Computer-Assisted Vocabulary Learning for Thai Deaf Students: A Case Study of Sot Suksa School for the Deaf

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Abstract

In a world without sound, learning to communicate, read, write, and expand one's vocabulary requires a community of expert communicators in sign language. For many deaf individuals in Thailand who are born into hearing-abled families, access to the expert assistance they need to learn communication skills does not begin until their first years of compulsory education. By that time, academically, they are already many years behind their hearing-abled peers. The present study employed an experimental research design to investigate the influence of computer-assisted language learning technology, DeafReader, on the vocabulary skills of deaf students in Thailand. After a six-week intervention, one-way ANOVA analysis showed no significant difference in pre-test and post-test scores between the treatment and control groups. Additional analysis found a significant difference in performance between male and female students. Age differences in the acquisition of foundation language skills between genders were considered to be an influencing factor in the results of this study. The author concludes that students may have lacked the basic language skills needed for technology intervention to be effective. The author recommends examining the effects on an older age group and exploring the use of DeafReader as a learning tool for fingerspelling, sign language, and mapping text to sign.

Keywords: Deaf, Hard of hearing, Vocabulary, Fingerspelling, Sign language, DeafReader

Introduction

One of the earliest developments children experience in their education is acquiring the ability to read. For many, their reading proficiency is hindered by factors such as dyslexia, attention-deficit/hyperactivity disorder (ADHD), and sight or hearing problems. The challenges that hearing-abled individuals face during this development stage are inconsequential when contrasted with those who have never experienced the sound of words, letters, or phonemes. Void of sound, learning to read seems an unattainable skill (Musselman, 2000), yet many deaf individuals have accomplished it (Azbel, 2004).

Reading involves recoding written symbols (words and letters) into their equivalent audio form and then relating that audio to spoken language (Cawthon, 2011; Harris, 2015). Therefore, one might assume that knowledge of phonetic sounds is a fundamental building block of reading. While the partially deaf may have some audio awareness, the profoundly deaf may have a scant understanding of such audio representation depending on the onset of their hearing loss (Möbus, 2010; Woll, 2013).

Few schools in Thailand are equipped with the expert support deaf students require during their education. According to the United Nations Children's Fund (UNICEF), deaf students in Thailand who cannot speak are prone to have poor academic performance or be excluded from educational institutions (United Nations International Children's Emergency Fund, 2018). Considerable research supports the argument that deaf students suffer academically from language deprivation (Cawthon, 2011; Morere, 2011; Razalli et al., 2018; Williams et al., 2015; Woll, 2019; Yoon & Kim, 2011). Concerning the Deaf, the report affirmed that learning the mother tongue language should precede learning to read or write. Unfortunately, for the Deaf, the mother tongue language is typically sign language (Razalli et al., 2018), which, unless born into a deaf family, is unlikely to be a natural acquisition (Joy et al., 2019; Razalli et al., 2018). Conversely, children born of deaf parents (second generation Deaf) often acquire sign language through natural exposure in the same way the hearing-abled acquire speech (Joy et al., 2019).

According to the National Statistics Office, Thailand, more than 380,000 deaf or hard of hearing (D/HH) people reside in Thailand (National Statistics Office, Thailand, 2017). Of those, 18.71% were deaf at birth (The Isaan Record, 2017). The reality of this statistic is that more than 71,000 members of the Deaf community had no experience of audible language when learning to read. Within the D/HH population, around 13.16% (50,000) attend school, of whom less than 10% attend a specialist school (The Isaan Record, 2017). In a survey of the disabled, more than one in three (37.8%) aged between 5 and 17 did not attend school (National Statistics Office, Thailand, 2017). Of those attending school, it was found that only 9.7% studied at a school that catered specifically to their disability.

Void of specialist education, the opportunities for deaf students to learn to communicate, either through sign, writing, or verbally, are greatly diminished. Research has repeatedly shown that reading scores for the Deaf are significantly poorer than those of hearing-abled students of an equivalent age (Morere, 2011; Razalli et al., 2018; Thurlow et al., 2009; Woll, 2019), with the difference widening with age (Razalli et al., 2018). In Thailand, D/HH students attain, on average, O-NET scores up to 50% lower than their hearing-abled peers (Iam-Khong et al., 2011). However, according to Mathews and O'Donnell (2018), this difference can be reduced using cochlear implants.

Nakhon Si Thammarat School for the Deaf is one of just a select number of schools in Thailand that offer specialist education for the D/HH. Established in 1991, the school provides residential tuition and tutors students from kindergarten (age five) to upper mattayom (age eighteen). Most students have diminished hearing from birth and are diagnosed as profoundly deaf. Students are assigned to classes based on their age and taught fingerspelling and sign language. The school teaches Thai Sign Language (TSL), which has similarities with American Sign Language (ASL). Students have access to a limited number of computers at the school but have no access to technology for learning reading, vocabulary, fingerspelling, or sign language. Teachers at the school expressed their existing methods for teaching new vocabulary are time-consuming and challenging for the students. The teaching methods mainly involved using pictures, fingerspelling, and sight words. Textbooks specific to learning vocabulary, such as shapes, colours, occupations, transport, etc., and story books that include the target vocabulary in sign or fingerspelling translation are non-existent.

Research objectives

This research aimed to address three objectives: 1) To evaluate the influence of an interactive web-based learning resource, DeafReader (Moxon & DeafReader, 2022b), on the vocabulary skills of deaf students studying in pratom levels one to six at Nakhon Si Thammarat School for the Deaf, Thung Song, Thailand. 2) Compare performance differences between genders. 3) Compare performance differences relating to age level.

Research questions

Based on the research objectives, the study needed to address three research questions:
1) To what extent can the use of DeafReader improve students’ range of vocabulary?
2) Does gender significantly influence students’ vocabulary acquisition in this study?
3) Does age significantly influence students’ vocabulary acquisition in this study?

Literature review

The literature search focused on the topics of teaching methods and technology used to teach reading and vocabulary to deaf students. Here, a review of the literature is presented, which relates to the current knowledge of how the Deaf learn to read in contrast with hearing-abled readers, plus existing technological solutions available for deaf readers and teaching pedagogy.

Differences between deaf and hearing-abled readers

Hearing-abled individuals often use internal monologue (also called “inner speech”) when thinking or reading silently and “private speech” (Morin, 2012) to verbalise their thoughts while completing a task. For the Deaf, this form of internal audio has been shown to manifest as a visual representation of sign language or fingerspelling (Williams et al., 2015). According to Morin (2012), private speech cannot exist without language and is a late development in people with limited verbal and social interaction skills, which is often the case for first-generation Deaf. Brain imagery suggests that the Deaf use areas of the brain, the left inferior frontal gyrus (Morin, 2012; Rönnberg et al., 2004), and auditory cortex (Finney et al., 2003; Harris, 2015) during tasks that require visual processing or utilise inner speech.

For the hearing-abled, most early vocabulary is acquired naturally through social interaction (Luckner & Cooke, 2010). This is somewhat reflected in the study by Woll (2013), who stated over 90% of deaf children are first-generation Deaf and have significantly smaller vocabularies than those born into deaf, signing families (second-generation Deaf). In a later study, Woll also found that reading proficiency in the Deaf correlates to their age when learning to sign; earlier signers tend to be more adept readers (Woll, 2019).

Technology solutions

While innovative designs have created solutions for aiding communication between the Deaf and hearing-abled through the use of translation applications (Arya et al., 2017; Elghoul & Jemni, 2009; HandTalk, 2022; Mahesh, 2018; Shinde & Kagalkar, 2015), the reading difficulties confronting the Deaf have been mainly ignored.

Baglama et al. (2018) studied the technology used to support D/HH students in their speaking, listening, and academic skills. The authors claim that D/HH students exhibited heightened motivation and interest when mobile applications were incorporated into their literacy training. In addition, they found instruction supported via computer applications increased the rate at which the D/HH learnt new vocabulary.

However, user interface design may hinder rather than aid the D/HH and those with reading difficulties (Möbus, 2010). A study by Elghoul and Jemni (2009) attempted to alleviate the problems faced by individuals with hearing and reading limitations while navigating and interacting with technological solutions. Their design consisted of a text-to-sign engine that gave signed feedback to the Deaf while using a PC. Using a signing avatar, their solution could translate on-screen text and assist navigation by providing cues for whatever was beneath the mouse pointer. As Möbus points out, adapted media, such as captions for audio, may be inappropriate when written language is not the user's first language, while maintaining signed video content poses many significant problems for the software creator.

As the D/HH rely on visual information, Lang and Steely found that deaf students' comprehension improved during online science courses through what they term "triad presentation" (Lang & Steely, 2003). Their concept provides the user with three visual forms of the same information; the text, the text translated into sign language, and an animated image representative of the text. The authors suggest introducing new vocabulary before the presentation and ensuring all text content is short and limited in vocabulary range. Razalli et al. (2018) also found that reading comprehension improved through the blended use of text and images. According to the authors, a lack of vocabulary and word comprehension prevented some students from decoding text to sign. Still, the image assisted the students in forming their understanding of the text and grasping novel information while maintaining their attentiveness. While there is potential for increased demands on the visual cognitive channel leading to cognitive overload, research already exists that suggests the Deaf can cope with increased visual information, possibly by utilising areas of the brain typically associated with audio processing (Azbel, 2004; Harris, 2015; Yoon & Kim, 2011).

Current teaching pedagogy

There has been significant research into how the Deaf learn to read and which teaching pedagogy best suits their needs. However, the actual mechanics of how the Deaf convert written text to language remains a much-debated topic. Some researchers (Cupples et al., 2014; Geers & Hayes, 2011; Paul et al., 2009; Trezek & Mayer, 2015) point to phonological awareness as the means to reading success, whereas others argue that language awareness, even a non-verbal language, is the answer (Goldin-Meadow & Mayberry, 2001; Mayberry et al., 2011; Schirmer et al., 2004). Some researchers argue that a combination of both forms of coding is required for reading skills to develop (Easterbrooks et al., 2015; Lasasso & Crain, 2015; Paul, 2013; Scarborough, 2001; Trezek & Mayer, 2015).

Luckner and Cooke (2010) state that high-frequency (sight) words, novel and complex concepts, and comprehending affixes, word roots, and context clues cannot be learnt indirectly through social interaction; they must be taught. With no comprehension of word roots and affixes, it is clear why the Deaf lag behind the Hearing in terms of vocabulary range and reading comprehension, an imbalance the authors state has been prominent in the research literature for over ten years. A generally overlooked issue in evaluating vocabulary is basing the measurement on the number of known words. Often, terms that are single words in written or spoken form consist of two or more words when signed (e.g., the word "puppy" is signed as "baby" and "dog") (Prezbindowski & Lederberg, 2003).

In what they term "the simple view," Hoover and Gough suggest that proficient reading is the product of decoding and language skills (Hoover & Gough, 1990). According to the authors, any enhancement in either component will enhance the reading proficiency of the individual, but if either factor is absent, the product, skilled reading, will be zero. This belief is supported by "Scarborough's reading rope" (Scarborough, 2001), in which skilled reading is exemplified through the interweaving of numerous component strands consisting of language comprehension and word recognition. According to Scarborough, word recognition combines phonological awareness, decoding, and sight recognition, whereas language comprehension encompasses background knowledge of a language, language structure, reasoning, literacy knowledge, and vocabulary.

In examining the literature, the case for non-verbal language and visual stimuli appears more probable and applicable to the students of this study, who have had little or no experience of sound and are not taught phonics. For example, Kuntze et al. (2014) argue that the Deaf should be trained to read using the same visual modality they use for communication, i.e., sign and fingerspelling. This viewpoint is reinforced by the research literature, which proposes a parallel between the time sign language skills are acquired and proficiency in reading (Goldin-Meadow & Mayberry, 2001; Musselman, 2000; Woll, 2019).

In sum, for the Deaf, learning to read is no different from acquiring a second language. For readers with a reduced vocabulary range, encountering verb forms and words with numerous meanings can result in comprehension problems. Void of phonological rule awareness, deaf readers must rely on the direct lexical path of identifying words, which requires prior knowledge to recognise and decode the word. These later two strands, decoding and word recognition correlate with the sight recognition and decoding strands from Scarborough's reading rope (Scarborough, 2001) and seem a universally supported idea in much of the literature discussed herein. The literature shows that using imagery can aid text comprehension, particularly in cases where a word has multiple meanings.

Research hypotheses

Based on the research literature, three hypotheses were posed thus:

H1: Using DeafReader will facilitate vocabulary acquisition.

H2: Gender is an influencing factor in vocabulary acquisition for the DeafReader users.

H3: Age is an influencing factor in vocabulary acquisition for the DeafReader users.

Research methodology

Research instrument

This study utilised an experimental design using pre-test and post-test scores as a measure of effect. Students were first divided into two groups based on their age level. Level one consisted of students studying in pratom levels one to three (age 7 to 9 years). Level two comprised students studying in pratoms four to six (age 10 to 12 years). Within each level, stratified random sampling was used to assign respondents to one of two groups, a control group (hereafter Classroom) or a treatment group (hereafter DeafReader). Respondents in each Classroom group were taught in separate classrooms by two teachers using flashcards and traditional teaching methods. In contrast, respondents in the DeafReader groups went to a computer lab and received guided supervision while using DeafReader (See Figure 1).

DeafReader is a web-based platform that facilitates textual comprehension by presenting students with media in a triad format (Lang & Steely, 2003). The site consists of vocabulary flashcard sets, a searchable picture dictionary, interactive reading exercises, and instant feedback quizzes. A contextual image, animated fingerspelling, and a signed video accompany all textual content. Reading exercises are presented page by page as a short section of text and a contextual image. Hotspot links connect areas of the picture with the words in the text, enabling student interaction and creating a dynamic association between vocabulary text and objects in the picture. Students can also highlight each word in isolation and view its corresponding fingerspelling, signed video, and image via a dynamic link to the picture dictionary. A video accompanies each story page to provide students with the sign language translation of the text. Personal user accounts enable each student to have a record of their performance, which the teachers can also monitor via a user progress dashboard. Although not used in this study, the user progress dashboard enables teachers to monitor quiz responses and quickly identify common errors.

After completing the pre-test, all students studied the target vocabulary within their relevant groups for one hour per week for six weeks. At the end of this period, all students completed the post-test. Between study periods, the user accounts in DeafReader were locked to prevent students in the DeafReader group from gaining additional practice time.

The pre-test and post-test questions for each level were based on thirty words selected randomly from a vocabulary list that formed part of the school's yearly learning outcomes. Two styles of multiple-choice questions were used; 1) Select the word that matches the picture. 2) Select the word that best completes the sentence. To prevent any practice effect, the order of pre-test and post-test questions were changed, and the style of each question was reversed. Four possible answers were presented for each question, one correct answer and three distractors. The distractors consisted of one related word (frog/fish), an unrelated word (frog/bicycle), and a word that is similar when signed (frog/neck) (See Figure 2). Where possible, different distractors were used in the pre-test and post-test questions.

Figure 1 Students learning target vocabulary words
Note: Left to right: Classroom group, deafreader group.

Figure 2 Similarly signed distractor words
Note: Left to right: Frog (กบ), Neck (คอ).

The learning features of DeafReader include interactive vocabulary-based short stories, keyword flashcards, knowledge review quizzes, and a searchable picture dictionary. The application links story and keyword vocabulary to picture dictionary entries to present vocabulary in image, text, fingerspelling, and sign language form (Lang & Steely, 2003). Before the study, staff were given access to administrator and student profile user guides via the DeafReader application (Moxon, 2022a; Moxon, 2022c).

Population and sample

While the school had 30 students registered in pratoms one through six, issues relating to COVID-19 meant only 21 were present and could participate in the study. Table 1 shows the participant's age level and gender and has been subdivided to show the distribution within each test group.

Table 1 Demographic information of assigned sample groups

Test Group	Age Level	Male		Female		Total	
		n	%	***n***	%	***n***	%
Classroom	Level 1	2	50	2	50	4	19
	Level 2	5	83	1	17	6	29
	Total	7	70	3	30	10	48
DeafReader	Level 1	1	25	3	75	4	19
	Level 2	4	57	3	43	7	33
	Total	5	45	6	55	11	52
Total		**12**	**57**	**9**	**43**	**21**	**100**

Data analysis

After completing the post-test, all data were collated and screened for completeness and correctness to ensure no erroneous data could interfere with the final analysis. The data were then screened for outliers and tested to ensure the assumptions of ANOVA were met. To ensure that the stratified random sampling had resulted in the creation of two homogenous groups, a one-way ANOVA was used to compare pre-test scores between the two test groups at the start of the study. The data file was then split to 1) compare scores by age level, then 2) compare scores by gender.

A one-way ANOVA was conducted to evaluate the mean difference between pre-test and post-test scores (hereafter Difference Scores) between students in the DeafReader and Classroom groups (Question 1). The data file was then split by gender, and a one-way ANOVA was conducted to compare mean Difference Scores between the DeafReader and Classroom groups when compared by gender (Question 2). Finally, a one-way ANOVA was conducted with the data file split by age level to compare mean Difference Scores between the DeafReader and Classroom groups when compared by age level (Question 3).

Results

Data screening

A Shapiro-Wilk test showed that pre-test and post-test Difference Scores for Classroom and DeafReader groups did not significantly depart from normality, $W(10) = .933$, $p = .475$ and $W(11) = .954$, $p = .700$, respectively. Scores for both groups were skewed to the left, $X(10) = -.503$, $z = -.732$ and $X(11) = -.287$, $z = -.434$ respectively, with platykurtic kurtosis, $X(10) = .158$, $z = .118$ and $X(11) = -1.128$, $z = -.882$ respectively. No outliers were detected (See Figure 3). In addition, no departure from normality was detected in the unstandardised residuals for Difference Scores $W(21) = .959$, $p = .490$, Skewness $X(21) = -.347$, $z = .693$, Kurtosis $X(21) = -.776$, $z = .798$ (See Figure 4). As the sample size was below 200, the Difference Scores were assumed to be normally distributed (Ghasemi & Zahediasl, 2012).

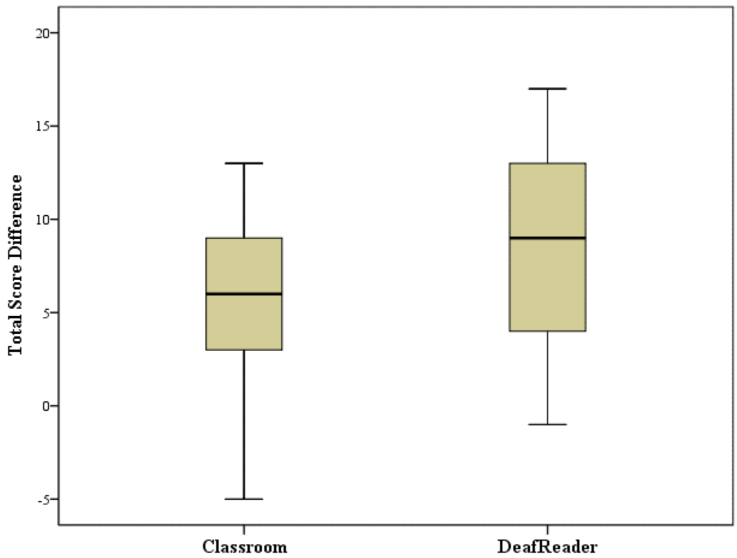

Figure 3 Boxplot of pre-test and post-test difference scores by test group

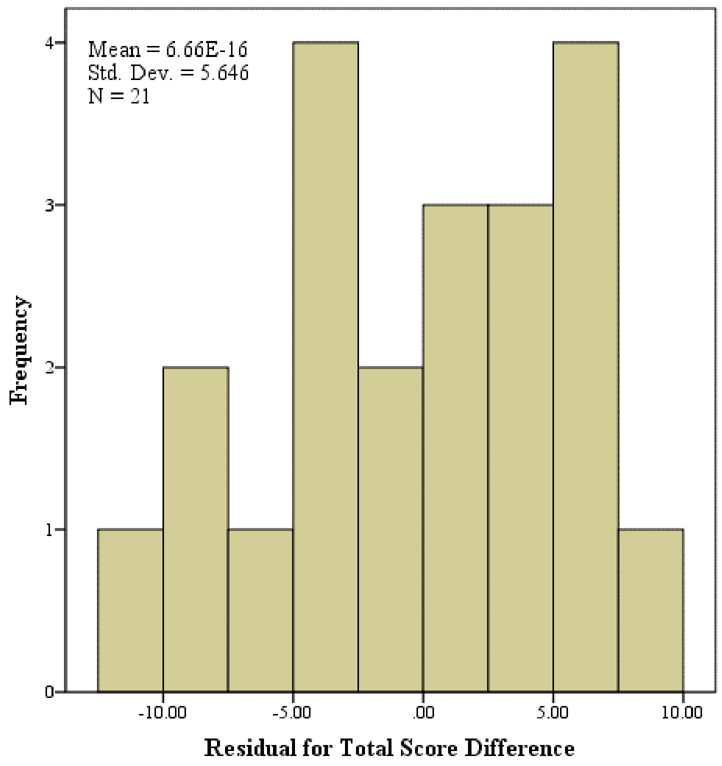

Figure 4 Distribution of pre- and post-test residual scores

In testing homogeneity between the groups, the ANOVA showed that pre-test scores for Classroom and DeafReader groups were not significantly different overall, $F(1, 19) = .020$, $p = .890$, $\eta^2 = .001$, 95% CI [-6.380, 5.580], when split by age level, $F_{\text{Level1}}(1, 6) = .042$, $p = .844$, $\eta^2 = .007$, 95% CI [-3.226, 2.726], $F_{\text{Level2}}(1, 11) = .000$, $p = .986$, $\eta^2 = .000$, 95% CI [-8.661, 8.818], or when split by gender, $F_{\text{Male}}(1, 10) = 1.006$, $p = .339$, $\eta^2 = .091$, 95% CI [-3.349, 8.835], $F_{\text{Female}}(1, 7) = .391$, $p = .551$, $\eta^2 = .053$, 95% CI [-18.321, 10.654]. Therefore, the groups were considered homogeneous in terms of vocabulary ability at the start of the study.

Question 1

Table 2 shows the descriptive statistics for pre-test and post-test scores by test group. Paired-samples *t*-test of pre-test and post-test scores revealed that both groups displayed statistically significant overall improvement in performance, $t_{\text{Classroom}}(9) = -3.352$, $p = .009$, 95% CI [-9.882, -1.918], $t_{\text{DeafReader}}(10) = -4.732$, $p = .001$, 95% CI [-12.569, -4.522] (See Table 3 and Figure 5). However, the one-way ANOVA revealed there was no statistically significant difference in pre-test and post-test scores between the Classroom and DeafReader groups, $F(1, 19) = 1.092$, $p = .309$, $\eta^2 = .054$, 95% CI [-7.943, 2.652] (See Table 4 and Table 5). The strength of the relationship between the Test Group and the Difference Score, as assessed by η^2, was medium, with the Test Group factor accounting for 5.4% of the variance in the Difference Score.

Table 2 Descriptive statistics for pre- and post-test scores by test group

	Test Group	*n*	%	*M*	*SD*	Min	Max
Pre-test Score	Classroom	10	48	11.60	5.80	5	23
	DeafReader	11	52	12.00	7.14	6	28
	Total	21	100	11.81	6.38	5	28
Post-test Score	Classroom	10	48	17.50	4.65	10	24
	DeafReader	11	52	20.55	5.61	8	27
	Total	21	100	19.10	5.28	8	27

Table 3 Paired-sample t-test pre-test and post-test scores by test group

Test Group	*M*	*SD*	*SEM*	*t*	*df*	Sig. (2-tailed)	95% CI of the Difference	
							LB	UB
Classroom	-5.900	5.567	1.760	-3.352	9	0.009**	-9.882	-1.918
DeafReader	-8.545	5.989	1.806	-4.732	10	0.001**	-12.569	-4.522

** $p < .05$ (2-tailed).

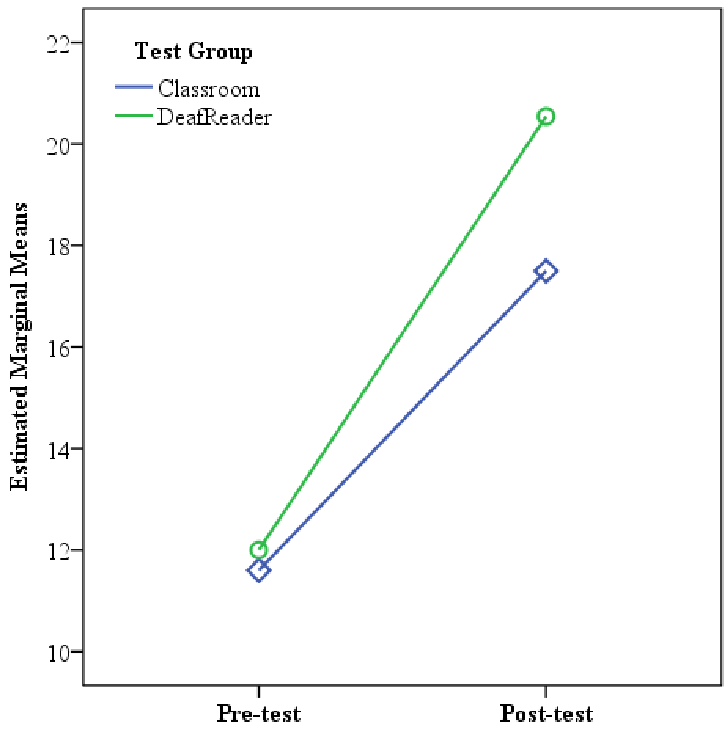

Figure 5 Mean Pre-test and Post-test Scores by Test Group

Table 4 Descriptive statistics for difference scores between test groups

	n	%	*M*	*SD*	*SE*	95% CI for Mean		Min	Max
						LB	UB		
Classroom	10	48	5.90	5.57	1.76	1.92	9.88	-5	13
DeafReader	11	52	8.55	5.99	1.81	4.52	12.57	-1	17
Total	21	100	7.29	5.81	1.27	4.64	9.93	-5	17

Table 5 Analysis of variance for difference scores between test groups

	SS	*df*	*MS*	*F*	Sig.	Partial Eta Squared
Between Groups	36.658	1	36.658	1.092	0.309	0.054
Within Groups	637.627	19	33.559			
Total	674.286	20				

Question 2

Descriptive statistics for Difference Scores between test groups compared by gender are shown in Table 5. The one-way ANOVA showed that Difference Scores between the Classroom and DeafReader groups were not statistically significantly different for female students $F(1, 7) = .057$, $p = .818$, $\eta^2 = .008$, 95% CI [-8.912, 10.912]. However, as shown in Table 6, the scores for male students were marginally statistically different, $F(1, 10) = 5.120$, $p = .047$, $\eta^2 = .339$, 95% CI [-13.269, -.102]. Figure 6 and Figure 7 show the mean pre-test and post-test scores between the Classroom and DeafReader groups for male and female students, respectively. For male students, the strength of the relationship between the Test Group and Difference Score, as assessed by η^2, was strong, with the Test Group factor accounting for 34% of the variance in the Difference Score. However, the relationship was weak for female students, with the Test Group factor accounting for .8% of the variance in the Difference Score.

Table 5 Descriptive statistics for difference scores between test groups by gender

Gender		*n*	*M*	*SD*	*SE*	95% CI for Mean		Min	Max
						LB	UB		
Male	Classroom	7	5.71	5.91	2.23	0.25	11.18	-5	13
	DeafReader	5	12.40	3.36	1.50	8.23	16.57	8	17
	Total	12	8.50	5.92	1.71	4.74	12.26	-5	17
Female	Classroom	3	6.33	5.86	3.38	-8.22	20.89	2	13
	DeafReader	6	5.33	5.96	2.43	-0.92	11.58	-1	15
	Total	9	5.67	5.57	1.86	1.39	9.95	-1	15

Table 6 Analysis of variance for difference scores between test groups by gender

Gender		*SS*	*df*	*MS*	*F*	Sig.	Partial Eta Squared
Male	Between Groups	130.371	1	130.371	5.120	0.047**	0.339
	Within Groups	254.629	10	25.463			
	Total	385.000	11				
Female	Between Groups	2.000	1	2.000	0.057	0.818	0.008
	Within Groups	246.000	7	35.143			
	Total	248.000	8				

** $p < .05$.

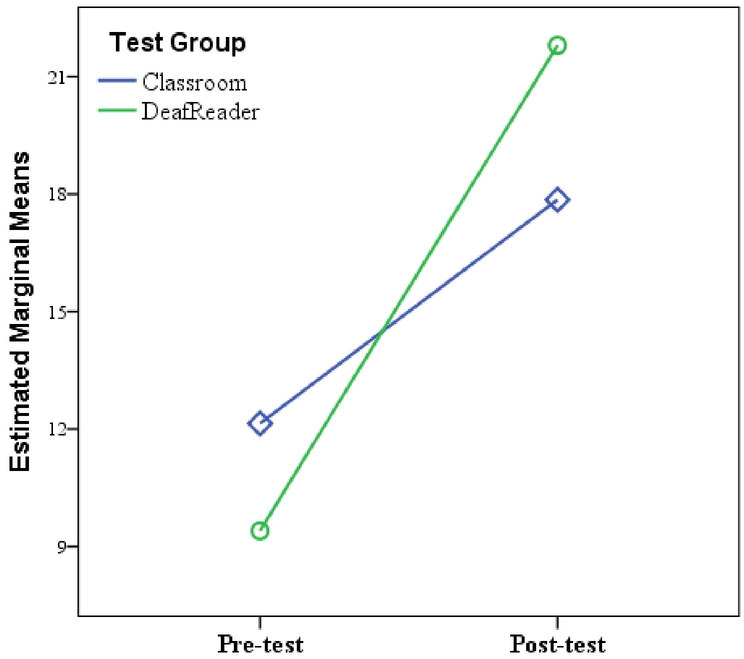

Figure 6 Mean pre-test and post-test scores for males by test group

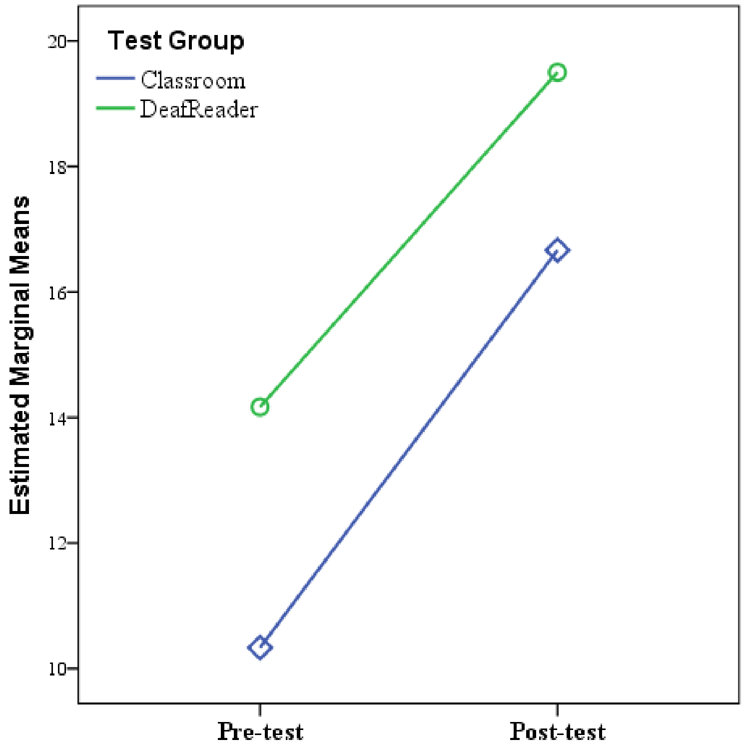

Figure 7 Mean pre-test and post-test scores for females by test group

Question 3

Descriptive statistics for Difference Scores between test groups compared by age level are shown in Table 7. As illustrated in Table 8 and Figure 8, the one-way ANOVA showed no statistically significant difference between the two groups, $F_{Level1}(1, 6) = .000$, $p = 1.000$, $\eta^2 = .000$, 95% CI [-8.991, 8.991], $F_{Level2}(1, 11) = 1.601$, $p = .232$, $\eta^2 = .127$, 95% CI [-12.066, 3.256]. For students in level 1, the strength of the relationship between the Test Group and the Difference Score, as assessed by η^2, was weak, with the Test Group factor accounting for 0% of the variance in the Difference Score. However, for level 2 students, the relationship was strong, with the Test Group factor accounting for 12.7% of the variance in the Difference Score.

Table 7 Descriptive statistics for difference scores between test groups by age level

Level		*n*	*M*	*SD*	*SE*	95% CI for Mean		Min	Max
						LB	UB		
1	Classroom	4	8.50	3.70	1.85	2.62	14.38	4	13
	DeafReader	4	8.50	6.35	3.18	-1.61	18.61	2	17
	Total	8	8.50	4.81	1.70	4.48	12.52	2	17
2	Classroom	6	4.17	6.21	2.54	-2.35	10.68	-5	13
	DeafReader	7	8.57	6.29	2.38	2.75	14.39	-1	15
	Total	13	6.54	6.41	1.78	2.66	10.41	-5	15

Table 8 Analysis of variance for difference scores between test groups by age level

Level		*SS*	*df*	*MS*	*F*	Sig.	Partial Eta Squared
1	Between Groups	.000	1	0.000	0.000	1.000	0.000
	Within Groups	162.000	6	27.000			
	Total	162.000	7				
2	Between Groups	62.683	1	62.683	1.601	0.232	0.127
	Within Groups	430.548	11	39.141			
	Total	493.231	12				

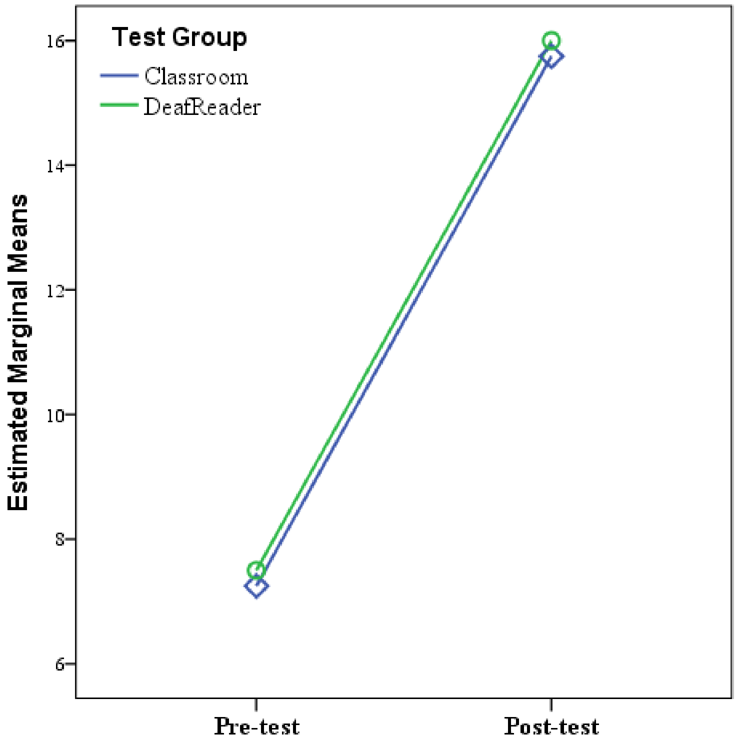

Figure 8 Mean pre-test and post-test scores for age level 1 by test group

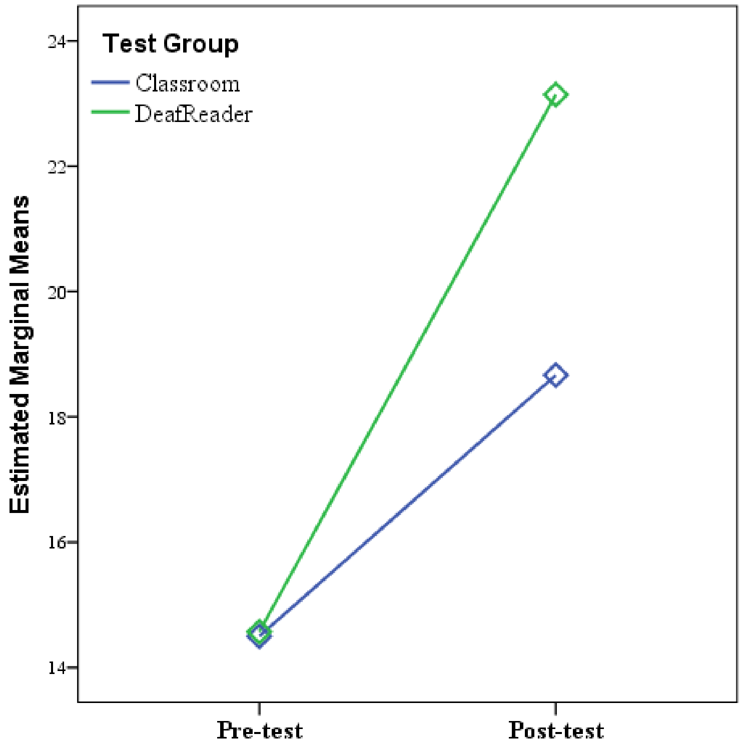

Figure 9 mean pre-test and post-test scores for age level 2 by test group

Discussion

This study aimed to evaluate the influence on deaf students' vocabulary skills using an interactive web-based learning resource, DeafReader. The measure of effect was the difference in pre-test and post-test scores of students using DeafReader, when compared statistically against scores attained by students in a control group.

In addressing research question one, while both groups displayed a statistically significant improvement, the comparison of Classroom and DeafReader mean Difference Scores were not statistically significant different. This suggests that while practice and repeated exposure may have aided both groups, the learning media modality was not a significant influence. While these findings are not reflective of the anticipated results based on the literature (Baglama et al., 2018; Lang & Steely, 2003; Luckner & Cooke, 2010), the overall effect observed in both groups is reflective of the findings of Allgood et al. (2009). Based on these findings, the use of DeafReader as a learning medium was deemed to be not dissimilar to traditional classroom instruction for the students in this study. Therefore, hypothesis H1 was rejected.

As the results of research question 2 suggest, the use of DeafReader had a more significant influence on the vocabulary of male students than females, with the Test Group factor accounting for 34% of the variance in their Difference Scores. Therefore, hypothesis H2 was retained. Several studies have highlighted gender differences in all aspects of language development (see Berninger et al. (2008), Burman et al. (2008), Lynn & Mikk (2009), Reilly et al. (2019), Schwabe et al. (2015). Development age differences may well have been an influencing factor in the findings of this study as the majority of females were in the younger age group, whereas the majority of boys were in the older age group (See Table 1).

While the results of research question 3 showed no statistically significant difference in performance between the two age levels, the comparison between Classroom and DeafReader Difference Scores for Level 1 students showed that, statistically, their mean Difference Scores were identical (See Figure 8). Based on these findings, hypothesis H3 was rejected. The results raise interesting questions regarding the threshold at which technology intervention for vocabulary learning becomes appropriate for the Deaf. While some studies have pointed to language as being the fundamental building block for reading and vocabulary (Joy et al., 2019; Mayberry et al., 2011; Schirmer et al., 2004), others have pointed to a proportional relationship between skills such as word recognition and vocabulary (Easterbrooks et al., 2015; Lasasso & Crain, 2015; Scarborough, 2001). It would seem, therefore, that the students in this study may be lacking in underpinning language skills.

Two contributing factors that may have influenced research question 3 in particular are:

1) Due to COVID-19 restrictions, students in pratom levels 1 and 2 received little or no formal tuition prior to the school reopening, meaning they were void of the basic fingerspelling and sign language skills needed to study and learn the target vocabulary.
2) Students who are first-generation Deaf may well have weaker language skills in general compared to students who are second-generation Deaf. The proportion of first- and second-generation Deaf in this study is unknown.

Conclusion

Advancements in mobile technology and artificial intelligence create infinite ways in which communication boundaries can be broken down. While some of these advancements may benefit the Deaf, limited vocabulary, reading, and language awareness often render the technology redundant. In this paper, the author has trialled a purpose-built software solution aimed at helping deaf students in Thailand improve the skills they need to overcome some of the communication barriers that hinder them in society.

The results of this study showed that using DeafReader as a teaching medium, while beneficial, was not significantly different from traditional classroom teaching methods in terms of student acquisition of vocabulary. The use of the software was found to have a significantly greater influence on vocabulary attainment in male students than in females, which may be attributed to a larger proportion of younger female students in the sample group. However, the results showed that, statistically, age was not an influencing factor in student performance. While the results of this study may not have been as promising as hoped, the data provides a valuable insight for future developments and enhancements to the software.

Limitations in the sample size and essential reading and signing ability of students in this study were a direct consequence of the school closure during the COVID-19 pandemic.

Time and resources were also limitations in this research. A more extended training period with a broader target vocabulary may have produced more significant results.

Future research should examine the effects on an older age group, who may be better equipped to absorb new vocabulary and study autonomously. Future studies should also explore other building blocks of reading and vocabulary for the Deaf, such as learning fingerspelling, sign language, and mapping sign to letters and words.

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