Leady: A Multisensory Approach in Mobile Application for Dyslexic Children

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***Abstract*—Dyslexia is considered the most common appearance of a learning disability in the world. Dyslexic students often suffer from emotional issues because of their educational failure experiences. Dyslexia cannot be cured. However, proper and continuous treatment can help students to achieve better results in their studies. The sooner the intervention happens, the better the outcome will be. The research presents the design and development of a mobile application to help dyslexic students to learn how to read. The application is called Learning Dyslexia (Leady). The Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model is used for developing the application. It uses a multisensory approach as the teaching method. Leady aims at young learners so that they can have the intervention from an earlier age. The application design also complies with the appropriate design for dyslexic students, such as in the selection of used fonts and background color. Then, Leady is demonstrated to five dyslexia caretakers (the teachers or parents) from a dyslexia school in Bandung. From the conducted survey, it can be inferred that the method is integrated well since all respondents agree that Leady can help dyslexic students to learn how to read. Most of them agree that the used method in Leady is suitable for dyslexic students.**

***Index Terms*—Multisensory Approach, Mobile Application, Dyslexic Children**

I. Introduction

PERHAPS, Percy F. is one of the first recorded cases of dyslexic students. In one of its volumes in November 1896, British Medical Journal reported Percy's case, who was intelligent and bright. Unfortunately, he could not learn how to read. Great length of efforts had been carried out to teach him to read but to no avail. At best, he could only spell out words of one syllable with difficulty [1]. Nowadays, Percy's case has been discovered as the most common appearance of a learning disability [2, 3]. It has a prevalence of 5–10% of the population [4]. Meanwhile, other researchers state the prevalence of people suffering from some degree of dyslexia can reach 17% of the world population [5].

The learning disability is called "dyslexia". It is originated from the Greek word "*dys*" (difficult) and "*lexia*" (word or vocabulary) [4]. Dyslexia refers to the difficulty in both written and spoken language. A dyslexic person suffers from excessive difficulties in learning how to read and write, remember letters, pronounce words, and differentiate specific sounds of letters [5]. However, not all difficulties in reading or writing are a dyslexia case. Many other factors can cause it. If the difficulty emerges without any external handicaps or impairment, such as sensory, intellectual, emotional, or socioeconomic factors, the person may be suspected of suffering from dyslexia [5, 6].

Dyslexia cannot be cured, and it will persist in the person who acquires it [1, 2, 7]. The symptoms of dyslexia usually manifest in children from an early age. If the adults around the children (their parents and teachers) do not recognize the symptoms, the children can be misjudged as incapable learners [1, 8]. As a result, the dyslexic students will suffer from an inferiority complex, low self-esteem, and emotional pain. They also fear that they will lose the love and support from their family because of their academic failure. If these conditions are neglected, dyslexic students may grow into bitter adults that are still affected by their educational failure experiences [7].

Proper and continuous treatment is needed to help dyslexic students [2, 9]. The sooner the intervention happens, the better the outcome will be [3, 5, 9]. The conventional method of learning how to read is not suitable for dyslexic students [10, 11]. They need

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extra supports and different methods to accommodate their learning disability [5]. The multisensory approach is acknowledged as the most effective teaching method for students with dyslexia to learn how to read. Students can learn more easily and successfully when the teaching is comprised of several senses. The multisensory approach is formerly and occasionally called the Orton-Gillingham (OG) approach. It utilizes auditory, visual, and kinesthetic senses in the teaching method [12].

In recent days, Information and Communication Technology (ICT) has been employed as an intervention method for dyslexic students [2, 10, 11]. This assistive software can help students to study and achieve the same learning progress as their non-dyslexic fellows [2, 10]. Employing ICT for dyslexic children can give them an interactive experience and increase their learning motivation [2]. It is used to assist students in the classroom environment [13] and at home, where students can use the application for independent learning [2, 3, 5, 10, 13]. With the rise of mobile programming, the development of mobile applications for dyslexic students has emerged [2, 5]. However, almost all applications are intended for elementary students and above. A few of them aim at early-age children, especially those in the Indonesian language.

To the best of the authors' knowledge, there is only one developed application for early-age dyslexic children, which is LexiPal [14]. LexiPal utilizes a multisensory approach that is one of the best teaching methods for dyslexia. It has several features to help children to cope with their disabilities. However, it is developed as a desktop application. Hence, its mobility is more restricted. Moreover, it must be used with teachers' or parents' supervision. However, it is important to develop an application that can be used without teachers' support [15].

In the research, a mobile application to help dyslexic children to learn how to read is designed and developed. The application is called Learning Dyslexia (Leady). It uses a multisensory approach as the teaching method. Leady aims at young learners so it can help early-age dyslexic children. The proposed application has several advantages over other applications in the Indonesian language. Leady is a mobile application so that the children can repeat and practice their study at home by themselves. Repetition and practice are essential in the learning process as learning effectiveness is enhanced through these activities. Repetitive information is believed to be easier to recall in the future [3]. The application is intended for younger children to give an early intervention, and it uses a multisensory approach to have the best result in teaching reading for dyslexic children.

II. Literature Review

A. Dyslexia

The International Dyslexia Association (IDA) gives a formal definition of dyslexia as follows. Dyslexia is a specific learning disability that is neurological in origin. It is characterized by difficulties with accurate or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected concerning other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede the growth of vocabulary and background knowledge [13].

If the disability is caused by brain damage, and the person does not have the problem before the damage occurred, it is called acquired dyslexia. On the other hand, developmental dyslexia refers to a learning disability without any external causes [16]. Some of the general symptoms of dyslexia are difficulties in learning to speak, learning letters and sounds, organizing written and spoken language, memorizing numbers, keeping up with and comprehending longer reading assignments, spelling, and learning a foreign language [13].

The impact of dyslexia on each person is various. It depends on how bad the condition, the timeliness, and the effectiveness of the intervention are. The main difficulties, which dyslexic people suffer from, include word recognition, reading fluency, spelling, and writing. These difficulties can be reduced by proper and early remedy, but dyslexic people may acquire other difficulties in more complex tasks later [13].

B. Multisensory Approach

The multisensory approach is broadly known as Visual, Auditory, Kinesthetic, and Tactile (VAKT) method [17]. It is believed as the best teaching method for dyslexic students. It integrates all modalities of study [12, 15, 17]. It incorporates all senses of seeing, hearing, and touching on teaching the students [15, 17]. It also tries to link eyes, ears, voices, and hand movements to make students understand the symbols. It is a suitable teaching method for dyslexic students since children with learning difficulties are believed to have more receptive sensors to help their learning processes [15]. The key aspect of multisensory elements can be seen in Table I [18].

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TABLE I
KEY ASPECTS OF MULTISENSORY ELEMENTS.

Elements	Key Aspects
Visual	Using eyesight to get information, read, visualize or record mental images, and memorize the information.
Auditory	Listening and talking in various ways. It is suitable to reinforce students to learn a new word.
Kinesthetic	Including motion with gross and fine motor skills. Examples of this learning modality are jumping, running, and placing.
Tactile	Touching with hands and fingers that engage fine motor skills.

C. Related Works

Some applications are developed to assist dyslexic children in the classroom environment. AGENT-DYSL combines speech recognition to evaluate students' reading performances, emotional state recognition of students via image recognition, and error type profiling via an adaptive knowledge core. In the teachers' tool, the teacher can evaluate the students, see students' profile descriptions, and print recommendation reports according to the profile [10]. Another research proposes an application with webcam to detect students' hand movements in tracing the alphabet from the set of three-letter words from the same word family. Then, the program, TraceIt, plays the sound of the alphabet after it is successfully traced. It is intended to be deployed in schools or dyslexia learning centers [3].

Assistive technologies to aid dyslexic children in their self-study occur along with Internet and mobile application development. Dyslexia Activity System (DAS) is an online educational game that uses the multisensory method to support dyslexic students in their individual learning. It has five activities: letter recognition, number recognition, number sequencing, vowel and phonics, and sequencing and character recognition exercise [15]. Meanwhile, Dyscover is another web-based application based on Orton-Gillingham (OG) principles [12]. Then, Easylexia is a mobile application that provides four different categories: words, numbers, memory, and books [2]. There are also applications for dyslexic students in other languages than English. For example, there is a developed application to learn Portuguese [5], and Bijak Membaca [19] and Dyslexia Baca [20] are developed mobile applications in Malay.

Developing assistive software with the native language of a country is important as each language has a different spelling and phonemic structure. Unfortunately, there are just a few applications in the Indonesian language. One of them is LexiPal, a desktop and web-based application that is aimed at 5 to 7-years-old children [14]. Another one is Two Dis, a mobile application to help dyslexia and dyscalculia students [21]. The last example is BacaYuk!, a mobile application for dyslexic students for Android and iOS platforms. BacaYuk! is used for a classroom environment that the teachers should arrange the activities for students based on materials provided by the application. Students' progress is also provided based on their performance in each activity [22].

III. RESEARCH METHOD

A. Methods

The research belongs to the software development category. Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model is used to develop the application [23]. The application will be examined with black box testing before assessed by five dyslexia caretakers (the teachers or parents) from a dyslexia school in Bandung. The respondents will be asked to fill in the questionnaire based on their experience in using the app. The questionnaire is arranged based on a 4-point Likert scale measurement.

In questionnaire measurement, the Likert scale is categorized as an attitude scale. It calculates an individual's tendency toward the experiment's object. In the Likert scale, the respondent denotes their degree of agreement (or disagreement) about a statement or item in the questionnaire regarding the experiment [24]. This measurement was first introduced in the 1930s by Rensis Likert as a five-point psychometric scale. The original Likert scale was Strongly Approve, Approve, Undecided, Disapprove, and Strongly Disapprove [25]. It has two disagreement points, two agreements, and one midpoint in the middle. Over time, the scale has expanded to several scaling. One of them is the 4-point scaling of Strongly Disagree, Disagree, Agree, and Strongly Agree [26]. The research uses this 4-point method for clarity, so the respondents do not choose the neutral midpoint.

The Likert score for a questionnaire is derived from its score for each item. The score can be obtained by calculated the respondent's response as each response has its point. The range of the point is from one to four, from Strongly Disagree to Strongly Agree. Then, this point is multiplied by the number of respondents that choose it. If three respondents select Strongly Agree, the point for Strongly Agree is 12 (3×4). The percentage for an item is calculated as shown in Eq. (1) [27]:

$$\text{Percentage} = \frac{\text{sum of total score}}{Y} \times 100. \qquad (1)$$

Equation (2) defines the product of the point and the total count of the respondent. For example, for an item that has two Strongly Agree, two Agree, and one Disagree chosen by five respondents, the sum is 16

$((2 \times 4) + (2 \times 3) + (1 \times 2))$. Then, Eq. (3) calculates the divisor, Y. It is the product of total respondents and the highest Likert point in the questionnaire.

$$\text{Sum of total score} = \sum(\text{count of respondent} \times \text{point}), \quad (2)$$

$$Y = \text{total number of responses} \times \text{maximum point}. \quad (3)$$

The research has five responses from five respondents. Meanwhile, the maximum point is four (Strongly Agree). The Likert scale has a slightly different mean value than a conventional percentage. It is because of the weight point of each item. The percentage of the 4-point Likert scale will range from 25% to 100%, with 62.5% indicates the even spread (not 50%) for this scale. Therefore, the average value in this measurement will be 62.5% [27].

B. Design Consideration

Leady is developed for the group age of kindergarten to the first grade of elementary school students. At these ages, children begin to learn how to read by recognizing the letters and connecting each letter with their corresponding sounds. However, the task will be difficult for children with dyslexia. They usually have trouble remembering symbols of letters and their sounds. They can also have difficulty in pronouncing and spelling [13]. There are other symptoms of dyslexia. Considering the target of this application, the research will only address the difficulty in writing letters and connecting the sound of the alphabet with the respective letters.

The application has two main activities: learning how to read (in this aspect, recognizing and remembering the alphabet) and learning how to write the alphabet. After the learning process, students' progress can be assessed in the evaluation menu. The menu is provided for both reading and writing evaluations. One drawback of using paperwork for dyslexic students to study at home is that they do not know their learning progress. This issue can lead to a lack of motivation [15]. The evaluation menu in this application shows students' progress in recognizing and connecting letters with their respective sounds. Besides motivation, evaluation can also attract children to use the application. Figure 1 illustrates the structure of Leady's menu. Then, the multisensory approach is integrated into both learning and evaluation for each activity. Table II describes the used multisensory elements in Leady.

However, there is some concern in developing the application to make it "dyslexia friendly". It helps to reduce the burden on dyslexic students and increases their chance to understand the content of the application. Even though there are differences, it is suggested to consider several factors [28–33]. First, Sans Serif (non-Serif) fonts are suggested over the Serif font type as they appear less crowded. The examples of Sans Serif fonts are Arial, Comic Sans, Verdana, Tahoma, and Calibri. Leady uses Comic Sans. The font gives the impression of an informal and quite cheerful situation. It is suitable for application for young age children.

Second, font sizes of 12–14 are recommended. The 14-point size is believed to be the ideal size. However, some dyslexic children may prefer a larger font size [28, 29, 32]. Leady uses standard font size. Third, there is different advice for font and background color. Single color background without a pattern and many pictures that can cause distraction should be used. It is also suggested that the background color is not bright and does not create high contrast. Therefore, black font on a white background is not recommended. However, recent researchers find that black or white pair and vice versa is preferable. It does not hamper dyslexic

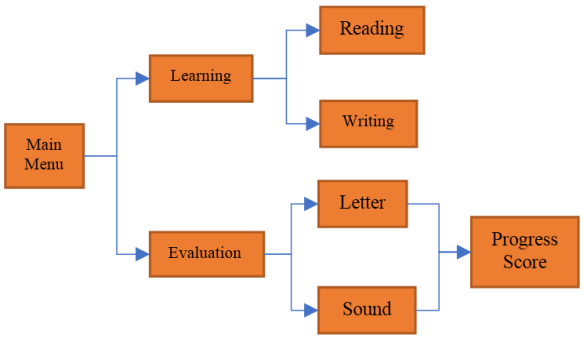


Fig. 1. Leady's menu.

TABLE II
MULTISENSORY ELEMENTS IN LEADY.

Menu	Module	Multisensory Approach
Learning	Reading	This menu involves visual and auditory modalities. An alphabet is shown in the center of the screen. By clicking the letter, the phoneme of the letter can be heard. The alphabet is arranged in three groups to make the interface more user-friendly.
	Writing	The menu emphasizes the visual and tactile modalities. A picture of a letter with a tracing sign is displayed in this activity. Students should follow the tracing sign according to the indicated number to write the letter.
Evaluation	Letter	The evaluation menu for letters incorporates visual and auditory modalities. When the picture of an alphabet is displayed, the student should pick the right sound from four available choices.
	Sound	This menu is the counterpart from the letter one. It incorporates visual and auditory modalities. When the sound of an alphabet is played, the students should pick the right letter from four available choices.

students' reading quality [31, 32]. Referring to these, Leady uses white font on dark blue background for the menu button. The color is similar to white or black. Then, black font on white background (and vice-versa) is used for the alphabet. It also applied not a too colorful guideline for the interface.

Fourth, lower case font is used for ease of reading. An italic or underlined word is not recommended. It should also avoid unnecessary capital. Character spacing is suggested to be separated more than usual spacing. These guidelines are implemented for both the learning and evaluation menu in Leady.

The user interface of assistive technology for dyslexic children is often too complicated and displays too much text that can make them confuse and overwhelm [15]. To avoid these deficiencies, Leady applies a simple user interface with adequate words. The words are only used appropriately, such as the button for menu or title of a screen. The use of buttons in this application is in line with the previous research [32] that tapping buttons to make a selection is used to avoid many steps, and it can be used to encourage fine finger motor movement.

IV. Results and Discussion

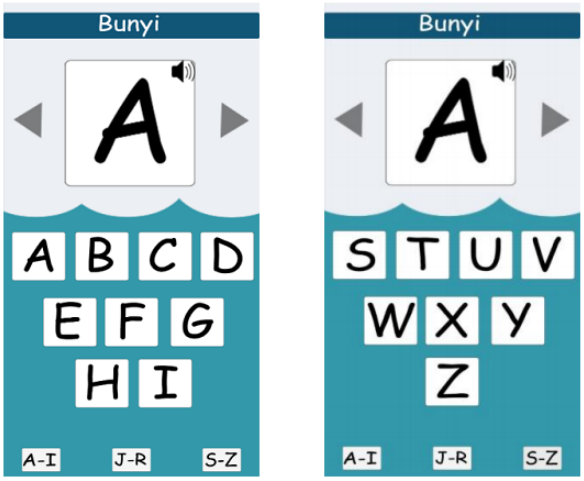
Leady is developed for Android smartphones. It is not heavy-weight software, as seen from the minimum user requirements to install this application. The requirements are one GB storage and one GB RAM for memory, Android v4.0.2 (Ice Cream Sandwich) for the operating system, and Qualcomm APQ8064 Snapdragon Quad-core 1.5 GHz for the CPU.

Figure 2 shows the user interface for the main menu and learning menu. There are three buttons in the main menu (Fig. 2a), such as "*Belajar*" (learning menu), "*Evaluasi*" (evaluation menu), and "*Skor*" (progress menu). There are also a help menu, a button to switch the letter case (from the capital to lower case and vice versa), and an about menu. The learning menu has two modules: "*Bunyi*" (sound) to learn how to read and "*Menulis*" (write) to learn how to write. The interface for the evaluation menu is similar to the learning menu. The only difference is the button that leads to the respective module for each activity. All interfaces use single color background and simple interface to avoid cognitive overload for the user.

Figure 3 illustrates the "*Bunyi*" (sound) module interface in the learning activity in the upper-case letter. It can also be switched to lower case. In this module, children learn to link a letter and its sound. In Fig. 3a, the children learn how to know the letter "A". Letters are grouped in a group of alphabets, from A to I. Other groups are J to R and S to Z. Forward button will change the letter to the next letter (in this case, "B").

(a) (b)

Fig. 2. Interface of Leady: (a) Main menu and (b) Learning menu. In the menu, there are *belajar* (study), *evaluasi* (evaluation), *skor* (score), *bunyi* (sound), and *menulis* (writing).



(a) (b)

Fig. 3. Interface of "*Bunyi*" (sound) module: (a) A–I group and (b) S–Z group

Meanwhile, the backward button will make the letter goes back to the previous letter. They can also change the letter by choosing one of the alphabets from the groups below the focus letter. To change the alphabet group, they click the group button at the bottom of the interface. Figure 3b shows "*Bunyi*" (sound) interface after they click the group button of S–Z. The focus letter is still in the previous letter (letter "A") since they have not chosen a letter from this group yet.

Figure 4 shows the module menu for "*Menulis*" (writing) in lower case letters. It can be switched to the upper case. Users should choose the letter from

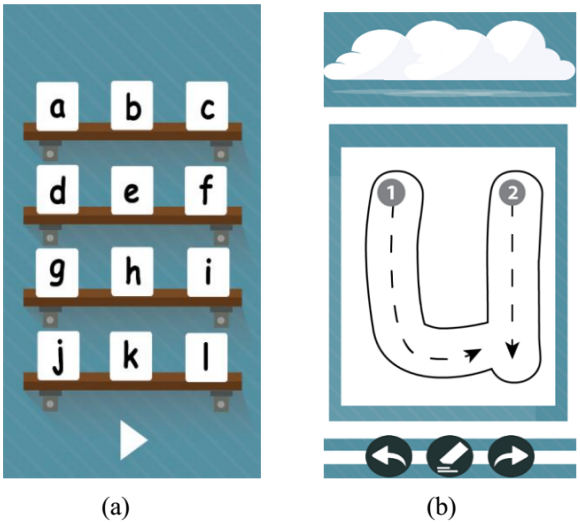


Fig. 4. Interface of "*Menulis*" (writing) module: (a) Picking the letter and (b) Tracing the letter.

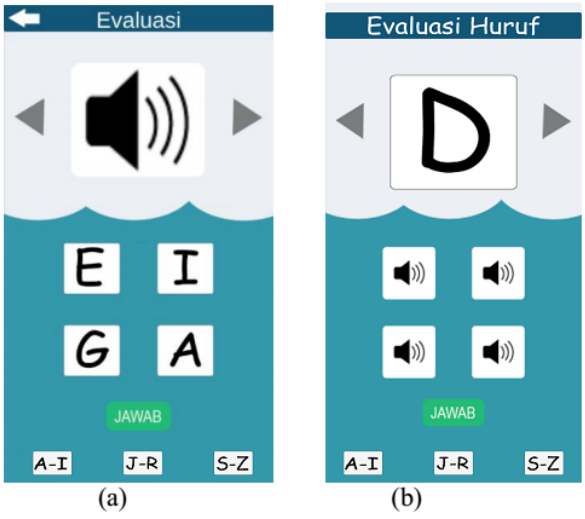


Fig. 5. Interface of evaluation module: (a) *Evaluasi Bunyi* (sound evaluation) and (b) *Evaluasi Huruf* (letter evaluation). In the menu, there is *jawab* (answer).

the group of alphabets. The next button will switch the interface to the rest of the alphabets (see Fig. 4a). Figure 4b describes the learning process for the writing module. Users should trace the signs based on their sequence. A warning sound will be played if users make a mistake when practicing the tracing. Forward and backward buttons are used to go to the next and previous letters.

Figure 5 displays the two modes of evaluation menu. First mode is "*Evaluasi Bunyi*" (sound evaluation) (see Fig. 5a). This mode assesses users' understanding of a letter by sound. Users should choose one letter from

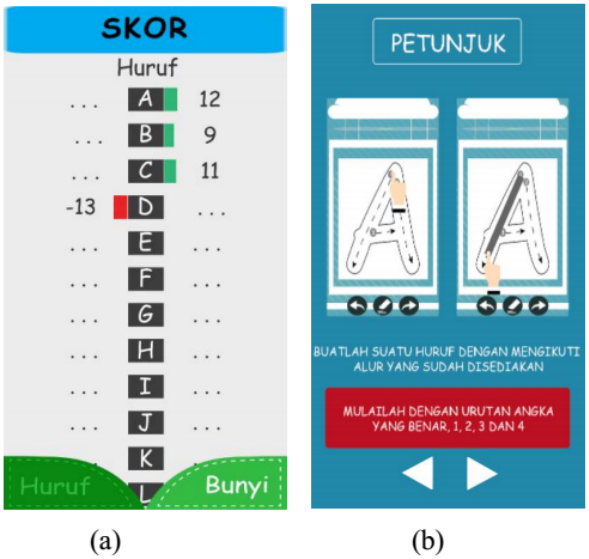


Fig. 6. Interface menu: (a) *Skor* (progress menu) and (b) *Petunjuk* (help menu). In the menu, there are instructions (*buatlah suatu huruf dengan mengikuti alur yang sudah disediakan* (make a letter by following the provided pattern) and *mulailah dengan urutan angka yang benar 1, 2, 3 dan 4* (start with the correct sequence of 1, 2, 3 and 4)).

the alphabet groups after hearing the sound. If the users pick the right choice, their score will increase by one. On the other hand, if their choice is wrong, their score will decrease by one. The second mode is "*Evaluasi Huruf*" (letter evaluation). It is the counterpart of the previous mode (see Fig. 5b). In this mode, users should choose the right sound from the available choice by seeing the letter.

Figures 6a and b display the "*Skor*" (progress menu) and "*Petunjuk*" (help menu), respectively. The progress menu shows the right and wrong of each letter for *Evaluasi Bunyi* and *Evaluasi Huruf* modes. Meanwhile, the help menu presents the guideline to use Leady. Since the help menu is intended for users' caretakers (the teachers or parents), this menu does not strictly follow the rules for developing applications for dyslexic children.

The developed application is tested by black box testing to measure its functions. It examines the buttons, sounds, and other features in the menu of Leady. After the test, it has a satisfactory result. All features have functioned properly without any noticed error. This result is the same as black box testing results from other similar applications, such as Two Dis [21] or Baca Yuk! [22]. In term of user acceptance, Leady use a similar approach as LexiPal application. Leady is not tested by its intended users, the dyslexic children, but by their caretakers in a dyslexia school. LexiPal also uses this method. The application is tested and

TABLE III
LIST OF QUESTIONS IN THE QUESTIONNAIRE.

Item	Question
1	User interface design is suitable for dyslexic students.
2	User interface works correctly and is user-friendly.
3	The sound of the application is clear and loud enough.
4	Learning process for the application is efficient.
5	The application can help dyslexic students to learn how to read the alphabet.
6	The evaluation menu can be used to assess students' progress.
7	Application features are user-friendly.
8	The application can be used in the learning process.
9	The application is interesting to be used for dyslexic students.

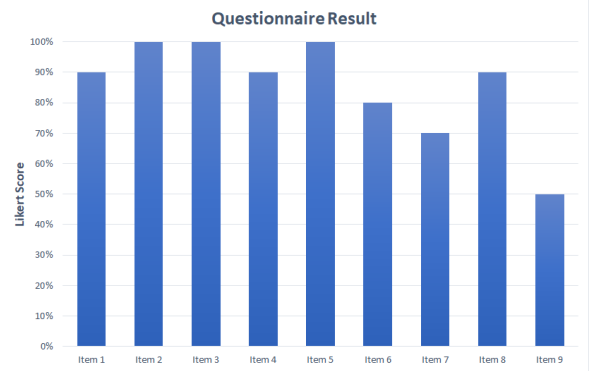


Fig. 7. Questionnaire result.

approved by the members of the Dyslexia Association of Indonesia [14].

Then, Leady is also demonstrated to five dyslexia caretakers from the dyslexia school in Bandung. There are nine statements in the questionnaire, as shown in Table III.

From the questionnaires that have been collected afterward, Leady can be used as assistive software for dyslexic students. Figure 7 depicts the questionnaire result for this application. All caretakers agree that Leady can be used to help students to learn how to read. They also approve that the user interface, such as the buttons in this application, works properly. It does not confuse the users. Moreover, most caretakers think that Leady has a suitable user interface for dyslexic students. However, the evaluation menu does not have a very good perception. Some caretakers feel that students' progress is not well evaluated in this menu. The application should also be improved to make the learning more enjoyable and interesting for the students.

V. CONCLUSION

The research proposes a mobile application to help students to learn how to read the alphabet. The application, Leady, incorporates a multisensory approach in its learning features. From the conducted survey, it can be inferred that the method is integrated well. All respondents agree that Leady can help dyslexic students to learn how to read. Most of them also agree that the used method in Leady is suitable for dyslexic students. However, the evaluation menu does not have a good result.

For future work, the research can test Leady from its respective users. The application will also be developed further to comply with the suggestions of the caretakers. Leady will provide a learning feature for reading a word, not just an alphabet. Another feature to be added is a writing assessment to measure the students' writing abilities.

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