when using it; the app also addresses the increased expectation of using technical resources in the classroom. In addition, the app allows each child to progress at his or her own rate, whilst also allowing teachers to zone

in on a particular context for the class or an individual. Furthermore, the app maintains the scores and progress made by each child, which are accessible to the teacher who can therefore identify problems as they arise and deal with them as they do.

4. Background to Yolŋu Orthography

Traditionally an oral language, the Dhuwaya alphabet is based on the English alphabet and consists of 31 symbols which include 6 vowels and 25 consonants, including a glottal stop. Diacritics represent four of the retroflex sounds (ṯ, ḏ, ṉ, and ḷ) and the long vowel ä. Digraphs represent the three interdental sounds (th, dh, and nh), the alveo-palatal (tj, dj and ny) and the rolled r, or trill (rr). The symbol ŋ represents the velar nasal, and the glottal stop is represented by an apostrophe (') (Morales 2020, p. 167). e, o and ä are used as the letters to represent long vowels counterparts to i, u and a. This is unique in Australian orthographies. The more common alternatives for long vowels are ii, uu and aa. The Yolŋu alphabet is as follows:

a ä b d ḏ dh dj e g i k l ḷ m n ṉ nh ny ŋ o p r rr t ṯ th tj u w y '

Dhuwaya orthography is more transparent than the complexity of English orthography. Dhuwaya is written phonemically so that a word written correctly in Dhuwaya should be relatively easy to pronounce. This makes it easier for children to decode the language since alphabetic decoding can be achieved through phonology because words can be more easily identified by sounding out than they can in English.

The orthography utilised in the app is that used across Yolŋu language varieties in formal contexts, such as bilingual programs, Bible translation, the Yolŋu Studies courses at Charles Darwin University and linguistic descriptions. It was initially developed for Gupapuyŋu, a western Yolŋu variety by Beulah Lowe, a missionary who arrived at Milingimbi in 1951. She became the first person appointed to a dedicated linguist position by the Missionary Overseas Mission in 1958, and her linguistic descriptions of Gupapuyŋu were the first for any Yolŋu language (see Wearing 2007). She analysed Gupapuyŋu as having 31 phonemes, 25 consonants and 6 vowels, and this formed the basis for the Yolŋu orthography she developed, and which is still used (Lowe 1975).

5. Dhuwaya Phonology and Its Relationship to the Yolŋu Orthography

While a uniform orthography is used across language varieties, there are distinctions in the phonologies. One of the main distinctions between Gupapuyŋu and Dhuwaya is that, in a number of positions, a fortis-lenis stop contrast is recognized. In Gupapuyŋu, it occurs in six positions: bilabial, lamino-dental, apico-alveolar, retroflex post-alveolar, lamino-palatal and velar. In Dhuwaya the contrast is reduced to two positions: the apico-alveolar and the retroflex post-alveolar apical stops. The retroflex contrast is widely attested within both Gupapuyŋu in the west and Dhuwaya in the east, while the apico-alveolar contrast is marginal in both languages, with a single formally attested word *gurudut* 'peaceful dove' for the lenis apico-alveolar. This reduction in the stops with a lenis-fortis contrast in Dhuwaya is found in other eastern Yolŋu varieties (e.g., Morphy 1983; Wood 1978; McLellan 1994). The reduction is attributable to the lenition of lenis peripheral and laminal stops in cognate words to the semivowels /w/ and /y/ respectively. There are well-attested cognates between language varieties, e.g., *djinaga* (Gupapuyŋu) and *djinawa* (Dhuwaya) 'inside'.

Thus, the consonant inventory for Dhuwaya is only 20–21[2] compared to the 24 or 25 for varieties with the stop contrast further west, such as Gupapuyŋu. This means that Dhuwaya literacy requires knowledge of spelling rules to determine the correct spelling of words with stop sounds in four places of articulation. For the apico-alveolar and retroflex

[2] The lower number excludes the marginal apico-alveolar stop contrast; the higher number includes it.

stop letters, knowledge of spelling rules is required for all contexts other than between vowels[3]. The orthographic letter representations and spelling rules are shown in Table 1.

Table 1. Orthographic consonant representations.

		Bilabial	Lamino-Dental	Apico Alveolar	Retroflex Post-Alveolar	Lamino-Palatal	Velar	Glottal
Stop letter spelling rules	Letters used • Beginning of words • Medially after nasals	b	dh	d	d̲ (also contrastive use medially between vowels)	dj	g	
	Letters used • Medially except after nasals • End of words	p	th	t	t̲ (also contrastive use medially between vowels)	tj	k	
Stop letters for different sounds				d (‘lenis’) (rare)	d̲ (‘lenis’)			'
				t (‘fortis’)	t̲ (‘fortis)			
Nasal		m	nh	n	n̲	ny	ŋ	
Trill				rr				
Approximant		w			r	y		
Lateral				l	l̲			

The use of the ‘voiced’ symbols, word initially and after nasals, and of ‘voiceless’ symbols elsewhere reflects the common phonetic realizations of these stops; details of the full range of realizations awaits further study[4]. The vowel orthography is shown in Table 2.

Table 2. Orthographic vowel representations.

	Front		Back	
	Short	**Long**	**Short**	**Long**
High	i	e	u	o
Low		Short	Long	
		a	ä	

The glottal stop is represented in the orthography as a segment (see Jepson 2019). However, it does have a distinctive distribution and is always syllable final. Alternative nonsegmental analyses have been proposed for eastern Yolŋu languages (see, e.g., Wood 1978; Morphy 1983; Chong 2011; Baker 2014, for further detail), but these also make use of the standard orthography in their general linguistic descriptions and have not generated any serious calls for changes to the orthography. Yolŋu have voiced their wishes to retain the current orthography.

6. Phonotactics

Dhuwaya syllable structure is the same as for many other Yolŋu language varieties: CV (C) (C) (/ʔ/). The range of syllable final clusters in Yolŋu languages and the possibility

[3] In Yolŋu languages with the full range of stop contrasts, spelling rules such as those for the apico-alveolar in Dhuwaya also occur. However, in these languages contrastive stops are restricted to intercontinuant contexts rather than just between vowels as in Dhuwaya.

[4] Yirrkala School Action Group have asked K Jepson to undertake a phonetic analysis of the stops in the Dhuwaya App recordings. Initial impressions of common realizations of these stops are as described here (Jepson p.c.).

of closure of any syllable type with a glottal stop are distinctive characteristics compared to other Australian languages. There are large numbers of two-syllable (monomorphemic) words, but the limited number of monosyllabic words is as widespread in Australian Aboriginal languages (Fletcher and Butcher 2014, p. 111; Baker 2014, p. 150). As discussed below, this did present some challenges.

7. Word Initial and Final Segments

The hierarchies of sounds that can occur as initial and final segments in words are based on data provided in Morphy's (1983) description of Djapu, an eastern Dhuwal Yolŋu clan language variety based on 3000 words which should be referred to for further detail. It is the only description of a language in this area to have quantified the data.

As a general rule, there are no words beginning with vowels (see Amery 1985, pp. 45–53 on the deletion of /w/ and /ŋ/ in fast speech in adult Dhuwaya). The contrast between retroflexes and apico-alveolars is limited in word initial position and confined mainly to loan words (Amery 1985, p. 36). Adult Dhuwaya speakers often replace initial retroflexes with apico-alveolars, but the distinction is still retained in specific words (Amery 1985, p. 46).

Consonant clusters occur intramorphemically in morphemes of more than one syllable. An overview is provided here with examples selected from the app to illustrate that young readers and writers are expected to be familiar with the full range of clusters. For fuller linguistic details of the range of clusters in Yolŋu languages, refer to Morphy (1983, pp. 22–24) and Wilkinson (1991).

- Nasal–stop combinations are common, both homorganic and nonhomorganic, e.g., *ŋayambalk* ('home', 'place'), *yawungu* ('yesterday'), *dhanhdhurruŋ* ('horn'); nasal–glottal stop–stop combinations also occur, e.g., *dhum'thum* ('wallaby'), *dhän'pala* ('mud mussel').
- Stop–stop and nasal–nasal combinations occur, e.g., *milmitjpa* ('afternoon'), *manymak* ('good').
- Laterals and rhotics combine with stops, nasals and semivowels, e.g., *djalkiri* ('foot'), *marwat* ('hair/leaf'), *marrtji* ('to go'), *dhurrwara* ('mouth/door/opening').
- Less common combinations are stop–nasal (*nyiknyik* ('mouse/rat')), stop–semivowel *wäkwak* ('waterlily') and semivowel–semivowel *gäywarr* ('box jellyfish') combinations.
- The only example in the app of a medial glottal stops following a nonobstruent C is *bul̲'manydji* ('shark'). This is commonly used to exemplify the glottal stop in alphabet charts.
- Intramorphemic clusters for three consonants occur involving combinations of laterals or rhotics with nasals and stops, e.g., *yalŋgi* ('weak/soft'), *garkman* ('frog'), *bal̲kpal̲k* ('peanut tree').

Cluster combinations between morphemes are different from those described here intramorphemically. Most of the target items in the app are single morphemes; for more information, refer to Morphy (1983) and Wilkinson (1991).

8. The Team and Positionality

The team changed to some extent over time. It initially consisted of Gillian Wigglesworth and Gemma Morales together with Yalmay Yunupiŋu, Banbapuy Ganambarr-Whitehead and Robyn Beecham. Subsequently, Jake Stockley, Fardin Elias and Melanie Wilkinson joined the team while Banbapuy became less involved due to other commitments, and Gemma returned to her native USA. Rärriwuy Marika, Gandhurrminy Yunupiŋu, Natasha Bulmirri Yunupiŋu and Bamuruŋu Mununggurr all worked on the app at Yirrkala Community School in various capacities, especially recording the language for the app, reviewing the app and testing the students' usage of the app.

Yalmay, Banbapuy, Rärriwuy, Bulmirri, Bamuruŋu and Gandhurrminy are all first-language speakers of Yolŋu clan languages and/or Dhuwaya. Rärriwuy, Yalmay and Banbapuy are Yolŋu elders and educators with decades of experience. Gandhurrminy,

Bulmirri and Bamuruŋu are all young Yolŋu educators. The Yolŋu team members all work at Yirrkala School and have known each other all their lives. The non-Yolŋu team members are Robyn, a teacher who worked at the school from 2003 to 2017 with a good knowledge of Dhuwaya and Jake, a teacher and literature production supervisor at Yirrkala school who lived in Yirrkala throughout his life and speaks Dhuwala, another Yolŋu Matha language. Melanie is a linguist who has worked for the Northern Territory Department of Education as the Language Resource Officer (East Arnhem) for 30 years and lived in Yirrkala for 18 years. She hears Dhuwaya while speaking Dhuwal, another Yolŋu language. These team members had worked together for years in the context of the Yirrkala School Literature Production Centre (LPC) (https://aeunt.org.au/news/yirrkala-lpc-arthurhamilton/) (accessed on 4 January 2021). Fardin and Gillian are based in Melbourne; Fardin is the software engineer who developed the app through his Melbourne based iOS development shop (Ohmi Labs Pty Ltd.); Gillian is a linguist from the University of Melbourne who has worked on various projects with the school in Yirrkala over a number of years. Fardin and Gillian had limited knowledge of the Dhuwaya language. Similarly, the Yirrkala team had limited experience and expertise in apps, so an interdisciplinary, intercultural and, in this case, interlingual team was essential to the successful completion of the project. There were limited timeframes to work within. Gillian and Melanie both worked full time as linguists, and all team members had several other roles. All team members contributed many days and weeks of their own time in kind, without which the app could not have achieved its potential within the budget constraints.

As a result of the group being located in different locations, with only two core team members consistently based in Yirrkala, carefully documenting progress and keeping others informed regarding developments was important. The respect and good faith within the group, and commitment to the app, allowed issues to be tabled and questions, explanations and solutions to be identified and discussed. Online communication via video conferencing proved to be an essential tool.

9. The App Development

An initial meeting was held during 2015 in Yirrkala to discuss the possibility of developing an app using Gemma's app as a starting point. This resulted in a number of activities over the next few months prior to a meeting in Melbourne to discuss these activities, which largely revolved around exploring available online apps in English and other languages. There are multiple apps on the web for learning and teaching phonological awareness, and Phonics Hero (https://phonicshero.com/) (accessed on 4 January 2021) was particularly useful with its wide range of animated games with increasing levels of difficulty. However, there were few apps which were aimed at first-language phonological awareness in an Aboriginal language, and which would be useful for teaching phonological awareness in bilingual programs. There were, however, many examples of apps for teaching vocabulary in Aboriginal languages to non-Aboriginal Australians, as well as Aboriginal language dictionary/word list apps and language revitalisation apps for teaching Aboriginal languages as second languages.

For the structure of the app, it was agreed that there would be 21 levels, each with four tasks. The early levels introduce syllable blending and segmentation, letter name identification and letter sound correspondences; the later levels also include sight word identification and adding appropriate suffixes to words. Once children have the ability to manipulate syllables, phoneme segmentation and blending are introduced.

Having identified the app developer, the many tasks were divided amongst the team. These activities are briefly summarised here. Following this, we turn to the linguistic challenges that were encountered during the two-year development process. The tasks were as follows:

- Development of the activity types to use for each activity and the progression of learning;
- Identification of vocabulary with different numbers of syllables and phonemes;

- Recording and editing sound files;
- Identification of culturally appropriate pictures;
- Checking pictures with children for comprehension and recognition;
- Preparation of instructions:
  - Initially in English;
  - Then, translation into Dhuwaya;
  - Checking the Dhuwaya translations;
  - Recording of instructions by a Dhuwaya speaker;
  - Preparation of detailed specifications for the app developer to prepare the app for every task and level;
- Checking the app tasks once developed;
- Trialing the app tasks with children at different ages;
- Managing changes to the app;
- Sufficient double checking throughout the development process;
- Communicating with team members on shared tasks and keeping everyone on track regarding the development of the app.

Once all aspects of each level had been identified, they were used to prepare a detailed and comprehensive set of specifications for the app developer, which included pictures, recording of sounds, words, syllables and phonemes as well as spoken instructions in Dhuwaya.

10. Challenges in the Development of the App

10.1. Images, Colours and Backgrounds

Icons and colours were essential to convey meaning, as written words would not be readable by the youngest students using the app in either language. Dhuwaya words were used dominantly throughout the app, and where English words were used to support student–teacher interaction and understanding, a smaller greyed font was used. Reward icons were objects which the children would recognise, would hopefully be appealing to them and were culturally inclusive. A selection of icons to represent each activity type required ongoing discussion and revision. The icon for the letter name activity, for example, had a picture of puzzle pieces with the English alphabet letters A, B, C and D written on them. This was revised to reflect the first four letters of the Yolŋu alphabet instead, as shown in Figure 2:

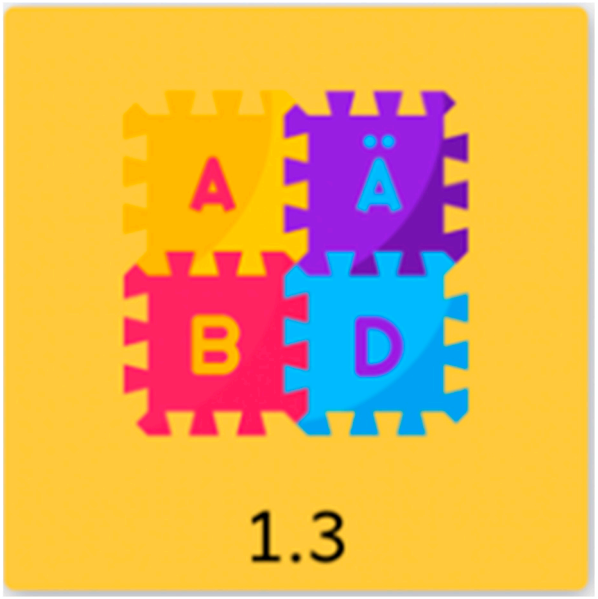


Figure 2. Image of alphabet letters reflecting Yolŋu letters.

Most tasks, particularly the lower level ones, required four culturally appropriate images for the child to identify the correct image for the word, letter or sound they had heard. The images were sourced from a variety of locations. The first preference was to use images from the previous app that Morales (2020) had developed or those that were held in the school's Literature Production Centre, either photographs or illustrations from books. The entire book collection and most of the photograph and image collections were searched. Words which required images not found in the collection were sourced from the Internet, limited to publicly available images not subject to copyright. Finding pictures of people and objects that the students could relate to with the limited number of pictures available was difficult, and many were not culturally inclusive of Yolŋu students. Images found on the Internet had to be checked by the Yolŋu team members to ensure they were suitable and represented the words adequately. In some cases, photos of plants and animals found locally were used. In others, previously selected target vocabulary had to be excluded if suitable illustrations were unavailable. Figure 3 illustrates a task from the app with pictures drawn from a variety of sources, including a drawing, a photograph and images available on the Internet and from the Language Production Centre. This task required the student to listen to a word broken into syllables (*mu–tha–li*': 'duck') and then select the appropriate image.

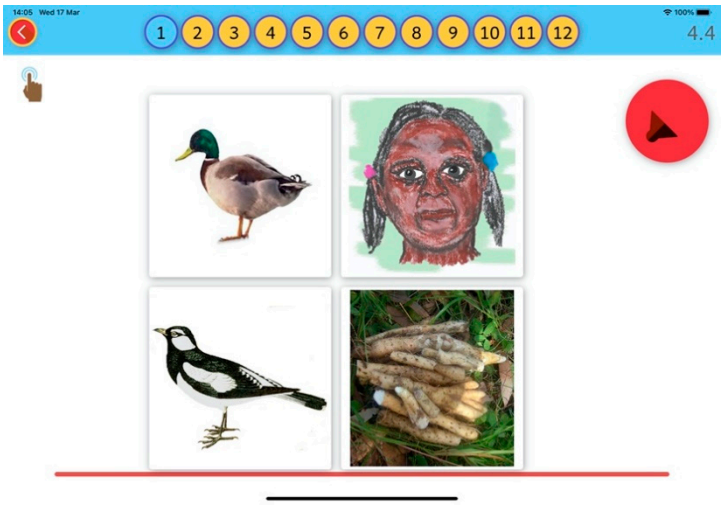


Figure 3. App with variety of picture sources.

Figure 4 (adapted from Morales 2020) demonstrates a task which appealed greatly to the students; the student touches a baby kangaroo, hears a sound, and drags the baby to the mother's pouch representing the sound (/i/ and /m/ have been done).

Background colours and pictures were initially chosen to appeal to early years students, using bright, primary and secondary colours, but full screen backgrounds were generally not used because they took the focus away from the target vocabulary or images. In the end, most of the background screens were clear and had blocks of colour surrounding focus words or syllables. Activities which required auditory discrimination and used pictures were left with blank white backgrounds. The one background image used to accompany the letter name identification activity was a picture, reflecting the area around Yirrkala, drawn by a local artist and long-term Yolŋu educator who passed away during the time the app was being developed (see Figure 5).



Figure 4. An image from the app (Identifying Letter Sounds).

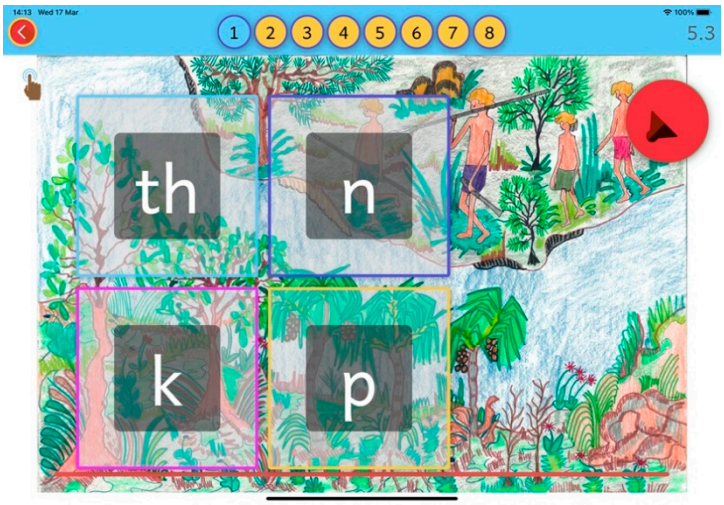


Figure 5. Culturally appropriate background to the app.

10.2. Selection of Sound Effects

Sounds for reinforcing correct and incorrect responses were chosen in consultation with the app developer and were used consistently throughout the activities, while the congratulatory terms which accompanied correct responses were all selected by Yalmay and recorded in Dhuwaya. Both formal and colloquial expressions were selected, e.g., *Manymak* ('Good') and *Dhapirrk!* ('Great!') designed to engage students.

10.3. IPad Related Metalanguage

The iPad system language, English, was also avoided wherever possible to maintain immersion in, and engagement with, Dhuwaya in the app. All navigation buttons with written Dhuwaya on them trigger the accompanying audio. The Yirrkala School had been involved for the previous three years in an iPad project to develop teachers' and students' learning and teaching using Apple iPads. This project included regular workshops with an Apple Professional Learning Specialist, online and in country, through which the Literature Production Centre (LPC) team developed the iPad language in collaboration with Apple Professional Learning Specialists, Yolŋu teachers and students. The purpose of developing language in Dhuwaya to talk about the iPad in the classroom was to avoid code switching and language shift. The use of the students' first language supports their understanding and reflects students' and teachers' natural language usage. Some Dhuwaya language used to describe the iPad includes *giniŋgarr* ('bellybutton' or 'knob') used for a button or icon

and *wäŋawuy giniŋgarr* used for the home button (*wäŋa* 'house' or 'place' *–wuy* associative suffix).

10.4. Font Selection

Font choice was restricted to the approximately 30 fonts which support the range of unicode (AuSIL Yolŋu) characters necessary for Dhuwaya, including the characters used to represent four of the retroflex sounds (ḏ, l̰, n̰ and ṯ), the long a (ä) and the velar nasal tailed n (ŋ). The upper case tailed N (Ŋ) can be represented in two formats depending on the font, but only one is used in the Yolŋu orthography:

Ŋ not Ɲ

A suitable font for early literacy development was also necessary, which included considerations of readability, development of early letter writing and student familiarity with characters, such as the closed a and g:

ɑ not a

g not g

The final choice of font for the app, Andika AuSIL[5] (http://ausil.org.au/node/3719) (accessed on 4 January 2021) is used widely in the school for Dhuwaya readers and worksheets.

10.5. Progress and Scoring

Early versions of the app were intended to be played in a linear fashion going through four activities with increasing difficulty. However, the idea of linear play and unlocking levels to proceed was abandoned in favour of free play through all the levels. This was to allow students and teachers to target specific skills through the app and integrate the use of the app into their existing classroom practice.

The ability to track student scores and progress was not part of the original plan for the functionality of the app, as it was designed as a teaching and learning tool rather than an assessment tool. However, reinforcement and correction are employed in a variety of ways throughout the app with interest created through the levels by changing activity styles. The scoring system rewards students with "stickers" for flawless completion of a level. The colour choice used as a code to track student progress was changed from red, yellow and green (i.e., traffic lights) to black, red and yellow representing the black skin (beginning), blood (middle) and yellow fat (the best)[6].

11. Words, Syllables and Phonemes

Vocabulary development was sourced from the Dhuwaya readers previously produced by the Literacy Production Centre at the school, which included a series of 20 basic readers, but also included some of the vocabulary the students often used in their writing and words used in the app developed by Morales (2020). It was important to find a range of words with between one and four syllables with which the children would be familiar and which were culturally appropriate. Lists of common words devised for early literacy programs in Dhuwaya or Djambarrpuyŋu are dominated by two-syllable words, followed by three-syllable words, but many fewer monosyllabic and longer words. They also include suffixes. Monosyllables that are familiar to young children are limited, and many of them are grammatical words, e.g., pronouns and question words that cannot be easily depicted by a picture for young children. No inflecting verbs are monosyllabic. Many hours were

[5] The Andika AuSIL font was especially developed to support early literacy in negotiation with various Yolŋu and Anangu. It was distributed to schools in 2011. It is available freely through AuSIL www.ausil.org.au or by being shared, without cost.

[6] Yellow fat is considered a great delicacy.

spent trying to identify monosyllabic words. Early literacy programs in Yolŋu bilingual schools have readily targeted disyllabic words for initial literacy, particularly those with combinations of open syllables to start with, but with closed syllables also featuring. Many children's names, a widespread target domain for initial literacy, have closed syllables, as reflected in the names of most of the Yolŋu contributors: Yalmay, Banbapuy, Rärriwuy, Bulmirri and Gandhurrminy.

11.1. Responding to Cultural Restrictions on Use of Words for Periods of Time

When Yolŋu people die, their names cannot be spoken for some years depending on the kinship relations between speakers and the deceased. In many cases there are other common words that sound similar to the name of a deceased person which also cannot be spoken following their death. There were several discussions within the team and with the Yirrkala School Council and the Yambirrpa Governing Committee around what to do with the app in this case. The modular nature of the app meant that with good funding or good will, selected levels could be locked and unlocked by the developer, and the words could be changed throughout the app, but in some cases, this could be very extensive. The students and teachers could chastise the iPad, as they would a child or clumsy speaker, for saying the word, or the teachers could take care to skip some levels. Ultimately the school council and the overarching governing body understood that the app would play out loud words that were not in use and agreed that it could continue to be used when supported at the school.

11.2. Identifying Words with Specific Phonemes for Blending and Segmenting

While finding words with varying numbers of syllables for segmenting and blending was relatively easy, this was more difficult where phonemes were concerned. There are limited numbers of two- or three-phoneme one-syllable words in Dhuwaya which can be represented in picture format as discussed above (unlike English which has multiple two-/three-phoneme single-syllable words, e.g., cat, dog, bag, bed, etc.). This limited the number of one-syllable words in Dhuwaya that could be introduced in the early stages since depiction in a picture was essential for the child to identify the correct word.

11.3. Cued Articulation

Cued articulation is a methodology used for teaching the sounds of English through the use of hand gestures (cues) (see Passy 2010). Cues for Australian language sounds had been developed for use in Australia, and Helen Botham worked with Shepherdson College on the development of cues for Djambarrpuyŋu[7]. These have been introduced to Shepherdson to support students with hearing loss and to introduce an additional sensory tool to assist with phonological awareness. It was very well received by Yolŋu teachers and students. It has also been used successfully by some non-Yolŋu teachers to support phonics learning in English. Below are examples for the long and short vowel cues from a Shepherdson College resource:



Cue for the long vowel ä



Cue for the short vowel a

The development of cues for Dhuwaya was in progress at Yirrkala as an independent project in the early stages of the app development and assisted with challenges outlined in the next section.

[7] The Sounds for Literacy online training package developed by Helen Botham in which the cues for Djambarrpuyŋu were available was withdrawn early in 2020. NT DoE is currently working on an adaptation.

As outlined above, in Dhuwaya there are eight stop symbols for only four sounds (p/b, k/g, t/d, t̲/d̲). Focussing on cues for actual sounds in Dhuwaya provided a challenge for Yolŋu teachers who held the general understanding that each Yolŋu letter represented a distinct sound. The work on cues for sounds, as opposed to letters, in the Cued Articulation project led to an acceptance that the situation was more complex for Dhuwaya, i.e., that not all letters represented single sounds.

This attention to Dhuwaya sounds through Cued Articulation highlighted the importance of ensuring that all sounds recorded for the app were authentic Dhuwaya sounds rather than English ones. One strategy adopted in the rerecording process was to ask people to say a Yolŋu word out loud and to focus on it before saying the specific sound they were being asked to record. This encouraged authentic Dhuwaya pronunciations. Attention to the mismatch between letters and sounds for many stops also informed the selection of options in activities connecting letter sounds and letters. Pairs of letters for single sounds, e.g., p/b, were never selected as co-occurring options.

The older generation of Yolŋu teachers were schooled through English and learned their literacy in Dhuwaya as adults. This could explain the unconscious use of English names and pronunciations of letter sounds by some of them. Reflecting on this requires detailed attention and conscious awareness of the relationship between English and Dhuwaya sounds and their orthographies. Projects such as developing Dhuwaya cues for cued articulation and developing the app together with ongoing linguistic studies into Yolŋu sounds and the stop contrast in northern languages, such as Gupapuyŋu (Butcher 1995), focussed attention on some of the details that need to be considered.

11.4. Integrating Phonemes and Syllable Segmenting and Blending Strategies

Levels 11–20 were initially designed for phoneme segmenting, but on piloting, the jump from segmenting syllables to segmenting phonemes proved challenging for the children. It was therefore decided to begin each item with syllable segmenting and to then move to segmenting the phonemes of the same word so that each item had two parts. This resulted in a restructuring of the higher-level activities for segmenting sounds in which each multisyllabic word was segmented first by syllables and then immediately by phonemes. This focus on syllables is in line with early literacy strategies for languages with more transparent orthographies than English and simpler syllable combinations, such as Spanish. To do this, words with different numbers of syllables were identified, which included consideration of the syllable complexity at different levels. Open and common closed syllables (CV and CVC) were included early on, and those with more complex syllable structure were included in the higher levels. The most complex syllable structure, CVCC', was not represented, but examples of CVCC, as in *bal̲kpal̲k* 'peanut tree', as well as CVC', as in the first syllable of *bul̲'manydji* 'shark' were included.

11.5. Glottal Stops

Glottal stops proved particularly challenging. In early recordings, glottals appeared on words which do not usually have them. This inconsistency became more apparent as the project proceeded, and it was late in the project, when the full extent of the inconsistency became apparent. As a result, there is some concern that other speakers may criticise the way certain words or syllables are pronounced in the app. Teacher notes will address this to an extent by talking about regional contrasting and noncontrasting stops, generational and regional variation in glottal stop usage and the influence of English literacy in how educators approach the pronunciation of stops in Dhuwaya.

The Yolŋu team members suggested there could be variation between Yolŋu varieties, e.g., Dhaŋu and Dhuwala, and between older and younger speakers, with younger Dhuwaya speakers potentially using more words with final glottal stops. Our understanding of this variation is still not resolved and will need monitoring when the app is used with younger speakers.

The second issue arose because of the technical way sound files were incorporated into the app. Where utterances in an activity were essentially the same with only the target sound, syllable or word changing, the sound files were recorded in chunks and then reassembled as part of the app design. This meant that the recording task often involved lists of sounds, syllables or words. This introduced some features which are found in the way people produce syllables and words in lists in Dhuwaya speech, which included the addition of a glottal stop after each item in the list, independently of the contrastive use of the glottal stop within words and morphemes. When these sound files were incorporated into the app, utterances which included a recording from the list form of the item with a glottal stop did not match the sound as it is normally produced within the word. This is an issue when the focus is on Dhuwaya phonics where the glottal stop is contrastive. This was only picked up late in the app development, requiring a substantial amount of rerecording with speakers having to control their use of the glottal stop. An example was the word *l̪irra* 'tooth/teeth', which was recorded when in the list of words as *l̪irra*' and in focus syllable lists as *rra*'. These had to be rerecorded as *l̪irra* and *rra*, respectively without the glottal stops. Using a cue word, using a word together with a suffix or embedding the word in a sentence before recording assisted people with this, as they could then focus on the sound in the context of an utterance, rather than a list, e.g., when rerecording the monosyllabic suffix *yi*, the speaker said the word, i.e., *wäŋayi* 'to the camp/place/home', and then the syllable *yi*.

11.6. Suffixes

Identifying suffixes was introduced as an activity at Level 13. All targeted suffixes are on nominal stems, with those specific to other word classes (verbs, demonstratives or pronouns) not included. One issue was whether the spelling rules should be targeted: for example, those concerning the letters for the stop in the middle of words resulting from suffixes with initial stops. However, these were excluded because knowledge of the spelling rules comes in middle to upper primary rather than in the early years. Suffix selection was based on their being phonologically possible, with the correct spelling for suffixes following a nasal and all stop initial suffix options modelling the correct spelling for the word it goes with.

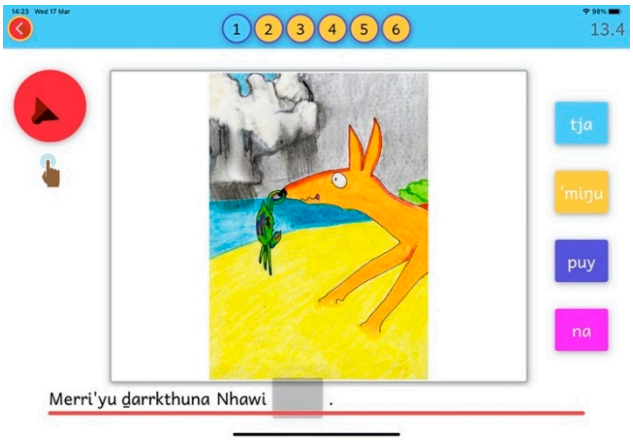
In the suffix tasks, the goal is to listen to a sentence accompanied by a picture, identify the missing suffix in written sentence from the four options provided and drag it to the gap in the sentence. Such cloze activities are a common early literacy teaching method. The correct suffix can be identified by matching the written form with the appropriate suffix heard in the sentence, i.e., using graphophonic skills. Skills related to grammatical knowledge are required, such as the types of nouns particular suffixes can co-occur with. In Figure 6 below, a suffix is missing form Nhawi—a dog's name. The suffix 'miŋu' would not be possible because it can only occur with a kin term; 'na' is the correct answer, marking an animate object of a transitive verb.

Knowledge about discourse suffixes is also required. These are high-frequency forms which occur on a wide range of word types and can follow other suffixes but are always the final suffix; these code meanings, such as focus, or a connected sequence of events.

Targeting discourse suffixes can reduce the number of possible options for suffixes. In example 16.4 Item 1 in Figure 7 below, only three options could be identified, because the target is a discourse suffix following another suffix. In this position, the only the possible options are forms of the discourse suffixes: *-tja*, *-ya*, *-na*.

Morphophonological knowledge also informs the selection of the correct suffix. For example, the allative is written as *thi* or *dhi* after stops and nasals, and *yi* after vowels, liquids and semivowels, with or without a glottal stop. As mentioned above, for any target suffix, forms that relied on knowledge of spelling rules were excluded. The selection of *thi* or *dhi* would be based on spelling rules so they could not co-occur as choices. Only the correct spelling for the target word would be included.

Other restrictions on possible forms of suffixes as options to choose from occurred for instances of free variation by speakers, e.g., *puy* or *wuy* (ASSOC) after a vowel, or of generational variation, e.g., older Dhuwaya speakers use of FOC *tja* after a vowel, versus younger speakers use of *ya*.



(The crab bit Nhawi.)

Figure 6. Item 1, 13.4.



'Ŋanapu	marrtji	wäŋa-yi-na'
1PLNOM	go	home/place-ALL-SEQ
Then we went	*home*	

Figure 7. Item 1, 16.4.

12. Metalanguage

The instructions for each activity necessarily involved including appropriate metalanguage, much of which was adopted from reflection and discussion activities during training workshops held over previous years for Yolŋu teachers about teaching early literacy using Dhuwaya. Some of their metalanguage was used, such as the use of *yäku* 'name' and *dhäruk* 'language/word' for words, and the general use of *rirrakay* 'voice', 'sound' when talking about sounds used in the app. Yolŋu teachers commonly use *rirrakay* on its own but link it with examples of sounds, e.g., /ŋ/ letter names such as 'ŋ' *wambalmi n* ('n with a tail') or syllables, e.g., *ŋa* as the context requires. There are ways of talking about these but they can be wordy, e.g., *rirrakay yäku* 'sound name' for letter, *rirrakay bitjan gulkthunami* 'sound thus cut up' for syllable. Instructions in the app needed to be unambiguous and simple, and the app was designed to be publicly available, so there needed to be consensus on

what language was used. Reflection and discussion about the metalanguage for teaching Dhuwaya literacy has been an ongoing topic in workshops with Yolŋu teachers.

For the app, it was agreed to borrow the word *djilabuḻ* from the English 'syllable', as had been done in other Yolŋu bilingual programs, and to reserve the use of *rirrakay* for single phoneme sounds. The expression *rirrakay yäku* was used for 'letter name'. Other metalanguage used in instructions includes *ŋurruŋu* 'leading/first', *dhuḏiŋu* 'final/last', *ṉapuŋga* 'middle' for positions within a word and *yuṯuŋgurr* 'thigh', 'constitutive part of something' for suffixes. Almost all the language depicted on screen in the app is in Dhuwaya, e.g., *Dhiṉ'thunami Wakal* 'having a trail/track games' for the main screen presents all the activities in order for users to select from. *ŋala'yuna* 'now play' appears on the play button.

One set of words remains in English in the app, and these are the words describing the underlying focus of the activity, e.g., Segmenting Phonemes, Blending Syllables, Identifying Sight Words and Identifying Suffixes (see Appendix A). Although the app instructions did not require the use of translations for segmenting and blending, some work on Dhuwaya descriptions of the underlying focus was begun at the end of 2020. In a workshop, Yolŋu educators played specific activities and then described what they thought the activity was teaching. When these Dhuwaya descriptions are complete, they are incorporated into the app as a sound button on the screens together with the English terms. The Dhuwaya translations used verbs such as *dhambay-manapan* 'join together' and *rrambaŋikum* 'put together' to describe blending and *gulkthun* 'cut up' to describe segmenting.

13. The Value of Face to Face

Crucial to the successful completion of this project was the sharing of linguistic and pedagogical knowledge and technical understandings that informed the development of the Dhuwaya app. Everyone in the group had different areas of expertise, and one challenge was to gain enough understanding of the expertise of other members to make appropriate decisions about the app. Most members of the group had existing relationships with other members of the team, which helped discussion and understanding. While there were several face-to-face meetings with subsets of members prior, there were few with all team members during the project. Despite this, over the three years everyone came to richer understandings about the interplay between the different areas of expertise. The face-to-face meeting of the entire group in Yirrkala in early 2020 was the milestone from which the final version of the app emerged. This meeting meant that all conversations were shared amongst the group, including discussion about glottal stops, the need for more syllable-focused activities and the cultural relevance of the graphics and language used, as well as other appropriate learning strategies to include in the app. The meeting also allowed the team to better understand the nature of apps, the world of digital games and the technicalities of app development, such as being able to store and access each students' scores and progress across devices. The app developer also realised he could rewrite the app in a new code, which would make revisions to the app much easier in the future, and enabled easier approaches to the app by putting everybody on the same Google spreadsheet and using a single Dropbox folder. The rewriting of the first 10 levels of the app based on decisions made and understandings gained in that face-to-face meeting occurred during 2020. The value of working face-to-face across skill sets with established relationships and easy open communication is a key characteristic of successful projects, with success grounded in providing time to build up understandings across cultures and languages, and the range of individual expertise reflecting Yolŋu cultural values (Marika et al. 2009).

14. Conclusions

Developing this app has been a learning journey for the whole team and a very useful one. It has meant that there is a much better understanding of the students' early

literacy knowledge and skills, as well as what to focus on in the classroom when the app is introduced into the classroom in 2021.

Actualising what is taught in the app and the understanding gained in the process of developing the app by the development team will need further consolidation with teaching teams in the school. This includes understandings around the concepts and the stop letters and sounds in Dhuwaya. Being a bilingual program, there are related issues around the relationship between Dhuwaya and English sounds and orthographies. This may also involve managing the reactions there might be to some of the Dhuwaya terms and pronunciations used in the app.

Finally, the app has been designed in modular format so that pictures, sounds, words, instructions, etc., can all be changed relatively easily. This will hopefully mean that other communities who wish to adopt the app for their own language or languages will be able to do so without having to entirely design a new app for this purpose. Understanding the concepts behind phonological awareness and phonics in Dhuwaya is important for the Yolŋu educators, and the app has already proven its usefulness as a tool for developing this understanding. It is much easier to learn about the role of syllable identification, etc., if activities related to this can be done in the first language with instructions in the first language. Additionally, it is fun to do this.

15. Postscript

The app was due to be introduced into the lower levels of the school at the beginning of 2020. To this end, a 20-item pretest, based on Morales (2020), was developed, and all children in the primary years in the school were tested and their scores recorded. The app was uploaded onto the school's iPads and was almost ready to go. Unfortunately, the impact of COVID meant that the planned introduction of the app into the classroom, and the subsequent post-testing of the children after interacting with the app, was not possible. This will take place in 2021, beginning in Term 2. However, the additional work done in 2020, following the face-to-face meeting early in the year, was without doubt of great benefit to the final version.

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Appendix A

Dhuwaya App—English Names for Activities

Levels	Name
0.1–0.4	Recognising Syllables
1.1–4.4	Segmenting Syllables
5.1–6.1	Segmenting Phonemes
7.1–20.1	Segmenting Syllables and Phonemes
1.2	Identifying First Syllables
2.2	Identifying Final Syllables
3.2	Identifying Medial Syllables
4.2	Identifying Syllables in Mixed Positions
5.2–7.2	Identifying First Phonemes
8.2	Identifying Final Phonemes
9.2	Identifying Medial Phonemes
10.2–12.2	Identifying Phonemes in Mixed Positions
13.2–18.2	Blending Syllables and Phonemes
19.2–20.2	Blending Phonemes
1.3, 3.3, 5.3, 7.3	Recognising Letter Names
2.3, 4.3, 6.3, 8.3	Recognising Letter Sounds
9.3–20.3	Recognising Sight Words
1.4–4.4	Blending Syllables
5.4–12.4	Blending Phonemes
13.4–20.4	Identifying Suffixes

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