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Application of the Game Development Life Cycle (GDLC) Model in Design and Development of Educational Games for Dyslexic Children

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Abstract:

Dyslexia is a type of Specific Learning Disorder that causes letter recognition and reading difficulties. In Indonesia, the prevalence of Dyslexia ranges from 3-10%, predominantly affecting school-aged children. Early intervention is crucial for Dyslexic children, as the academic demands increase with each school level. With the rapid advancement of technology, the author has been motivated to develop an intervention application for Dyslexic children aged 6-8 years in the form of an educational game. This educational game is developed using the Game Development Life Cycle (GDLC) model, ensuring that each stage of development complies with specified requirements and meets quality standards. The game also incorporates the Gillingham-Stillman multisensory learning method, which helps Dyslexic children learn letter recognition, reading, and writing from the basics. It employs visual, auditory, and tactile sensory input across four main features: letter recognition, reading, writing, and a quiz, which integrates the learning elements from the previous features. In addition to the Gillingham-Stillman method, the game includes a Character Recognition technology that matches the child's handwriting input with predefined templates. The game undergoes testing using two methods: Black Box Testing and Usability Testing. The results indicate that applying the GDLC model successfully produces a high-quality educational game tailored to the needs of Dyslexic children. This is supported by Black Box Testing, which confirms that all functional features operate correctly, and Usability Testing which yields an average score of 86.2%.

Keywords: Dyslexia, Education Game, Game Development Life Cycle, Usability Testing, Reading.

Introduction:

A specific Learning Disorder (SLD) in reading that includes unusual difficulty with word recognition and sentence comprehension, plus special problems moving letters through a normal form [1] it is well-known as Dyslexia. It is a lifelong, genetically inherited disorder [2]. Jamshidifarsani revealed that the prevalence of Dyslexia worldwide ranges from 5-20% [3]. Meanwhile, based on data from the Dyslexia Center Indonesia, the prevalence of Dyslexia in Indonesia ranges from 3-10% [4]. It is not completely curable but can be managed through intervention. Generally, this disorder only becomes visible and can be confirmed when a child is 6-8 years old, as this is the age when children begin to become aware of sounds and recognize most letters [5].

Technological advances have significantly influenced the development of intervention media for Dyslexic children. Currently, intervention media for Dyslexic children are not only provided conventionally through alphabet puzzles, letter cards, or sandboards as mediums for writing letters, but also through educational games. This development offers a new and flexible approach to intervention, unbounded by time and space. Additionally, educational games can assist teachers in delivering more effective and efficient instruction to Dyslexic children, as the learning process can be repeated as needed, unlike conventional teaching methods. Educational games are specifically designed to incorporate educational elements to improve users' skills, concepts, and knowledge [6]. Additionally, educational games are designed to provide a more interactive and enjoyable learning experience, enabling users to understand the presented material more quickly [7].

Building educational games cannot be done haphazardly, rather, a special framework is needed to ensure that the games being built comply with established requirements and quality standards. One framework often used to create games is the Game Development Life Cycle (GDLC) model. GDLC is an iterative development model consisting of six stages: initialization, pre-production, production, Alpha-testing, Beta-testing, and release. This GDLC development model has been applied to create various educational games, including games introducing household appliances aimed at early childhood [8], Horror genre games like Buana Ruh [9], Games introducing typical Yogyakarta Batik motifs for children [10], mobile-based game platforms [11].

Several previous researchers have applied educational games as intervention media for Dyslexic children. For example, research conducted in Saudi Arabia provided educational games as intervention tools in the form of matching words with pictures, word construction, word arrangement, and word listening [12]. Additionally, other studies have incorporated phonics elements into educational games, such as the use of consonant digraphs, letter sound identification, CVC and CVCe words, vowel digraphs, open vowels, and closed vowels [13]. The phonics method is also applied in the educational game DysleRead, which uses two approaches: the Phonic Method and the Sight Word Method [14].

Unlike previous research that only applied the Phonic or Sight Word Method, this study applies the Gillingham-Stillman multisensory method to the design of educational games. The Gillingham-Stillman approach is a systematic and sequential multisensory method for teaching the concepts of spelling, writing, and reading. This method teaches children to read starting from the roots, namely recognizing the sounds of letters, arranging letters into syllables, forming syllables into words, and then rearranging them into complete word sequences [15]. Typically, this learning method is applied conventionally, however, in this research, the Gillingham-Stillman multisensory method is applied to educational games.

This educational game will be developed using the Game Development Life Cycle (GDLC) model to ensure that the development process adheres to predetermined requirements and meets quality standards. The GDLC model will be tested through Black Box Testing during the Alpha-testing stage and Usability Testing in the Beta-testing stage, which will follow Jocab Nielsen's usability testing characteristics.

The research problem is twofold: first, how the GDLC model is applied to the game development stages, and second, how effective the model is when designing educational games for Dyslexic children. Several limitations are imposed on the development of this educational game. The game is designed for Dyslexic children aged 6 to 8 years, aiming to improve their ability to recognize letters, read, and write. It includes a quiz feature to measure the children's understanding, consisting of five levels, with questions that combine previous learning activities related to letter recognition, reading, and writing. This study will use Character Recognition technology to evaluate the accuracy of the children's handwriting compared to predefined letters. The game is built using the multisensory Gillingham-Stillman teaching method and is designed following the GDLC model.

Methodology

This research employs the GDLC development model. This model consists of three main stages encompassing six development phases, as shown in Fig.*1*, initialization, pre-production, production, alpha-testing, beta-testing, and release [16].

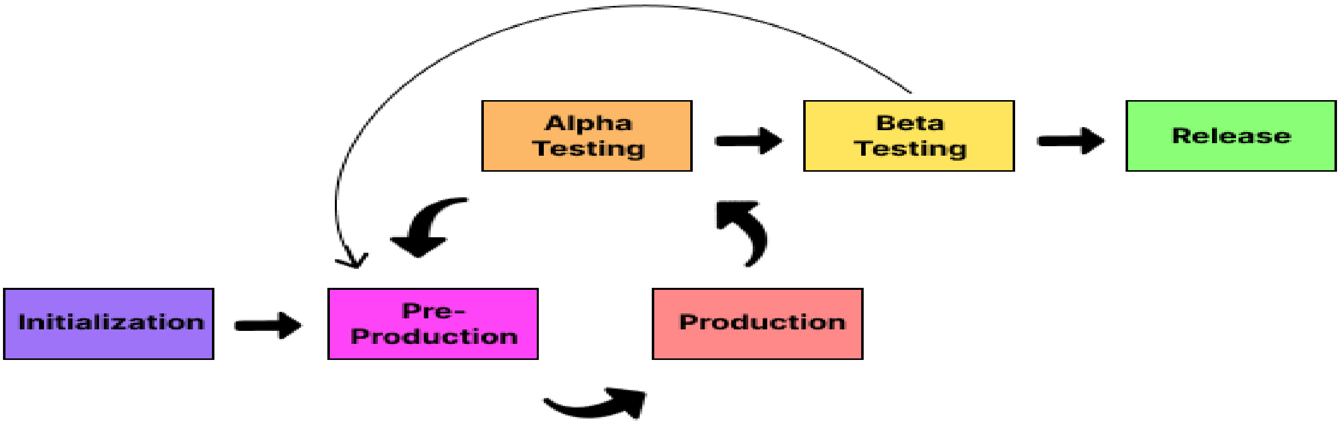

Fig.1 GDLC Flow

The GDLC Flow in Fig.*1* illustrates the iteration stages that occur in the pre-production, production, and alpha-testing phases. These iterations allow for changes or development of features to achieve the best results throughout the game development process. The beta-testing and production stages also incorporate iterative processes, enabling continuous refinement and expansion of the application's functionalities. This methodology guarantees that the developed application aligns with and fulfills the user-specified criteria. A more detailed explanation of the phases contained in the GDLC flow is described as follows.

1. Initialization
   The game concept creation stage includes the topic, target users, game workflow, level design, and materials needed to build an educational game.
2. Pre-Production
   The design stage and design improvements are used to create educational game prototypes. The pre-production stage is an important phase in game development because it functions as a foundation. During this stage, the materials needed to build educational games are collected.
3. Production
   The core stage in educational game development is the production phase. This phase encompasses the generation of assets, implementation of code, and compilation processes to ensure proper game functionality.
4. *Alpha-testing*
   This is an internal testing stage to assess game functionality, ensure there are no bugs in the game, and verify that the game runs properly and correctly.
5. *Beta-testing*
   This is an external testing stage to ensure that there are no errors in the game when it is run directly by users.
6. *Release*
   The final stage of game development for publication to users [8].

The beta-testing stage in this research will be carried out using the Usability Testing method, which measures the application's usability, efficiency, ease of use for new users, and the user's ability to remember interactions when running the application without mistakes or errors. The game application testing stage conducted using the Usability Testing method differs from other application testing stages because, in Usability Testing, each question in the questionnaire is not fixed and can be adjusted according to the Usability Testing criteria indicators. This Usability Testing stage adopts Jocab Nielsen's testing criteria, which consist of five aspects with the following details:

1. *Learnability*
   Aspects that refer to how easily new users can operate and learn the functionalities of the application.
2. *Efficiency*
   Aspects that refer to the user's speed in executing each feature of the application.
3. *Memorability*
   The user's ability to remember interaction when executing each feature of the application.
4. *Error*
   Aspects are designed to minimize the occurrence of errors when users operate application features.
5. *Satisfaction*
   User interest and satisfaction in running each application feature [17].

The testing method was then converted into a questionnaire with five Likert scale levels, Very Good (VG), Good (G), Average (A), Bad (B), and Very Bad (VB). The questionnaire will be given to teachers who assist Dyslexic children in using the Abiba educational game. This approach is taken because teachers are familiar with the conditions, abilities, and characteristics of Dyslexic children when studying at school. Each aspect of the testing method is formulated into questions as shown in Table ***1***.

Table 1. Usability Testing Criteria

Usability Aspects	**Testing Indicators**
Learnability	The suitability of the fonts used in the game (font type and font size).
	Clarity of features contained in the game.
	Clarity of how the game works.
Efficiency	Smoothness of the game during gameplay.
	Game processing speed when running.
	Compatibility of features with the game's functions.
Memorability	The layout of the buttons in the game.
	Display a description of the features contained in the game.
Error	Smooth gameplay without unresponsive features when clicked.
	Smooth gameplay without unfinished features when clicked.
Satisfaction	Complete features in the game.
	Suitability of supporting visual elements in the game (including color selection, contrast, and background images).
	Suitability of educational functions contained in the game.
	The meaning contained in the game.
	Consistency of the game's appearance with its theme.

Result and Discussion:

This research stage began with the initialization phase through an interview process with a child psychologist as a resource person and expert from the Esya Sebaya Therapy Center. From the interview process, user requirements were obtained with the following details.

1. The learning method used at Esya Sebaya Therapy Center is a multisensory approach.
2. Children's names may be included in the game during play, but not for distribution.
3. The order in which letters are written is important, as Dyslexic children have difficulty with sequential activities.
4. In addition to struggling with sequential activities, Dyslexic children also have working memory and expressive language issues, tending to remember the function of objects more than their names.
5. There's no need to be too strict with time, as the main goal is to improve Dyslexic children's ability to recognize letters, read, and write without excessive pressure.
6. Some Dyslexic children can recognize the alphabet but have difficulty sounding it out (phonologically).
7. As the main goal is to improve Dyslexic children's ability to recognize letters, read, and write, the features being developed focus only on letters, not numbers.
8. The vocabulary used in the questions must have meaning.
9. Avoid using complex affixes in the middle of words, for example, "jumlah".
10. Game models can be designed with levels to challenge children.
11. Provide feedback in the form of positive affirmation sentences, whether the child's answer is correct or incorrect, to increase motivation in learning through the educational game.
12. Provide an attractive and colorful UI.

Based on the user requirements obtained through the interview stage with a child psychologist, a concept for designing educational games for Dyslexic children can be formulated as outlined in Fig.*2* below.

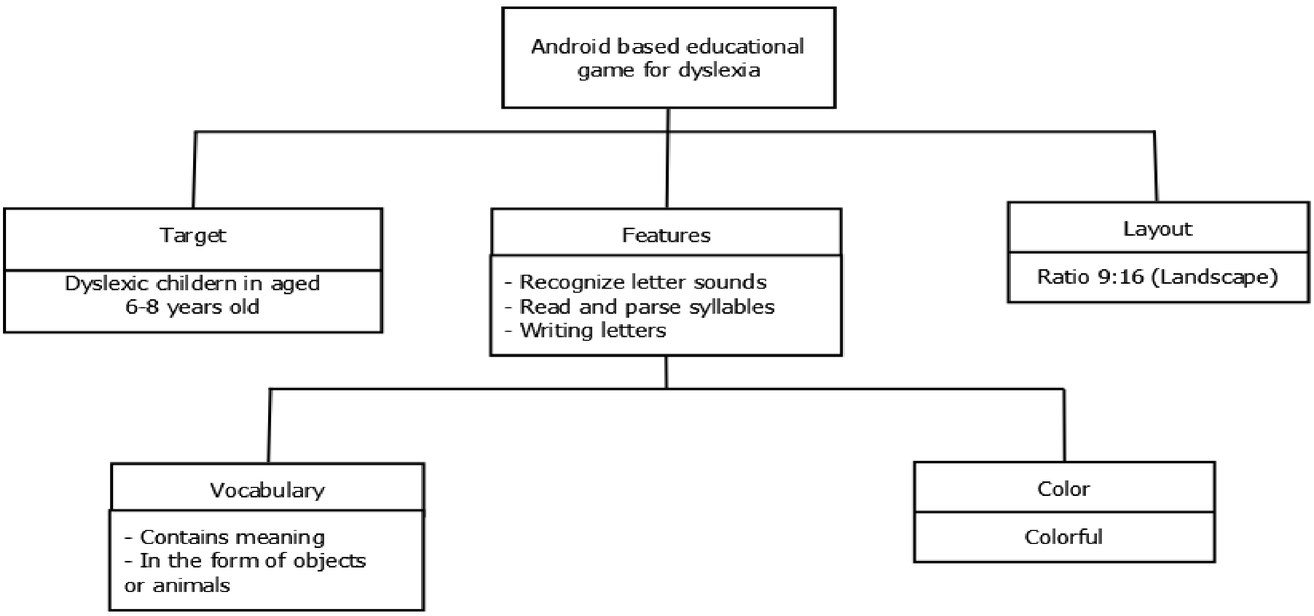

Fig.2 User Requirement Chart

The educational game for Dyslexic children will be called "Abiba," derived from the phrase "Aku Bisa Baca (I'm able to read)." This name indirectly motivates children to learn reading. The game will be designed using the Gillingham-Stillman learning method, with a 9:16 ratio or landscape layout, and is targeted at Dyslexic children aged 6-8 years. This educational game consists of four main features, namely recognizing letters, reading and parsing words, which includes four sub-features (reading a syllable, reading two syllables, reading three syllables, and reading consonants), writing letters, which includes two sub-features (writing uppercase and lowercase letters), and quiz. Abiba's educational game is designed using meaningful vocabulary, including names of objects and animals accompanied by pictures to train working memory and expressive language for Dyslexic children. The game will feature a colorful design to attract children's attention while learning to recognize letters, read, and write. The game comprises five quiz levels with increasing difficulty. In levels 1-3, children will be asked to guess the answer to a voice-over question consisting of one word. Levels 4-5 children will be asked to guess the answer to voice-over questions with similar-sounding alphabets and to guess answers to questions consisting of two words.

In this educational game, the basic aspects of reading are implemented through the reading feature and quiz feature. Gillingham-Stillman's multisensory aspect in the Abiba educational game is implemented in several features, such as the letter recognition feature which adopts visual-auditory stimulation to help Dyslexic children understand the phonology of each letter. The reading feature adopts visual-auditory stimulation to help Dyslexic children understand word forms and how to read them, and is equipped with pictures to improve Dyslexic children's working memory. In contrast to the letter recognition and reading features which only adopt visual-auditory sensory, the letter writing and quiz features adopt visual, auditory, and tactile stimulation to teach children to recognize letter shapes, how to pronounce them, and how to write letters according to predetermined directions. The letter-writing feature in this game is also equipped with template images and tracing images to guide Dyslexic children in writing letters sequentially. With the integration of various sensory modalities applied in the game, making it more interactive for children with dyslexia, this game can stimulate and enhance their ability to recognize letters, read, and write.

Next, in the pre-production stage, preparations are made for both the system design and educational game design, as shown in *Fig.3*.

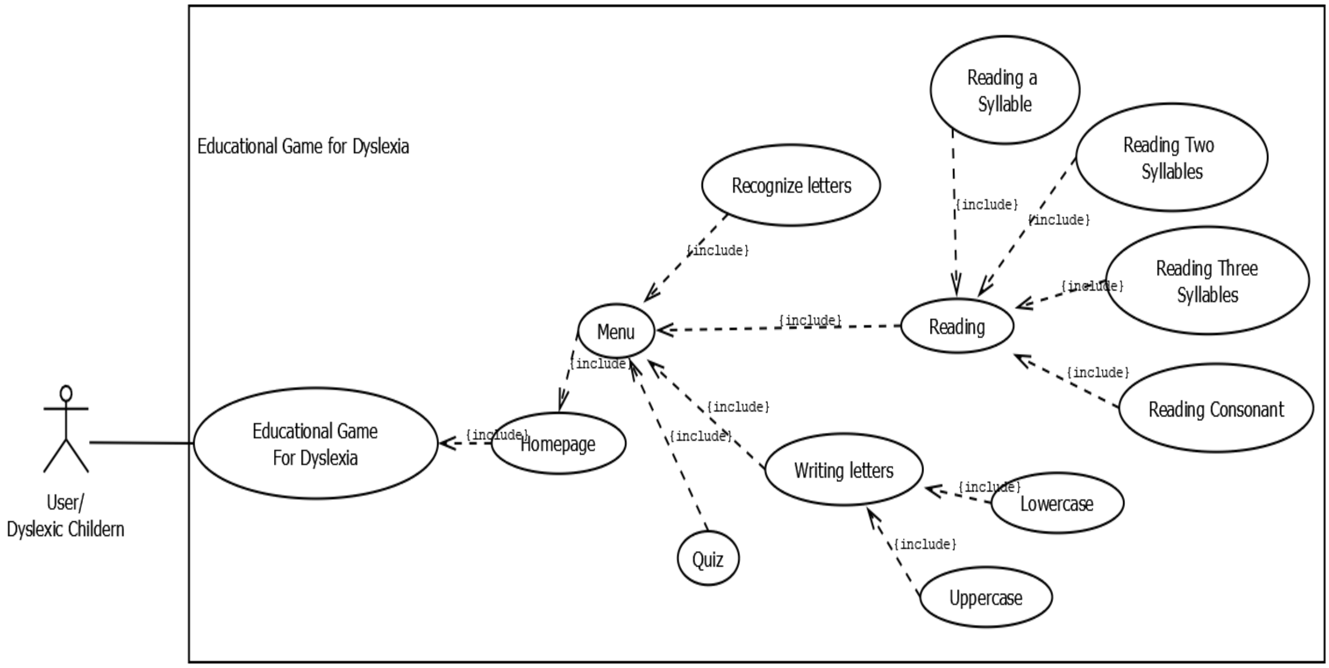

Fig.3 Use Case Diagram

Based on the Use Case Diagram shown in *Fig.3*, users can operate the educational game application by first accessing the homepage and inputting their name before entering the menu page. On this page, users can choose from features such as recognizing letter sounds, reading, writing letters, or taking a quiz. When selecting the reading feature, users are presented with sub-features for reading 1 to 3 syllables and reading consonants. Similarly, when selecting the writing feature, users are given a choice of sub-features for writing uppercase or lowercase letters.

In addition to the Use Case Diagram, the application design preparation stage is also presented through the Deployment Diagram shown in Fig.*4***.**

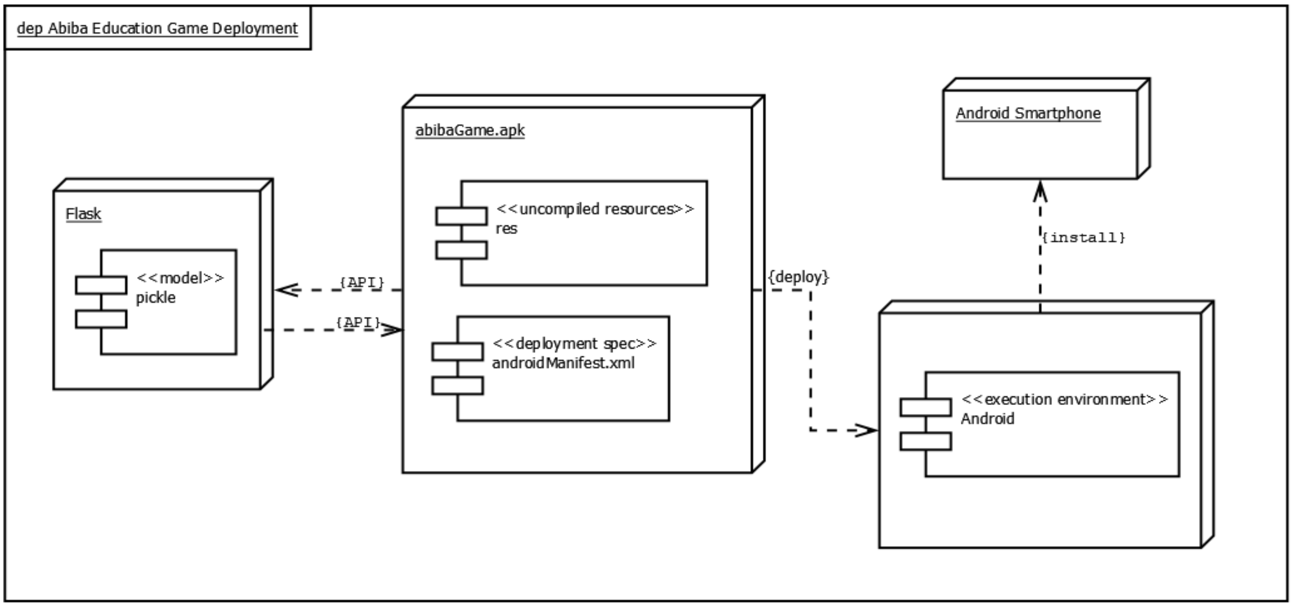

Fig.4 Deployment Diagram

The Deployment Diagram illustrates the physical configuration of hardware and software components involved in the design of Abiba educational games. In this case, the Character Recognition model, built using Google Colab with the Python programming language, is saved in pickle format and loaded into the Flask API.

The results of letter writing from the Abiba educational game application, built using Android Studio with the Java programming language, are encoded into base64 image format and then sent to the Flask API to check their conformity with the predetermined image template. Before the letter-writing results are matched using the Template Matching method, the input image is first checked based on its filename. This is done to facilitate the process of matching the input image with the image template, ensuring that the matching process focuses only on the specific alphabet being matched. The Flask API captures the input image sent from Android Studio in imagebase64 form and then decodes it back into image form. This image is then matched using the Template Matching method. After image matching, the results are returned to Android Studio with the outcome "same" or "not same" and displayed as a true or false feedback image.

After completing the system design stage, the next phase is the UI design stage of the educational game application. This educational game design was created in high fidelity using Figma and Adobe Illustrator to create game assets, as shown in Fig.*5*.

Fig.5 High-Fidelity Home Page

Fig.*5* shows the home page display design, which presents information regarding the user's name, level, and score, as well as the Main button to start the game.

After designing the educational game UI, the design was submitted to a psychologist to obtain feedback for improving the UI design from a Dyslexia expert's perspective. Following the system design and application appearance design stages, the next step was to develop a Character Recognition model using Google Colab. Subsequently, experiments were conducted on the built model to determine the threshold correlation and threshold similarity values, which function to match the input image with the template.

The game development process then continued with the production stage. At this stage, coding of the page display and functional game features was carried out, as shown in Fig. *6* to Fig. *8*.

Fig. 6 High-Fidelity Menu

Fig. 7 High-Fidelity Reading Page

Fig. 8 High-Fidelity Writing Page

In this research, the Gillingham-Stillman multisensory learning method is applied to each feature of the Abiba educational game, which teaches children to read starting from the basics, such as recognizing letters, reading one to three syllables, reading consonants, writing letters, and concluding with a quiz. The letter recognition and reading pages adopt visual-auditory sensory methods, which help Dyslexic children understand the phonology of each alphabet and word. Meanwhile, the letter-writing pages and quizzes incorporate visual, auditory, and tactile sensors to train Dyslexic children in writing letters.

After the production stage, the next phase is Alpha-testing using the Black Box testing method. This method is used to test game functionality and ensure that all features in the game run correctly without examining the program code structure. The Black Box Testing results show that the paint function works well for writing letters in the application. Additionally, every button in the application functions properly. These buttons include the play button, new player button, save button, letter recognition button, reading, writing, quiz, home button, next and previous arrows, one to three syllable reading button, consonant reading, delete button, check button, and level buttons. Logos, images, animations, and sounds work well when the game is played. However, there was an issue with sound overlap when buttons equipped with sound were pressed continuously.

The Black Box Testing demonstrates that the functional features in the Abiba game are running well. Before testing, the researchers improved the overlapping sounds by stopping the current sound playback before playing the new sound, thus eliminating the overlap. Subsequently, this educational game was resubmitted to experts for evaluation and validation. After the application was declared valid, it was released on the official Abiba website to make it publicly accessible to Dyslexic children. Following this public release, the game was then tested directly on Dyslexic children.

After carrying out the Alpha-testing stage, the testing process continues with the Beta-testing stage. This testing stage was carried out using Usability Testing using Jocab Nielsen's criteria and obtained average results of 91.67% in the learnability aspect, 91.67% in the efficiency aspect, 75% in the memorability aspect, 87.5% in the error aspect, and 85% in the satisfaction aspect. Thus, the total average Usability Testing score was 86.2%, which shows that the educational game application built has a very good usability score. In addition to structured inquiries, the Usability Testing incorporated an open-ended question soliciting feedback and recommendations. This approach yielded a valuable suggestion for improvement: adapting the application's phonic sounds to align with Indonesian phonetics.

Summary:

The conducted study shows that the GDLC development model applied with the Gillingham-Stillman multisensory learning method and Character Recognition makes it possible to create educational games for Dyslexic children with great quality. This is achieved through initialization, preproduction, production, alpha testing, beta testing, and release. The effectiveness of educational games can be observed from alpha testing using the Black Box testing method. These results demonstrate that the functional features of educational games work effectively within the initial limitations that are set in the introduction, notwithstanding a few minor issues with noises that overlap. However, this problem can be overcome by stopping the playback of the current sound before playing a new sound. Furthermore, the effectiveness of the Abiba educational game can also be seen from the Usability Testing results which produced an average score percentage of 86.2%. Even though the usability scores were very high, it still points to future research directions. Suppose the main focus of the next researcher is to develop a letter-writing application for Dyslexic children. In that case, it can be considered to collaborate the Template Matching method with the Node Matching method that forms each letter to ensure that Dyslexic children write correctly in the predetermined order so that the sequence of how to write the letters becomes more accurate. However, if the main focus of the next researcher is to develop a reading application for Dyslexic children, then they can consider adapting the phonics applied to Indonesian phonics. Researchers can then consult with language experts or child development experts. This can help develop a better alternative way of pronouncing the letters suitable for Dyslexic children.

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