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Hearing Screening Test Mobile Games Application for Kids

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Abstract: In literature, around 34 million children suffer from hearing impairment, and it does not happen overnight. As a result, parents should keep an auditory check on their children at all times. Unfortunately, the existing applications available are not suitable for children due to their complexity level. This paper outlines the creation of an Android-based application KidzLing, which implements the Ling Six Sound Check approach to conduct the screening test. KidzLing is a 2D mobile application that performs screening tests using the gamification approach for children aged three to six years. The ADDIE model, which consists of five phases: analysis, design, development, implementation, and evaluation, used to assist the project development. The software opted for the development process is Unity 2D, Visual Studio for C# scripting, and Adobe Illustrator for asset creation. Firebase Realtime cloud database is selected to store the user's data. The findings of beta testing show KidzLing is completely functioning as expected. In addition, the application's usability score on the System Usability Scale (SUS) is 89%, which is within the acceptable range. Thus, KidzLing application can help parents to keep track of their child's auditory level.

Keywords: Hearing Impairment, Ling Six Sounds, Gamification

1. Introduction

Hearing impairment is when one or both ears are unable to hear sound partially or completely [1]. Hearing impairment usually develops slowly over time and is common in old-age, but it is becoming common in children, affecting almost 1.9% of them [2]. A variety of factors causes hearing loss among children, such as earwax accumulations and ear infections. Many parents often overlook the early indications of hearing impairment, while some wait for too long before taking action, even after noticing the symptoms [3]. When children have hearing loss, it can be challenging for them to communicate and understand a language. The impairment frequently leads to poor academic and isolation. On this basis, parents should not neglect their children auditory. Parents should make an effort to carry out screening tests for their children every day to keep track of their auditory level. Early detection and treatment are vital to allow the child to reach maximum potential. Since everything is just a tap away due to the

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massive revolution of mobile applications, parents opt to look for applications that can help them conduct screening tests.

Unfortunately, most of the existing applications are not suitable to do screening tests for children because there are not attractive enough for children. Besides, the applications also do not have proper instructions to guide parents to do the test.

There are three objectives highlighted in the development of Kidzling.The first objective is to design KidzLing application with casual gameplay using unity 2D. The second objective is to develop KidzLing application on Android platform. The third objective is to test the functionality of KidzLing application on the users ranging in age from three to six years old. The KidzLing application uses the gamification technique to implement the Ling Six Sound Check concept. The application includes three modules: a listening module, a game module, and an about module. The games are created to correspond to the Ling Six Sound detection and implementation tasks. The application is linked to a database, allowing parents to record and retrieve scores to keep track of their child's auditory level.

This proceeding paper has five sections that explain the whole development process of KidzLing application. The first section of this paper covers the background of this project which consists of problem statements, objectives, and scope of the project. The second section describes the scholarly article's analysis on the related technology and terms used in the application development. The second section also consists of a comparative analysis of similar applications available with the proposed application. The third section explains each phase in the ADDIE model with the task carried out during that phase. The fourth section outlines the results of the user acceptance test that is carried out to determine the acceptability of the KidzLing application among users. The fifth section summarizes the whole development process of KidzLing application.

2. Related Work

This section comprises explanations for Ling Six Sounds, the technology used in developing the application, and comparative analysis between the current application and the proposed application.

2.1 Ling Six Sound Check

The Ling Six Sound Test developed by Dr. Daniel Ling is based on the principle of using a range of speech sounds that spans the speech spectrum from 250Hz to 8000Hz [4]. The Ling phoneme sounds are used to assess a child's capacity to distinguish speech sounds at low, medium, and high frequencies. Ling's sounds are made up of vowels and consonants. The sounds are “ah,” “mm,” “ee,” “sh,” “ss,” and “oo.”. Simple words are used to symbolize the sounds such as “ah” for father, “oo” for the moon, “ee” for key, “sh” for shoe, “ss” for sock, and “mm” for mommy. The test is meant to assess ear training of detection, discrimination, and identification [5]. If children are able to hear these sounds, they should be capable of understanding spoken language sounds. By conducting Ling Six Sound Check daily, parents will be aware of the change in auditory level due to middle ear fluid or infection. Figure 1 demonstrates the speech banana where the sounds lie in an audiogram in terms of pitch and loudness [6].

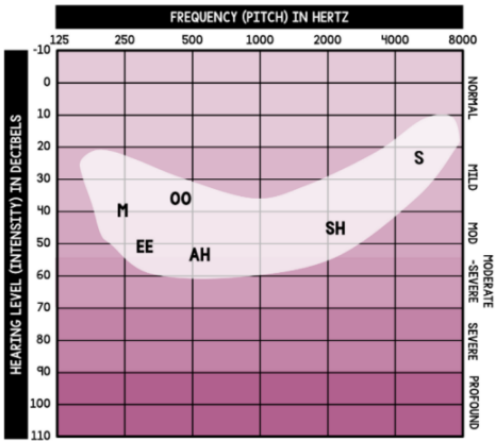


Figure 1: Ling Six Sound Audiogram [6]

2.2 Technology Implemented

KidzLing application is developed to run on Android platforms because Android is the most popular operating system (OS) with 87% shares in the global market in the year 2019, whereas Apple (iOS) only has 13% shares [7]. The application's release on Android allows it to be used by a wide number of individuals. The KidzLing application applies the gamification concept to make screening tests more enjoyable. Game mechanics such as points, badges, countdowns, and leveling are implemented in the KidzLing application. Firebase real-time cloud database is used to store data so that parents can retrieve the previous scores to keep track of their child's auditory level.

2.3 Comparative Analysis of Existing and Proposed Application

The current applications related are examined to discover any issues or difficulties that users may have. The comparison of existing applications with a similar approach to the KidzLing application is based on three hearing test applications which are Kids Hearing Game [8], Hearing Test [9], and Eartone Hearing Test [10], shown in Figure 2. All these applications are available on Google Play Store.

(a) (b) (c)

Figure 2: (a)Kids Hearing Game [8], (b)Hearing Test [9], and (c) Eartone Hearing Test [10] Main Interface

Table 1. Comparative Analysis between Existing Applications and Proposed Application

Application / Features	Kids Hearing Game	Hearing Test	Eartone Hearing Test	KidzLing
Operating System	Android / iOS	Android	Android	Android
Gamification Concept	Yes	No	No	Yes
Ling-Six Sound Concept	No	No	No	Yes
Multimedia Elements	Audio, Text, Animation	Audio, Text	Audio, Text	Audio, Text, Images Animation and Video
Tutorial	Inadequate	No	No	Yes
Module	No	No	No	Listening, Game and About module

Table 1 shows the comparative analysis between the existing application with the proposed application. Not all of the current applications are suitable for children due to the complexity. Thus, the

KidzLing application is developed by implementing the gamification concept and using multimedia elements to increase interactivity.

3. Methodology

The methodology opted for the development process of KidzLing application is ADDIE model. The acronym ADDIE represents **A**nalyze, **D**esign, **D**evelopment, **I**mplementation, and **E**valuation [11]. ADDIE is a five-step linear method, where one phase has to be fully completed before beginning the next phase. This methodology is selected because it creates clear and efficient training programs. The phases in the ADDIE model are shown in Figure 3 [12].

Figure 3: ADDIE Model [12]

3.1 Analyze Phase

Analysis is the first phase of the ADDIE methodology. The requirements for this application are gathered by interviewing the Subject Matter Expert (SME), Madam Jagjit Kaur a/p Berdewa Singh, an audiologist at the Earmed Services, Ipoh. As suggested by SME, the Ling Six Sound approach is used to do screening tests in KidzLing application, and the application development will focus on children aged 3 to 5 years. A content structure is developed to provide an overview of the application. Figure 4 shows the content structure of the KidzLing application.

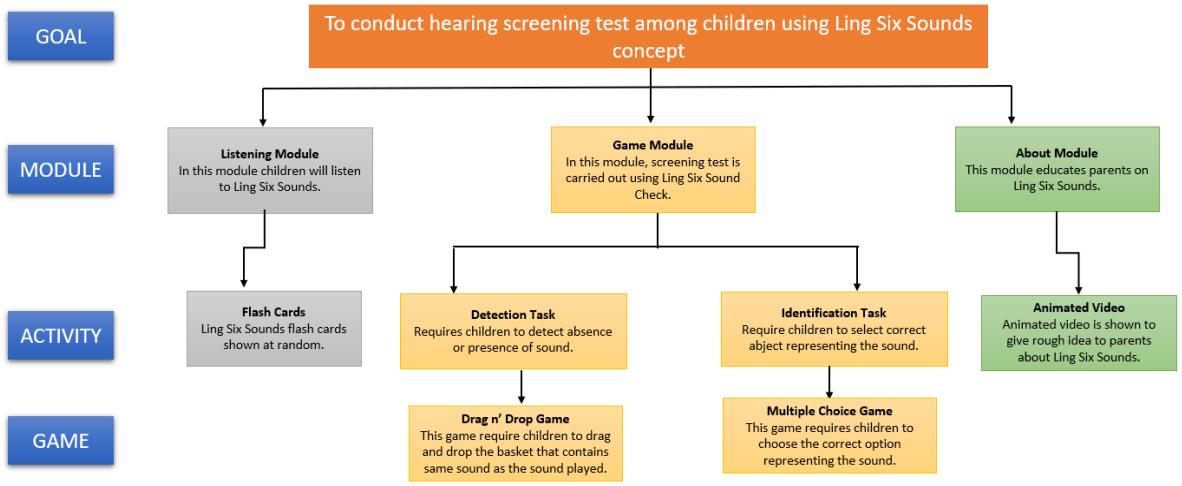


Figure 4: Content Structure

In Figure 4, the content of KidzLing is divided into goals, modules, activities, and games. KidzLing application has 3 modules with their respective activities. There are two casual games in this application that corresponds to the detection and identification activities. The requirement analysis, which comprises functional and non-functional, is done based on the interview session with SME and

comprehensive research regarding Ling Six Sounds. Tables 2 and 3 provide the functional requirements and non-functional requirements, respectively.

Table 2. Functional Requirements

Functional Requirement	Description
User Interaction Support	• The system shall provide users the ability to click on the start button to launch the application.
	• The system shall provide users the ability to log into their account and logout of their account using login and logout button.
	• The system shall provide users the ability to insert their email, password, username and player name.
	• The system shall provide uses the ability to pause and replay the activities.
	• The system shall provide users the ability to replay the ling sound by clicking on the button provided.
	• The system shall provide users the ability to move to the next stage of the game by clicking on the button
	• The system shall provide users the ability to save data into database and retrieve the data from database by clicking on the button.
	• The system shall provide users the ability to select the options in the main menu using the buttons provided.
Autonomous System Activity	• The system shall automatically calculate the scores while playing the games.
	• The system shall automatically decrease the time allocated to answer each question
	• The system shall automatically detect the ambient sound and change the button colour accordingly. For instance, if the ambient sound is loud then the button shall be red and if the ambient sound is quiet the button shall be green.
	• The system shall save the user data into the database and retrieve the data.

Table 3. Non-Functional Requirements

Non-Functional Requirement	Description
Performance	• The application shall be able to respond less than 1 second for most of the Android mobile.
Implementation	• The application shall be able to operate on any Android platform.
Usability	• Users shall be able to access this application at all times.
Legal	• Users can only view the displayed information but cannot modify.
Cultural	• This application uses simple English language.

The functional requirement of the KidzLing application can be divided into user interaction support and autonomous system activity. All the functional requirements stated are included in the KidzLing application to allow the application to function as intended. The non-functional requirements are divided into performance, implementation, usability, legal, and cultural. Non-functional requirements are carefully implemented because they determine the behavior of the system and how it affects users.

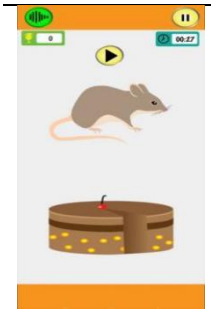
3.2 Design Phase

The design phase is the second phase of the ADDIE Model. A flowchart is created to explain the workflow of the KidzLing application. The flowchart is illustrated in Appendix A. The assets such as buttons and images are designed using Adobe Illustrator and Adobe Photoshop. A low-fidelity prototype is developed, and the main interface designs are shown in Table 4.

Table 4. User Interface Design

User Interface Design	Description
	Start Scene • The name, logo and slogan of the application is displayed. • There is a START button to launch the application.
	Login Scene • There are two input-text fields, to insert the email and password of registered account. • There is a login button to navigate users to the next scene, if successfully logged in. • The register button navigates users to register scene. • There is an exit button to exit the application.
	Main Menu Scene • This scene consists of three modules to select, which are listening module, game module and about module. • There is an exit button to exit the application. • The listening button navigates users to listening module. • The game button navigates users to game module. • The about button navigates users to about module.
	Listening Module • There is a sound meter button to detect the ambient noise. • The pause button freezes the ongoing activity • The stars represent the number of Ling Sounds heard. After each sound played the star is filled with yellow colour. • The next button displays the next flashcard. • When the sprite is clicked the Ling Sound replays.

Table 4. (continued)

User Interface Design	Description
	Implementation Task Game • There is a sound meter button to detect the ambient noise. • The pause button freezes the ongoing activity. • There is a scoreboard, each time users get a point the scores get updated. • The is a timer, 30 seconds provided to answer each question. • There is a play button, to replay the Ling Sound. • The sprites are the options to be chosen by the users after hearing the Ling Sound played.
	Scoreboard Scene • Home button navigates users to main menu • Scores for all the levels is shown in the scoreboard. • Save button saves the data into the database. • Score button retrieve data from the database.
	Detection Task Game • The pause button freezes the ongoing activity. • There is a scoreboard, each time users get a point the scores get updated. • There is a play button, to replay the Ling Sound. • Each of the basket at the bottom can be dragged and it contains the Ling Sounds.

3.3 Develop Phase

The develop phase is the third phase in the ADDIE Model. In this phase, a high-fidelity prototype is developed. All the assets are deployed into Unity 2D for compilation and integration. To build the application Visual Studio Code software is used along with C# programming. Figure 5 shows one of the scenes along with the code segment for scene transition.

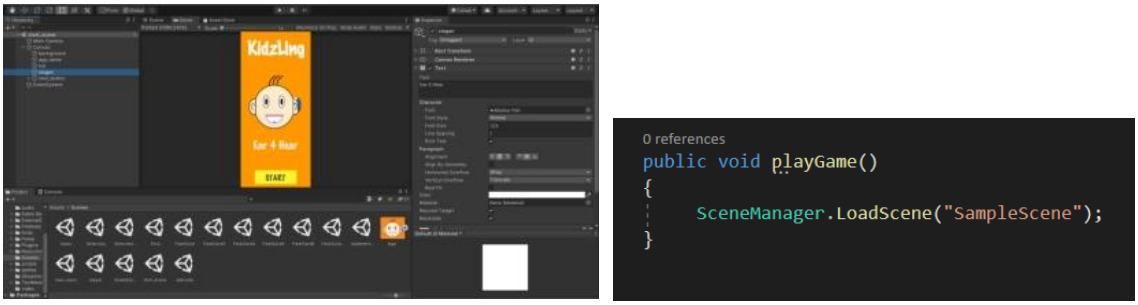


Figure 5: Scene and Code Segment

3.4 Implement Phase

The implement phase is the fourth phase of the ADDIE method. In this phase the beta testing is carried out by randomly by 10 children, aged 3 years to 5 years old. To aid the beta testing process the application is released in the Google Play Store. Figure 6 shows the building process of KidzLing in

Unity application before deploying to the Play Store. To build the application for Play Store an API Level of 29 is required with target architecture of ARM64. The build App Bundle (Google Play) checkbox is ticked. Figure 7 shows the KidzLing application on the Play Store. The link to the application is **https://play.google.com/store/apps/details?id=com.DefaultCompany.kidzling.**

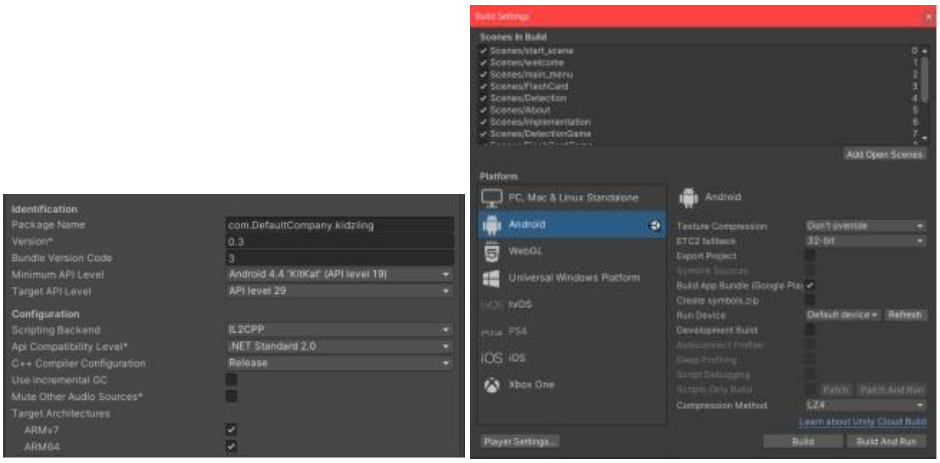


Figure 6: Building KidzLing for Play Store Release

Figure 7: KidzLing Application Released on Play Store

3.5 Evaluation Phase

Evaluation is the final phase of the ADDIE model. To evaluate the effectiveness of the KidzLing application, functional testing and usability testing is carried out. Functional testing is done to test if the application is developed as planned. The functional testing evaluates the functionality of the buttons, the authentication, and the database. The functional testing and the corrective measures are displayed in Table 5. For the usability testing, System Usability Scale (SUS) survey method is used. A set questionnaire that comprises 10 close-ended questions is created using Google Forms. The form is filled by the adults that assist the children while using this application. The results are gathered, tabulated, and then the usability of the application is calculated.

Table 5. Functionality Testing

Test	Expected Output	Actual Output	Corrective Measures
Start Button	Navigates to login scene	Works as expected	Not required.
Successful Login	Navigates to welcome scene	Works as expected	Not required.
Exit Button	Shows exit warning panel	Works as expected	Not required.
Skip Button	Navigates users to main menu	Works as expected	Not required.
Save Player Button	Navigates to detection game scene	The navigation takes some time	Reduce the coroutine time.

Table 5. (continued)

Test	Expected Output	Actual Output	Corrective Measures
Pause Button	Pauses the game and shows a panel	The audio keeps playing	Add AudioSource variable to the script and use the audio.pause() function.
Save Data	All the player data saved to realtime database	The data gets overwritten when the same data is inserted for instance player name	UpdateChildrenAsync() method to prevent overwritten data.
Retrieve Data	The saved data should be retrieved and arranged in table form	Data retrieved in Debug.Log but not displayed in the UI	Use the scrollview UI and set make a prefab of the content. Initialize the prefab for every retrieved data.

According to Table 5, there are some functions in the application which were not well functioning. All the bugs identified are resolved before releasing to the users.

4. Results and Discussion

The beta testing method is carried out with ten children ranging in age from three to six. The children are assisted by their adults while the testing is conducted. The adults are given a set of close-ended questionnaires, to provide their feedback based on their child's performance and interest in the application. The options provided in the questionnaires are based on Likert Scale. Figure 8 and 9 shows the outcome of the beta testing.

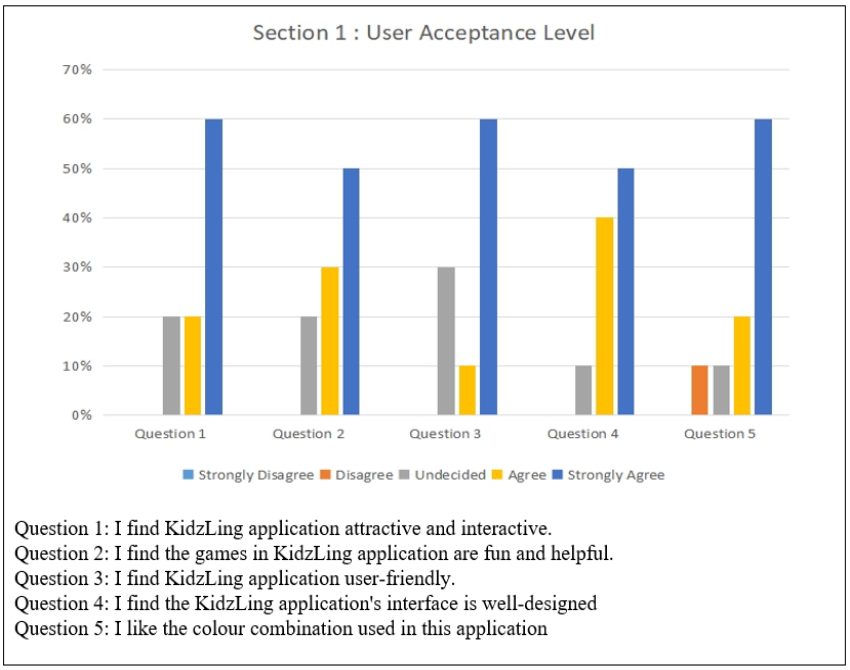


Figure 8: User Acceptance Level Analysis

According to the chart in Figure 8, most of the users strongly agree for all the questions related to user acceptance level for KidzLing application. However, one user disagrees to the colour combination used.

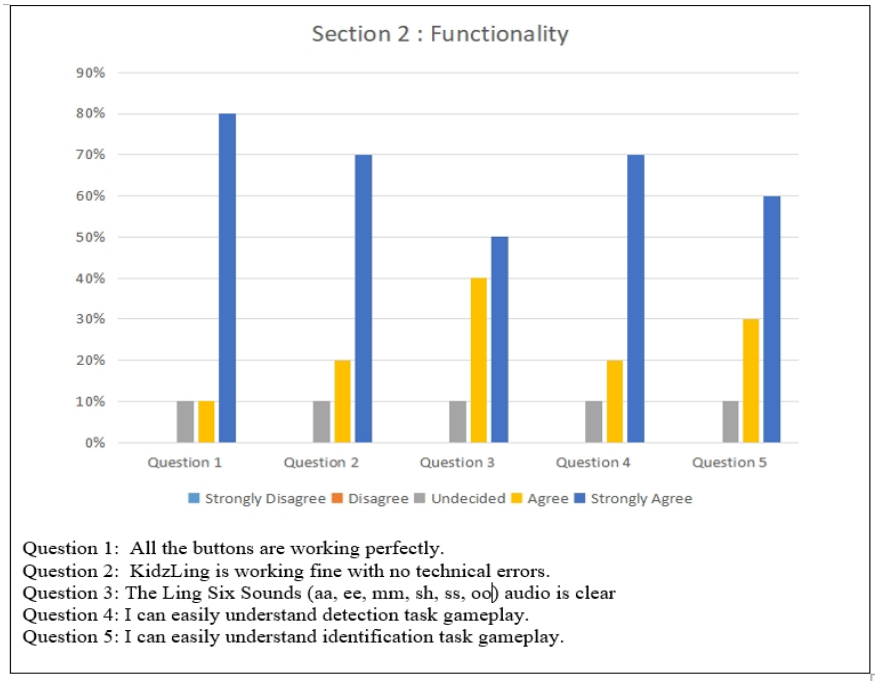


Figure 9: Functionality Analysis

According to the chart in Figure 9, most of users strongly agrees that KidzLing application is well functioning. However, the audio should be enhanced.The data gathered from the questionnaire is measured using the System Usability Scale. Firstly, the total respondent scores are calculated as shown in Table 6.

Table 6. Respondent's Scores Based on Likert Points

No.	Question	Likert Points					Marks
		1	2	3	4	5	
1.	I find KidzLing application attractive and interactive.	0	0	2	2	6	44
2.	I find the games in KidzLing application are fun and helpful.	0	0	2	3	5	43
3.	I find KidzLing application user-friendly.	0	0	3	1	6	43
4.	I find the KidzLing application's interface is well-designed	0	0	1	4	5	44
5.	I like the colour combination used in this application.	0	1	1	2	6	43
6.	All the buttons are working perfectly.	0	0	1	1	8	47
7.	KidzLing is working fine with no technical errors	0	0	1	2	7	46
8.	The Ling Six Sounds (aa,ee,mm,sh,ss,oo) audio is clear	0	0	1	4	5	44
9.	I can easily understand detection task gameplay.	0	0	1	2	7	46
10.	I can easily understand identification task gameplay.	0	0	1	3	6	45
						TOTAL	445

Based on Table 6 the survey obtained a total of 445 marks based on the Likert Scale points. The data gathered is measure using the SUS formula:

$$Y = \frac{P}{Q} \times 100 \quad Eq.1$$

Where:

P = Total scores of respondents for each question.
Q = Total maximum of respondents scores
R = Percentage score.

Hence:

$$Y = \frac{445}{500} \times 100$$

$$= 89\%$$

The acceptability ranges in System Usability Scale (SUS) are not acceptable, marginal and acceptable. Figure 10 shows the system usability scale [13].

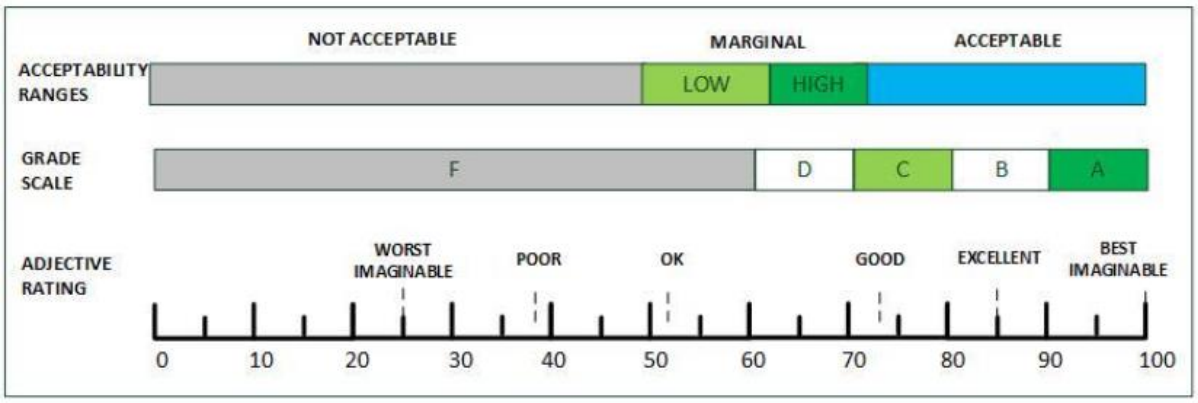


Figure 10: System Usability Scale (SUS) [13]

The results of usability testing obtained is 89%, it falls in the acceptable range. The result indicates the needs for minor improvement in the design of KidzLing application. Overall, KidzLing application is accepted and can be used by parents to carry out screening test.

5. Conclusion

The KidzLing application is successfully developed within the period allocated by using a well-planned ADDIE methodology. All of the three objectives are achieved. KidzLing is a gamification-based application that includes two sorts of casual games. Furthermore, the KidzLing application was created for the Android platform and is available on the Play Store. The beta version of the KidzLing application is tested by ten random children aged 3 to 5 years. The KidzLing application is approved by users, according to the results obtained by the System Usability Scale which is 89%.

The benefits of this application are it has a high user acceptance level because most of the users find this application attractive and useful. Parents are able to keep track of their child's auditory level because they can retrieve scores from the database and compare them.The drawback is this application is not released on iOS platform, so some people cannot access this application. Suggestions on overcoming the application's drawbacks is to release the application on the iOS platform as well. This application serves as a platform to help parents conduct their child's screening test and keep track of their auditory level from time to time. By using this application parents will be able to do early detection if their child is having difficulties in listening.

Acknowledgement

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Appendix A

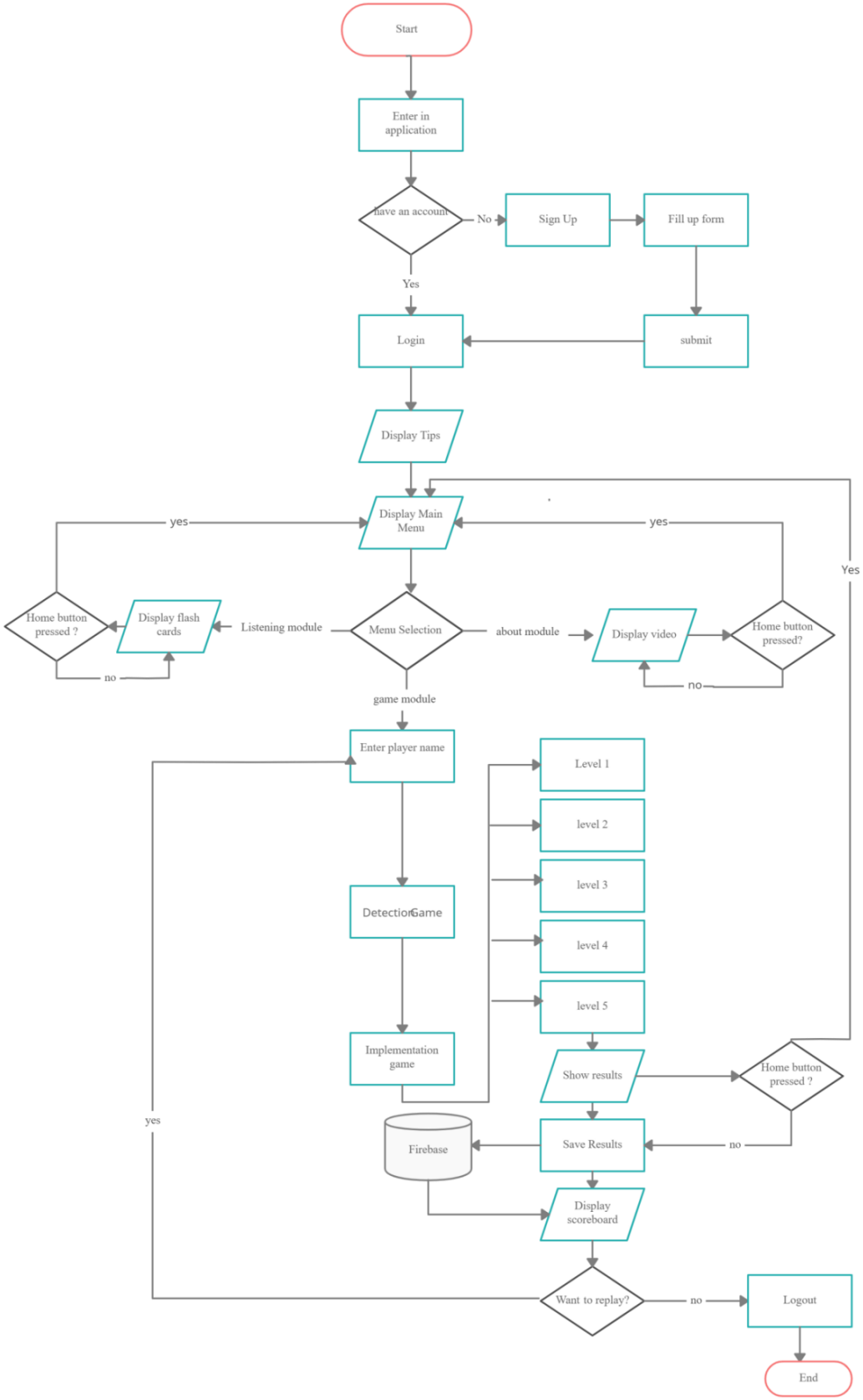

Figure 1: Flowchart

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