Using the Technique of Interaction Design (IxD) and Augmented Reality (AR) as Assistive Technology for Students with Disabilities

Onintra Poobrasert*, Sirilak Luxsameevanich, and Paweena Meekanon

***Abstract*—This paper considers the implement of Kids Can Read Application to assist kids with learning disabilities to spell and read correctly. The researchers applied the advantage of Quick Response (QR) code technology into the interaction design. The Kids Can Read will install on smartphone or tablet and will be using with word card with QR code integrated, kids will scan the QR code, and the spelling instruction will appear with sound of each word. Kids will be able to open the application to reviewing the word afterward without the re-scan the QR code. The interface design of the Kids Can Read is easy to use and kids friendly. Most of the kids in this study prefer to use Kids Can Read to help them learn and practice of word reading and spelling. As a result, when the application was conducted into practice in schools, the sample in this study had a statistically significant increase in spelling ability at 0.05. This is in consistent with the hypothesis that the ability to read word spelling of the Grade 3 students with learning disability in reading is higher after using the Kids Can Read. Hence, we anticipate that all of students with learning disabilities who study in Grade 3 in the country will have chance to use the application by the end of next year.**

***Index Terms*—Assistive technology, augmented reality, interaction design, learning disabilities, quick response code**

I. Introduction

According to the 2021 survey of the Basic Education Commission, there are 391,552 students with Learning Disabilities (LD) in 24,391 schools [1]. This number of LD students is remarkably high. At present, Assistive Technology (AT) is available for helping LD students to learn but this technology is not much available. The technological facilities are instruments to increase potentials or adjust proficiency of LD students to learn more with more effectiveness. In addition, technological facilities are useful for teachers to use for facilitating learning arrangement as well as for providing learning opportunities for LD students. As a result, the research team was interested in developing a reading assistive tool for LD students and trailed it in the real classroom. The trial results were satisfying as the tool can assist the students in the experimental group to increase their reading proficiency with the statistical significance at 0.05 and most students were satisfied with the tool at the 'most' level.

Manuscript received December 20, 2022; revised March 16, 2023; accepted March 22, 2023.

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A. Objectives of the Research

The study on the effectiveness of the assistive application for reading used with LD students in Grade 3 consists of the following objectives.

1) To study the ability to read word spellings of Grade 3 students with learning disability in reading after using the assistive application for reading.
2) To compare the abilities to read word spellings of Grade three students with learning disability in reading before and after using the assistive application for reading.
3) To study the satisfaction of the Grade 3 students with learning disability in word-spelling reading after teaching with the assistive application for reading.

B. Scope of the Research

The target group in the experiment included 15 students with learning disability in reading who were studying in Grade 3 from 2 schools in Bangkok. The participants were selected by the purposive sampling.

C. Hypotheses of the Research

Hypothesis 1: The ability to read word spelling of the Grade 3 students with learning disability in reading after teaching with the assistive application for reading is at the 'good' level.

Hypothesis 2: The ability to read word spelling of the Grade 3 students with learning disability in reading after teaching with the assistive application for reading is higher.

Hypothesis 3: The satisfaction of the Grade 3 students with learning disability in reading after using the assistive application for reading is at the 'much' satisfaction level.

II. Background

A. Reading Skills

Coltheart [2] states about students' reading problems that reading problems can be in various aspects, depending on individual students with problems in which learning skills. To develop students' fluent reading skill, students' reading skills must be developed in letter recognition, word recognition, knowledge of letter-sound rules, and understanding of word meaning. If the students have problems in any skills, their overall reading skill cannot be normal and complete. Temple and Marshall [3] proposed dual-route model which shows two different processes of oral reading: searching words in mental dictionary/mental lexicon or reading seen or read words and using letter-sound rules or reading by blending letters.

doi: 10.18178/ijiet.2023.13.8.1921

Reading skills derived from using letter-sound rules or letter blending can be compared with reading Thai word practice with distribution of word spelling in which the students have to remember various letters and letter-sound rules to read words orally. The studies on reading disabilities show that students with reading problems are confused with letter forms and sounds [4].

Reading with distribution of word spelling has been a method for practicing Thai word reading in elementary education from the past. Sirikanjanapong [5] found that Thai class book in the past used different methods to teach reading. Some books taught to read with the blending method of vowels, consonants, and tone marks such as Thai Reading Practice Book in Grade 1 by the Governor Phra Wiphatwitthayasit [6]. Another current teaching method is to teach reading with syllable blending, smooth syllables and checked syllables, words with the focus on meaning, and contents. The Thai class book of the Department of Curriculum and Instruction Development in 1977 taught contents reading with the main characters — Mana and Mani — to run the stories. According to Potibal [7], this book taught to read with letter blending, spelling distribution with meaningful and non-meaningful words, consonant blends, diphthongs and leading letters, and short sentences.

Thai teaching is taught by the method of grammar in word spelling, distribution, and letter conjugation. The teaching method which facilitates reading on word spelling is the discarded or synthetic method by setting symbols to represent sounds for blending words by words. There are four main types of phonic methods to teach reading [8]. The method which the research team has tested on its appropriateness for LD students is the flowing sound method to teach word spelling in steps as follows:

Step 1: consonant, vowel such as bor-ar-ba [บอ-อา-บา] (new word 1)

Step 2: consonant, vowel, final consonant such as ba-nor-ban [บา-นอ-บาน] (new word 2)

Step 3: consonant, vowel, tone mark such as ban-tho-baan [บาน-โท-บ้าน] (new word 3)

In addition, the reading method with distribution of word spelling refers to reading letters of consonants, vowels, and tone marks which are blended into Thai words or syllables according to Thai orthography and spellings in several possible ways. The research team selected the method to read Thai word spellings by considering on word sounds and written forms by firstly reading sound components in initial consonant and vowel before adding word marks and final consonant.

The pattern of word-spelling reading is initial consonant sound + vowel sound > reading sound – reading sound + marks + final consonant > word form.

B. Interaction Design (IxD)

Information on previous research about reading skills for students with learning disabilities were mentioned above. Thus, we concerned about how to convey the information to the students who have reading disorder. We therefore studied about the interaction design. Interaction Design (IxD) is the design of interactive products that a designer intends to focus on the items in development to include the way users will interact with it [9, 10]. The designer should carefully understand how users especially, people with disabilities and technology communicate with each other [11–13]. In this study we also concern about the usability testing. According to [14, 15] explain usability as being made up of five principles which are learnability, efficiency, memorability, errors, and satisfaction.

III. Methodology

A. Research Instruments

The research instruments for the data collection in development of ability to read word spellings of the Grade 3 students with learning disability in reading by using the assistive application (Kids Can Read) for reading are as follows:

1) The Kids Can Read application and flash cards with QR code on each of them.
2) Lesson plans for developing the ability to read word spellings of the Grade 3 students with learning disability in reading.
3) The assessment form on ability to read word spellings.
4) The assessment form on satisfaction in using the assistive application for reading.

Additionally, our team conducted questionnaires for the users (students with learning disabilities, parents, and teachers) before the development of the Kids Can Read application. We concerned with the interaction design for the application as the goal of creating products that enable the user to achieve their objectives in the best way possible as mentioned earlier [16]. Thus, the design and development of the Kids Can Read include the following:

1) *System function analysis and design:* Reading system is a mobile application development, so it requires to have a data sync between smartphone and server [17, 18] it will require to protect confidential data. So, the developer needs to design the system with security in mind, and to have a functionality meets the main requirement and to make data in QR code form [19].
2) *Data security*: To make a QR code, the team will need data. The developer is analyzing the data and creating a new data group to generate a QR code, while also ensuring data security by encrypting the data [20]. To enhance data security during development, all data will be stored in the Cast-128 encryption system using CBC (Cipher Block Chaining) [21] and a key named "AA" will be used. This encryption method will convert the data into alphabetic and special characters [22] as

กุ้ง* = Cast128+key =>rn28sARIB67YKbxMDSse4RYwmWTMVF

(*กุ้ง [kung] meaning shrimp in English)

3) *QR code:* The team finishes encryption process, converts into QR code, and makes QR code in each grade level (distinguish by color) as shown in Fig. 1.

Fig. 1. QR Codes in each grade level.

4) *Primary function:* Primary function is a design of system workflow and will explain in mockup by showing the system from start to main function. As the primary function of the reading system begins from the starting page, the user will be able to choose between the Scan or History page. When the user selects one of the functions, the system will send them back to the select page. The difference between the Scan and History pages is that the Scan page works with the user's smartphone camera to scan the QR code [23]. After scanning is complete (with the QR code already encrypted by the system), the user will be sent to the Show page. The History page will display a chart of the QR codes that the user has already scanned, as shown in Fig. 2

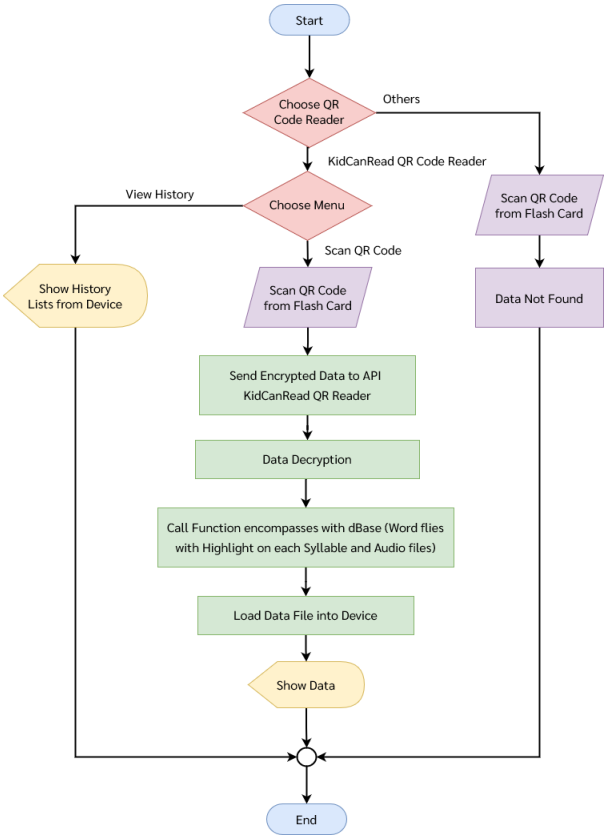

Fig. 2. Flowchart of primary function.

5) *Screen*: Each function of reading system is required User Interface or (UI) such as:

Homepage: a starting page, user need to choose what function they want to interact between Scan and History as show in Fig. 3.

Fig. 3. Homepage.

Scan: a page for user to scan a QR code to go to a Showing Result page.

Showing Result: this page will show up after user scans a QR code, there will be animation of word spelling and sound as shown in Fig. 4.

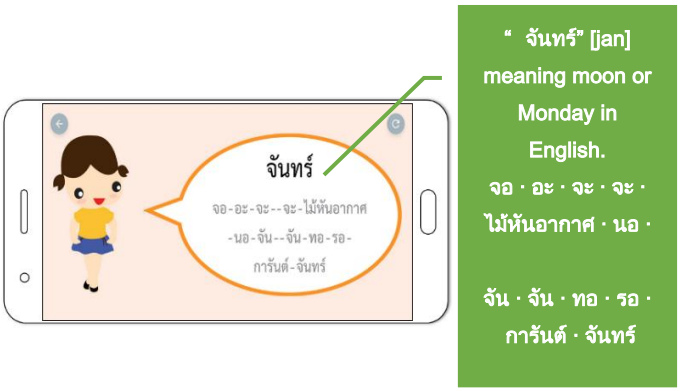

Fig. 4. Showing result page.

History: inside of History page, there will be a data chart of previous QR code scanning and can be used to re-appear in Showing Result page.

B. *Application Development*

Homepage is used for both of "SCAN ME" and "HISTORY" button.

Scan page: if user is never allowing the application to use the camera, the OS will ask user for permission to use the camera. After finishing the scan, the system will take user back to Homepage to start the process again.

Showing Result page will be an animation and voice of word spelling that user already scan. It will include cartoon character by grade level and color in the screen will change according to grade level. At this time, user can spell along the animation of word spelling [24, 25].

History page will show past word spelling that user already scanned, user will be able to enter Showing Result page of the word from the chart in history page, the spelling information is sorted according to the time it was scanned. The last scanned word is always at the top of the screen as shown in Fig. 5.

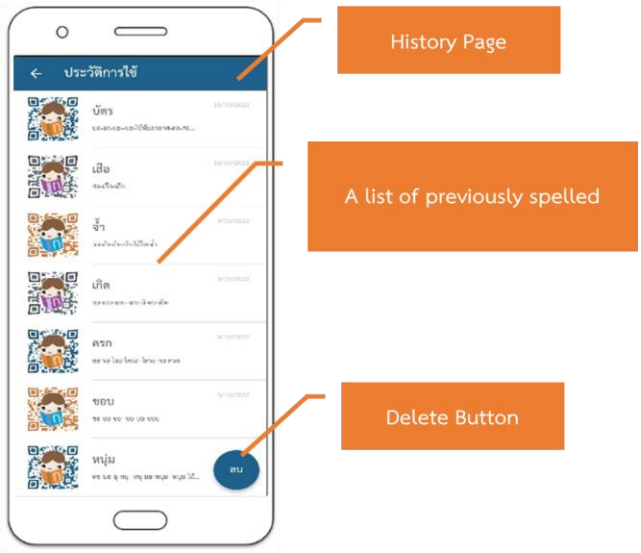

Fig. 5. History page.

C. Integrating AR into the Kids Can Read

Augmented Reality (AR) is a technology that additionally combines the virtual world with the real world to make it as close as possible to the reality by combining the reality with the artificial virtual world through software and connected devices. However, the main benefit of AR is that it can combine digital elements and Third Dimension (3D) with the real world perception of an individual. AR has a wide range of usage, from helping to make decision to entertaining. It has been widely applied in various fields, including art area, medical area, commercial area, and educational area. AR is another technology that is developed to be used in conjunction with storybooks to stimulate children to acquire knowledge and have more fun with reading. From a plain storybook, it will become a living story with both 3D animation and sound, which augment the interest of children to listen to the story inside the mentioned AR integrated storybook. In addition, the AR technology system based instruction media can help enhancing the learning efficiency of the learners because the instruction media is interesting for the learners to learn, especially in young learners.

Nowadays, children access to technology easier. Parents and teachers should pay attention to the young children's technology usage. Technology has many advantages, and they are in the capability of the children to practice using them. Technology can help children develop their cognitive skill, such as the Kids Can Read, it allows children to practice through the application.

The Kids Can Read is not only used in conjunction with QR code attached vocabulary cards, but students can also use AR technology with the developed Reading Exercises for Kids. Students can scan the page to spell words. There will be image and spelling sound sprung out from the page that is scanned, which make children enjoy with the image and sound and they can practice by themselves at home and school. The research team realizes that the technology cannot replace all the teaching instruction for children, but it help to teach them more efficiently and acts as a medium that helps the children around these ages to acquire knowledge, especially children with learning disabilities or Attention Deficit Hyperactivity Disorder (ADHD). The application will be able to help children concentrate and enjoy learning. From the previous research, young children can receive the benefit from technology usage such as they have developed learning skill, prolonged memories, stimulated learning through observation, developed speaking and problem-solving skill, compared to those who do not have the experience in learning through technology. It also helps to develop social, emotion, language skill, as well as support and expand the learning scope of the children [26].

To apply AR technology in this research, we have used the technology to combine the reality world with the virtual world by connecting devices, such as camera, computer, smartphone, or tablet with the software system. The AR system contains:

1) Marker or sensor which is the symbol or picture that designated to compare with the data in Marker Database.
2) Camera, smartphone, tablet, or any device that can detect sensors to analyze the image.
3) Display monitor, mobile screen, or any monitor to display the image.
4) 3D object generating system, such as a computer program that project 2D images from 3D models.

The application of AR together with Reading Exercises for Kids developed with a total of five activities in the display section, which are MainActivity, QRscanActivity, ArscanActivity, ContentActivity and ARshowActivity, with the details as shown below:

MainActivity screen: This is the first screen of the application, which is used to access the read aloud function with text highlighting or the 3D model display function.

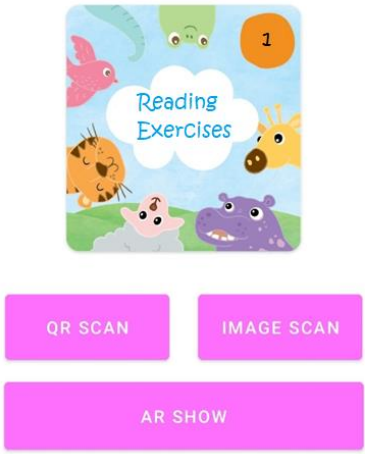

Fig. 6. Reading exercises for kids.

- **QRscanActivity screen**: This is used to scan QR codes in the exercises to access the read aloud page with text highlighting.
- **ARscanActivity screen**: This is used to scan pictures from the exercises to access the read aloud page with text highlighting.
- **ContentActivity screen**: This is the screen with the read aloud function with text highlighting that fetches data from the database to be displayed.
- **ARshowActivity screen**: This is used to scan pictures from the exercises to display the 3D model.

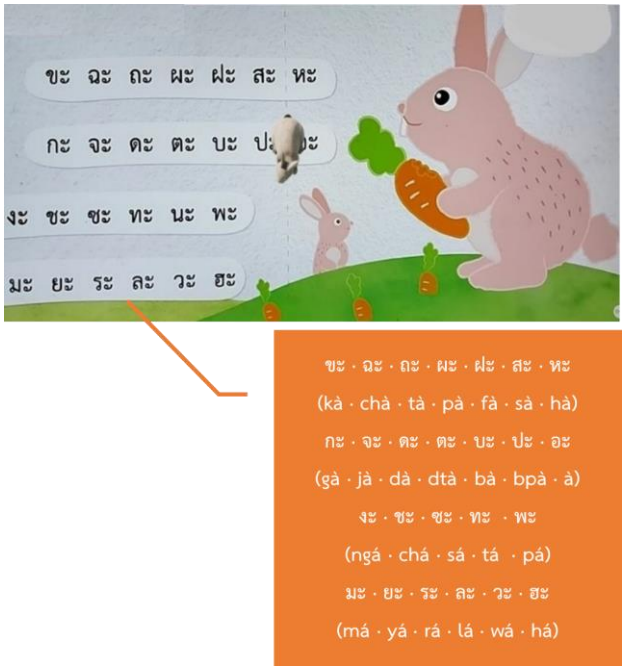

Fig. 7. Augmented reality shows screen.

For the application of AR, we have summarized the work process as in the flowchart below.

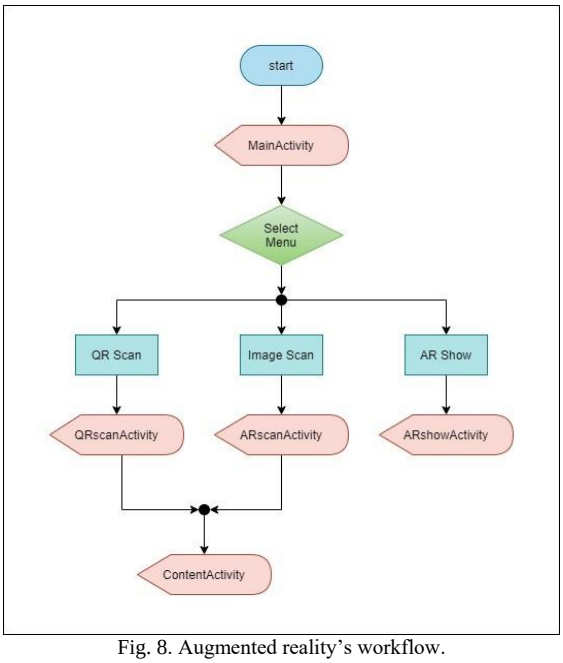

Fig. 8. Augmented reality's workflow.

1) 3D display model function

To enable 3D model displaying function, we must import the library called AR Core to detect images in the exercises section to display 3D models. The mentioned image detection uses the same image database with one that is accessed by the Reading Exercises for Kids scanning, which uses *Image detects* function in AR Core library [27] by selecting the image detection section. It is supported on Android version 7.0 and above.

2) 3D model displaying

To display 3D models on the application, we will use the library called *Sceneform* SDK version 1.16.0 [28] to help rendering 3D model files on the application, whose system is supporting gITF and glb file extension.

AR used in education purposes to open the world of imagination can be integrated with other media, for example, integrated with a traditional media that can only present information via texts and pictures, it will upgrade the performance of that media to the multimedia level which can interact with students. It will contain pictures, sounds and animations or 3D models [29]. These will urge children to develop learning skill and imagination.

IV. Analysis and Results

The data were analyzed by using the statistics of median, interquartile range, and the Wilcoxon Matched-Pairs Signed -Rank Test.

The samples in this study were in Grade 3 students with learning disability in reading from two schools. The experiment was in the form of the one group pre-test post-test design.

The research instruments included 1) the assistive application for reading with flash cards, 2) lesson plans for developing ability to read word spellings of the Grade 3 students with learning disability in reading by using the assistive application for reading, 3) the assessment form on the ability to read word spellings, and 4) the assessment form on satisfaction in using the assistive application for reading. The assessment form on the ability to read word spellings included 20 items with difficulty at 0.32–0.80, discrimination at 0.21–0.64, and reliability at 0.78. The assessment form on satisfaction in using the assistive application for reading had IOC at 1.00. This means that the assessment form on the ability to read word spelling and the assessment form on satisfaction in using the assistive application for reading had validity or item objective congruence appropriate for uses. According to the criteria of Khongsat and Thammawong [26], the items with IOC at 0.50–1.00 have acceptable validity whereas the items with IOC at less than 0.50 need to be improved and cannot be used.

The research results on development of ability to read word spelling of the Grade 3 students with learning disability in reading by using the assistive application for reading are presented as follows.

1) Ability to read word spellings of the Grade 3 students with learning ability in reading after teaching with the assistive application for reading.

According to Table I, the ability to read word spelling of the Grade 3 students with learning disability in reading before teaching with the assistive for reading has the scores at 0 – 8, median at 3, interquartile range at 7, and their ability is at the 'poor' level. After teaching with the assistive application for reading, the median is at 18, the interquartile range at 4, and the ability at the 'excellent' level. This result is consistent to Hypothesis 1 that the ability to read word spellings of the Grade 3 students with learning disability in reading after teaching with the assistive application for reading is at the 'good' level.

TABLE I: Scores, Median, and Interquartile Ranges of the Ability to Read Word Spelling of the Grade 3 Students with Learning Disability in Reading before and after Using the Assistive Application for Reading (N = 15)

Schools	Classes	No.	Pre-test Scores (Full score of 20)	Ability Levels	Post-test Scores (Full score of 20)	Ability Levels
School 1	Grade 3	1	8	Poor	20	Excellent
		2	8	Poor	18	Excellent
		3	8	Poor	20	Excellent
		4	0	Poor	8	Poor
		5	5	Poor	15	Very good
		6	0	Poor	9	Poor
		7	0	Poor	10	Poor
School 2	Grade 3	8	0	Poor	18	Excellent
		9	6	Poor	20	Excellent
		10	2	Poor	18	Excellent
		11	3	Poor	17	Excellent
		12	7	Poor	18	Excellent
		13	5	Poor	19	Excellent
		14	2	Poor	17	Excellent
		15	0	Poor	16	Very good
Mdn			3	Poor	18	Excellent
IQR			7		4	

According to Table II, the ability to read word spellings of 15 Grade 3 students with learning disability in reading before teaching with the assistive application for reading is at the 'poor' level (100%). No students have the ability at the average, good, very good, and excellent levels. After using the assistive application for reading, however, three students have the ability at the 'poor' level (20%), two students at the

'very good' level, and ten students at the 'excellent' level whereas no students are at the average and good levels.

TABLE II: PERCENTAGE OF THE GRADE 3 STUDENTS WITH LEARNING DISABILITY IN READING CLASSIFIED ACCORDING TO THE ABILITY TO READ WORD SPELLINGS BEFORE AND AFTER TEACHING WITH THE ASSISTIVE APPLICATION FOR READING

Score Criteria (Full score of 20)	Ability Levels	Number of Students Before Teaching	Percentage	Number of Students After Teaching	Percentage
17–20	Excellent	0	0.00	10	66.67
15–16	Very Good	0	0.00	2	13.33
13–14	Good	0	0.00	0	0.00
11–12	Average	0	0.00	0	0.00
0–10	Poor	15	100.00	3	20.00
Total		15	100.00	15	100.00

2) Comparison of the ability to read word spellings of the Grade 3 students with learning ability in reading before and after teaching with the assistive application for reading.

According to Table III, the ability to read word spelling of the Grade 3 students with learning disability in reading after teaching with the assistive application for reading is higher with the statistical significance levels of 0.05. This result is consistent to Hypothesis 2 that the ability to read word spellings of the Grade 3 students with learning disability in reading after teaching with the assistive application for reading is higher.

TABLE III: THE RESULTS OF THE COMPARISON OF THE ABILITY TO READ WORD SPELLINGS OF THE GRADE 3 STUDENTS WITH LEARNING DISABILITY IN READING BEFORE AND AFTER TEACHING WITH THE ASSISTIVE APPLICATION FOR READING

No.	Scores		Score Difference (D = Y−X)	No. of Difference	Rank by Signs		T
	Before Teaching (X)	After Teaching (Y)			+	−	
1	8	20	12	7.5	+7.5		0*
2	8	18	10	4	+4		
3	8	20	12	7.5	+7.5		
4	0	8	8	1	+1		
5	5	15	10	4	+4		
6	0	9	9	2	+2		
7	0	10	10	4	+4		
8	0	18	18	15	+15		
9	6	20	14	10	+10		
10	2	18	16	13.5	+13.5		
11	3	17	14	10	+10		
12	7	18	11	6	+6		
13	5	19	14	10	+10		
14	2	17	15	12	+12		
15	0	16	16	13.5	+13.5		
Total					$T^+ = 120$	$T^- = 0$	

* Statistical significance level at 0.05

3) Satisfaction of the Grade 3 students with learning ability in reading after teaching with the assistive application for reading.

According to Table IV, the satisfaction of the Grade 3 students with learning disability in reading after teaching with the assistive application for reading is found at the 'most' level with the mean of 4.76. This result is consistent to Hypothesis 3 that the satisfaction of the Grade 3 students with learning disability in reading after teaching with the assistive application for reading is at the 'most' level. The satisfaction on each aspect is described as follows.

Part 1: Assessment on the characteristics of the assistive application for reading.

The satisfaction on the characteristics of the assistive application for reading is at the 'most' level in all five aspects: 1.1) user-friendly design, 1.2) appropriateness for use, 1.3) appropriateness of font size, 1.4) appropriateness of font type, and 1.5) appropriateness of sound with the means of 4.73, 4.33, 4.67, 4.87, and 4.73 respectively.

Part 2: Assessment on accuracy and operational effectiveness of the assistive application for reading.

The satisfaction on accuracy and operational effectiveness of the assistive application for reading is at the 'most' level in all three aspects: 2.1) accuracy in word spellings, 2.2) quickness in processing, and 2.3) user-friendliness of the application with the means of 4.73, 4.67, and 4.93 respectively.

Part 3: Assessment on the flash cards.

The satisfaction on the flash cards is at the 'most' level in three aspects: 3.1) appropriateness of the flash card size, 3.2) appropriateness of the letter size and the flash card size, and 3.3) appropriateness of the background color and the letter color in the flash cards with the means at 4.80, 4.60, and 5.00 respectively.

Part 4: Overall satisfaction assessment.

The assessment on the overall satisfaction on the assistive application for reading is at the 'most' level with the mean of 5.00.

TABLE IV: MEANS AND THE SATISFACTION LEVEL OF THE GRADE 3 STUDENTS WITH LEARNING DISABILITY IN READING AFTER TEACHING WITH THE ASSISTIVE APPLICATION FOR READING

Part/No.	Assessment List	Satisfaction Levels	
		$\bar{x}$	Levels
Part 1: Assessment on the characteristics of the assistive application for reading			
1.	User-friendly design	4.73	Most
2.	Appropriateness for use	4.33	Most
3.	Appropriateness of font size	4.67	Most
4.	Appropriateness of font type	4.87	Most
5.	Appropriateness of sound	4.73	Most
Part 2: Assessment on accuracy and operational effectiveness of the assistive application for reading			
1.	Accuracy in word spellings	4.73	Most
2.	Quickness in processing	4.67	Most
3.	User-friendliness of the application	4.93	Most
Part 3: Assessment on the flash cards			
1.	Appropriateness of the flash card size	4.80	Most
2.	Appropriateness of the letter size and the flash card size	4.60	Most
3.	Appropriateness of the background color and the letter color in the flash cards	5.00	Most
Part 3: Overall satisfaction assessment			
	Overall satisfaction on the assistive application for reading	5.00	Most
Mean		4.76	Most

V. DISCUSSION

In the study on effectiveness of the assistive application for

reading used with Grade 3 students with learning disability in reading, the assistive application for reading has been developed to enhance the students' ability to read word spellings. Accordingly, the students use mobile phones to scan the code printed on the flash cards in a user-friendly design. When the students use the mobile phone to scan the code on the flash card, the program processes the data and read that word spelling such as the word "Jai" [ใจ] spelled with "Jor-ai [จอ-ไอ] – Jai [ใจ]" etc. Moreover, while the word is being spelt, the letters are highlighted with color for the students to observe and recognize how to spell such word with each letter. The students can repeat after the word spellings or listen to the word spellings repeatedly if needed.

According to this experiment, the students were more capable to read word spelling correctly. Before the teaching with the application, the students' scores were at the range of 0 – 8 from the full score of 20 with the mean of 3 scores, meaning that their ability to read word spellings was at the 'poor' level. However, after teaching with the assistive application for reading, the students gain scores at the range of 8 – 20 from the full score of 20 with the mean of 18 scores, meaning that their ability to read word spelling was at the 'excellent' level. This result is consistent to Hypothesis 1 that the ability to read word spellings of the Grade 3 with learning disability in reading after teaching with the assistive application for reading is at the 'good' level. And the result is also consistent to Hypothesis 2 that ability to read word spellings of the Grade 3 with learning disability in reading after teaching with the assistive application for reading is higher. This is because the students are enthusiastic and interested in learning with the new method with assistive technology for word-spelling reading. According to the teacher's observation, the students rushed to the classroom at the scheduled time and some students came so early before class time. At the beginning of the teaching, some students were not proficient in scanning by mobile phones so the teacher helped them one by one until they could use it skillfully and were allowed for doing self-study. The students were able to do self-study after receiving the flash cards from the teachers to practice spelling words by themselves with the code-scanning method.

Teaching by using the assistive application for reading can enhance students' self-study, and repetition of listening to word spelling is helpful for students to recognize the spelling of each word. Repetitive reading is a practical educational way for students with learning disability to develop their reading ability [30]. Repetitive reading can be used to develop students' basic reading skills with fluency [31]. In the primary education, reading should be implemented in a quiet place. Students and a teacher read aloud at least three times. If the students make errors in reading or are hesitate longer than five seconds, the teacher repeats reading such word for students to read that word again correctly and repeat reading it until they can read it fluently. Teaching with the assistive application for reading has function for students' repetitive listening for several time as well as for them to practice word-spelling reading by themselves. As a result, the ability to read word spellings of the Grade 3 students with learning disability in reading is higher. This method also encourages the students to learn because the assistive application for reading is helpful for them to do self-study, to correct their reading errors by themselves [32], to practice reading as needed, and to spend time for learning by themselves . According to the data analysis, although 15 students had the ability to read word spelling at the 'poor' level before the experiment, ten students increased their ability to read word spelling to the 'excellent' level, two students to the 'very good' level, and three students still at the 'poor' level.

VI. Concluding Remarks

In conclusion, the experimental development of the ability to read word spelling of the Grade 3 students with learning disability in reading by using the assistive application for reading, and their ability to read word spelling was higher. Before the experiment, the students' pre-test scores were at the range of 0–8 from the full score of 20 with the mean of three scores and their ability to reading word spelling was at the 'poor' level. After teaching with the assistive application for reading, the students' scores were at the range of 8 – 20 from the full score of 20 with the mean of 18 scores and their ability to read word spelling was at the 'excellent' level. This result is consistent to Hypothesis 1 that the ability to read word spelling of the Grade 3 students with learning disability in reading after teaching with the assistive application for reading is at the 'good' level. This is because the students spelt words according to their clear listening to the model sounds from the assistive application for reading and they practiced by repeating word-spelling reading repeatedly until they could remember such words correctly.

This finding is consistent with the previous study on semi-experimental study on learning mobile application to develop Chinese reading skills and attitude after the trial method. The purposes of their study were on the effects of the application on Chinese reading skills. In their study, 53 participants were divided into two groups: an experimental group and a control group. Their study found that the students taught with the application had higher reading scores and liked to develop reading skills by using the application.

In addition, the results of our study is similar to the study on the development of mobile application for enhancing the skill in English reading aloud of the students in Grade 3 with the flipped classroom technique. The application used the sound-recognition technique and converted texts into sound for enhancing oral reading skill in words and conversation between the students and the application. They found that the students' learning achievement from learning through the mobile application to enhance the skills in English reading aloud was higher at the end of the experiment with the statistical significance level at 0.05 and the students were satisfied in the mobile application for enhancing the skills in English reading aloud at the 'most' level.

The present research has also assessed the satisfaction of the Grade 3 students with learning disability in reading after teaching with the assistive application for reading and found that the students' satisfaction was at the mean of 4.76. This finding is consistent to Hypothesis 3 that the satisfaction of

the Grade 3 students with learning disability in reading after teaching with the assistive application for reading is at the 'much' satisfaction level. This is because the assistive application for reading has been developed from the analysis on learning aspects of students with difficulties in word spelling, and its development is based on principles for designing learning technology. These data were used in the design and improved according to the experts' suggestion before using it in the experiment on the students with learning disability in reading. Therefore, the students' satisfaction was at the 'most' level.

In addition, the result of the effectiveness assessment on the assistive application for reading reveals the students' opinions that the application is interesting and user-friendly for spelling practice and revision. The students like the assistive application for reading because it is good for reading practice and makes them enjoy with practice on word-spelling reading and gain more knowledge. The students suggest that more words should be included to increase variety of words; and picture, time, and quickness of word presentation should also be increased.

Finally, from this study, we noticed that the ability to read word spellings of the Grade 3 students with learning disability in reading after teaching with the assistive application in reading (The Kid Can Read) was at the 'excellent' level. The scores from the post test results also have shown that the ability to read word spellings of the Grade 3 students with learning disability in reading after teaching with the assistive application in reading was higher and the satisfaction of the Grade 3 students with learning disability in reading after teaching with the assistive application in reading was at the 'most' level. Therefore, according to the test on effectiveness of the assistive application for reading in this study, suggestions are given for people who want to use this application for developing the ability to read word spellings of the students with learning disability in reading. Hence, we anticipate that all elementary students with learning disabilities in the country can use the application shortly.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Onintra Poobrasert, the correspondence author led the team through this work of study conception and design, data collection, analysis, and interpretation of results. Additionally, all authors worked evenly in writing and manuscript preparation.

Funding

This research was funded by Assistive Technology and Medical Devices Research Center (A-MED), National Science and Technology Development Agency (NSTDA) Thailand, grant number P1850494.

Acknowledgment

We would like to acknowledge the contributions of the late Assoc. Prof. Dr. Putthachart Potibal.

References

[1] Ministry of Education. (November 2021). *Basic Education Core Curriculum: Standard T201*. [Online]. Available: http://academic.obec.go.th/newsdetail.php?id=75

[2] M. Coltheart, "Analysing developmental disorders of reading," *Speech-Language Pathology*, vol. 7, no. 2, pp. 49–57, Taylor & Francis Group, June 2005.

[3] C. M. Temple and J. C. Marshall, "A case study of developmental phonological dyslexia," *British Journal of Psychology*, vol. 74, no. 4, pp. 517–533, November 1983.

[4] J. K. Torgensen and P. G. Mathes, *Assessment and Instruction in Phonological Awareness*, Florida State University, pp. 1–11, 2002.

[5] K. Sirikanjanapong, "Orthographical System in the thai primer of the department of curriculum and instruction development," thesis, Chulalongkorn University Graduate School, 1996.

[6] P. Potibal, "Difficulties in reading and writing for thais," presented at Conference on Language, Brain, and Technology, Kasetsart University, 10–12 March, 2010.

[7] P. Potibal, "Difficulties in spelling and reading for dyslexia: Difficulties in Thai orthography," presented at Workshop on Language, Brain, and Technology, the 5th International Convention on Rehabilitation Engineering and Assistive Technology, (iCREATe 2011), Bangkok, Thailand, 23 July, 2011.

[8] C. Pattamadilok, R. Kolinsky, S. Luksaneeyanawin, and J. Morais, "Orthographic congruency effects in the suprasegmental domain: Evidence from Thai," *Quarterly Journal of Experimental Psychology*, vol. 61, issue 10, pp. 1515–1537, 2006.

[9] D. Saffer, *Designing for Interaction: Creating Innovative Applications and Devices (Voices That Matter) New Riders*, 2nd ed., 2009, ISBN-10: 0321643399.

[10] D. Norman, *The Design of Everyday Things: Revised and Expanded Edition Basic Books*, 2013, ISBN-10: 9780465050659.

[11] J. Tidwell, *Designing Interfaces: Patterns for Effective Interaction Design*, O'Reilly Media, 1st ed., 2015, ISBN-10: 0596008031.

[12] J. M. Bastien, "Usability testing: A review of some methodological and technical aspects of the method," *International Journal of Medical Informatics*, vol. 79, issue 4, pp. e18–e23, 2010, ISSN: 1386-5056.

[13] J. B. Schumaker, L. D. Walsh, and J. B. Fisher, "Effects of computerized instruction on mastery and generalized use of commas strategies by students with LD," *Journal of Special Education Technology*, vol. 36, no. 1, pp. 29–43, 2019, Doi: https://doi.org/10.1177/0162643419878146

[14] J. Nielsen. (May 2022). *Accessible Design for Users with Disabilities*. [Online]. Available: https://www.nngroup.com/articles/accessible-design-for-users-with-disabilities/

[15] B. Shneiderman, C. Plaisant, M. Cohen, and S. Jacob, *Designing the User Interface: Strategies for Effective Human-Computer Interaction*, 5th ed. Prentice Hall, 2009.

[16] T. Siang. (February 2022). *What Is Interaction Design?* [Online] Available: https://www.interaction-design.org/literature/article/what-is-interaction-design

[17] M. F. Martins, T. Lima, P. N. M. Sampaio, and M. Paiva, "Mobile application to support dyslexia diagnostic and reading practice," in *Proc. 2016 IEEE/ACS 13th International Conference of Computer Systems and Applications (AICCSA)*, pp. 1–6, Doi: 10.1109/AICCSA.2016.7945710

[18] I. Avishka, K. Kumarawadu, A. Kudagama, M. Weerathunga, and S. Thelijjagoda, "Mobile App to support people with dyslexia and dysgraphia," in *Proc. 2018 IEEE International Conference on Information and Automation for Sustainability (ICIAfS)*, pp. 1–6, Doi: 10.1109/ICIAFS.2018.8913335

[19] M. F. Tretinjak, "The implementation of QR codes in the educational process," in *Proc. 2015 38th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, pp. 833–835, Doi: 10.1109/MIPRO.2015.7160387

[20] K. Carrondo and H. Gil, "The potencial of 'QR Code' in education a study in the 1st cycle of basic education," in *Proc. 2019 14th Iberian Conference on Information Systems and Technologies (CISTI)*, pp. 1–4, Doi: 10.23919/CISTI.2019.8760735

[21] C. Rekha and G. N. Krishnamurthy, "An optimized key scheduling algorithm for CAST-128 using dynamic substitution S-box," *International Journal of Recent Technology and Engineering (IJRTE)*, vol. 8, issue 3, September 2019.

[22] N. Nopriadi *et al*., "Utility software design to comprehend the cryptography CAST-128 method," *Journal of Physics: Conference Series*, vol. 1364, 012049, Doi:10.1088/1742-6596/1364/1/012049

[23] B. Kouninef, G. Merad, and M. Djelti, "The use of QR codes and mobile technology in the blended learning approach," in *Proc. 5th International Conference on e-Learning (econf)*, 2015, pp. 135–143, Doi: 10.1109/ECONF.2015.90

[24] J. Rikala and M. Kankaanranta, "Blending classroom teaching and learning with QR codes," in *Proc. 10th International Conference Mobile Learning*, 2014.

[25] S. Goyal, S. Yadav, and M. Mathuria, "Exploring concept of QR code and its benefits in digital education system," in *Proc. 2016 International Conference on Advances in Computing, Communications, and Informatics (ICACCI)*, pp. 1141–1147, Doi: 10.1109/ICACCI.2016.7732198.

[26] S. Khongsat and T. Thammawong. (March 2022). *IOC : Index of Item Objective Congruence*. [Online]. Available: https://www.mcu.ac.th/article/detail/14329

[27] A. R. Core. (June 2022). Augmented images for Android. [Online] Available: https://developers.google.com/ar/develop/java/augmented-images

[28] Sceneform. (July 2022). [Online] Available: https://developers.google.com/sceneform/c develop

[29] P. Srifa, "Augmented reality card game development ramakien literature, thai subjects for prathomsuksa 6 students, schools under chanthaburi primary educational service Area office 1," *CMU Journal of Education*, vol 5, no. 1, January-April, 2021.

[30] P. Tshering, D. Norbu, S. Dorji, N. Dema, and P. R. Dhungyel, "Experience of a gamified spelling solving by students for learning spelling: development of kids spell dzongkha App," in *Proc. 2018 International Conference on Current Trends towards Converging Technologies (ICCTCT)*, pp. 1–5, Doi: 10.1109/ICCTCT.2018.8550865

[31] C. Jones, D. Khalil, K. Mander, A. Yeoh, and C. Moro, "Providing dementia education with augmented reality: A health sciences and medicine feasibility pilot study," *Research in Learning Technology*, vol. 30, 2022, Doi: https://doi.org/10.25304/rlt.v30.2668

[32] P. Oleksandr *et al.*, "Special aspects of using modern multimedia technologies within the educational process," *International Journal of Information and Education Technology*, vol. 12, no. 12, pp. 1436–1442, 2022.

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