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E-Learning Mobile Software for Arduino & Its Application (ELA)

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Abstract: In this era of globalization, telecommunications systems that lead towards the 5G generation have led to E-learning or Electronic-learning that enables students to gain their knowledge through the utilization of electronic equipment or electronic medium. With the utilization of e-learning mobile applications, students can learn and gain knowledge regardless of time and place. However, Arduino users have difficulty finding knowledge about it. They faced problems in the learning process that they do not know what they need to learn about Arduino. Therefore, the project is aimed to develop a mobile application of "ELA" or "E-Learning Arduino & Its Application" that enables and facilitates students in the learning process and enhances knowledge related to Arduino. Android Studio is used in this project to develop "ELA" mobile applications in the form of APK (Android Application Package) or AAB (Android Application Bundle) that are accessible by smartphone and be able to publish to Google Play Store with the utilization of Android app. This app is easy-to-use, and it is completed with information such as the history of Arduino, identification of different Arduino boards & Arduino IDE, and a few examples of electronic projects implemented with Arduino. As a result, ELA was successfully published to the Google Play Store and received 80 ratings with an average rating of 4.875 and 60 reviews from users. "Google forms" had also been used to collect and analyse users' information, users' experience with educational mobile applications, and user opinions on ELAs in application evaluation criteria. ELA had successfully solved ELA user problems in Arduino learning. With the usage of Google Form as a user satisfaction questionnaire platform, all information related to the performance of this application is stored and analysed for the purpose of improvement. From the user feedback, it shows that the level of user satisfaction is good and very helpful to those who are new in learning knowledge related to Arduino.

Keywords: E-Learning, Mobile Application, Arduino, Android Studio, Java, XML, Firestore, Google Play Store, Google Form

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1. Introduction

In today's digital technology era, individuals especially students learn things at fast paces and self-dedicated style. These learnings processes became easier with the ease of the internet or any electronic platform or gadget. The learning process with electronic gadgets is called e-learning. The e-learning process can be done through many methods such as learning with the mobile phone, laptop, or any other electronic device. When the mobile phone is used for e-learning, the mobile application is responsible for the e-learning platform, while websites act as the e-learning platform when laptops computers. E-learning mobile application is the software designed to be implemented on mobile devices for educational purposes [1].

E-learning mobile application is normally known as an educational mobile application, and it is categorized in "Education" of the application market such as Google Play Store and Apple App Store. E-learning applications offer many benefits to learners or users such as control over the content, self-control on time spent in learning [2]. The educational mobile application has been an increase in population as the trends of e-learning became more popular especially during the COVID-19 pandemic periods that encouraged the learning process in the ways that it is not face-to-face or close contact [3].

Teenagers in Malaysia usually learn Arduino through self-learning with the e-learning process where they learn Arduino in methods that were not systematically. They do not have direction in the whole learning process such that they learn everything they found on the internet without knowing whether the knowledge that learns is suitable for their condition or not. They do not possess a good understanding of the specifications of Arduino, the steps to compile and load Arduino coding into the Arduino boards or any other knowledge about Arduino that needs to be known by every beginner to Arduino.

This research project is aimed to develop an Android-based educational (e-learning) mobile software that teaches users knowledge about Arduino. This android app namely "ELA" or "E-Learning of Arduino & Its Application" is developed in APK and AAB format, it is then published in the Android application market, which is the Google Play Store to ensure this mobile app really benefits the users with knowledge such as the histories & functions of Arduino, comparison of specifications of different types of Arduino boards, and examples of electronic projects which implement with Arduino. The examples were given at the beginners' level and sorted according to the types of Arduino to ensure there is no difficulty in the learning process for the beginner that introduced to Arduino. The guidance video on the basic knowledge about Arduino is presented in the mobile app to teach users on how to use Arduino in an easy way. There is also comment features in the examples that allowed users to exchange their opinion related to the examples of Arduino projects given in the mobile application. The mobile application is developed with programming language Java, markup language XML and the real-time database, Firestore.

1.1 Arduino

According to [4], Arduino is an open-source electronics prototyping platform that includes a microcontroller, programming language, and IDE (Integrated Development Environment). It is a tool that is designed for beginners to create simple projects and allowed experts to create complicated electronic projects.

Arduino includes the Arduino software (Arduino IDE), and Arduino hardware such as Arduino boards. Arduino IDE is the Arduino firmware with runtime code, software libraries developed by "Arduino.cc". It builds and loads software for an AVR chip (microcontroller of Arduino) by utilization of the avr-gcc compiler and related tools to build and execute the binary executable code for an AVR device. The programming languages used for Arduino IDE is C or C++. [5]

Arduino hardware mainly referred to Arduino boards that contained many varieties of models which included MEGA, UNO, NANO, LEONARDO etc. Arduino board consists of a microcontroller (AVR ATmega), voltage regulator, power port, digital pins, analog input pins, TX RX LEDs, USB Interface Chip and USB connector. It is an electronic circuit board that is used to control the electronic circuit or project operations such as reading inputs from sensors, executing outputs such as sending analog or digital data, activating dc motor etc.

In the developed mobile application ELA, the differences of Arduino boards (Arduino MEGA, Arduino UNO, Arduino NANO) were presented with the user manual and pin configurations that clearly shown their own advantages and disadvantages. According to [6], the performance of Arduino MEGA is lower compared to Arduino UNO although it possessed more digital pins, EEPROM (Electrically Erasable Programmable Read-Only Memory) and flash memories than Arduino UNO.

2. Materials and Methods

Throughout the project and development of the mobile application, the project flowchart as shown in figure 1 is used to represent the overall workflow of the development process.

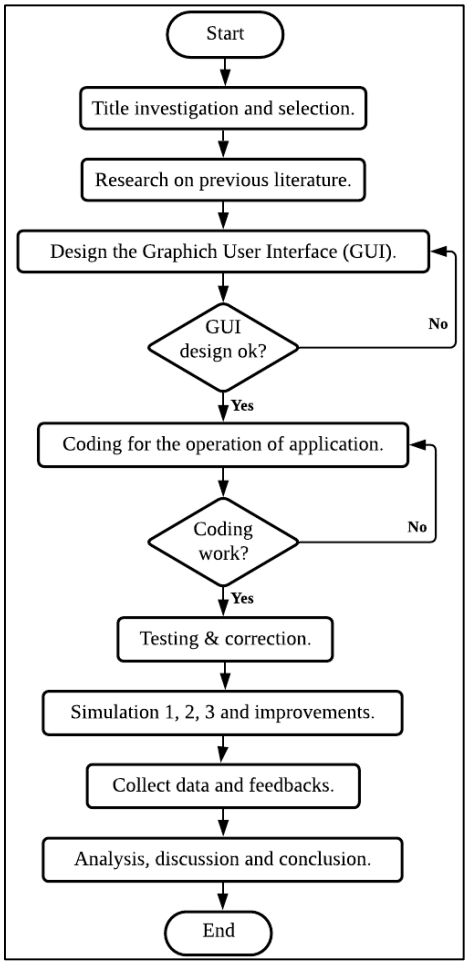

Figure 1: Project Flowchart

The whole project is started with the title investigation and selection which the problem found is investigated and analysed with the suitable objectives and scopes to solve the problem. The previous literature that found in internet had been researched and reviewed which these are the journal possessed the similar title with current project or these literature had useful information in related to the information needed in this project. The information included the development of educational or e-learning mobile application which is based on Android OS.

The design of Graphic User Interface (GUI) of ELA is developed with XML (eXtensible Markup Language) through utilization of Android Studio IDE. The background image implemented throughout the mobile application is edited with computer image editor software, GIMP (GNU Image Manipulator Program). The design of GUI or UI is checked whether it can be simulated without any error. On the other hand, the operations, or functionalities of mobile applications such as navigation between screens, parse users to websites or videos, and the functionalities of comment features are implemented with Java programming language through the utilization of Android Studio IDE.

The simulation process is then completed with 3 simulations in AVD (Android Virtual Device) function found in Android Studio IDE. AVD is the virtual device that can be adjusted with different specifications such as screen density (in DPI), Android version and device models. After the simulation and the correction or improvements done to mobile application with the result found in simulation process, the mobile application is then published to Google Play Store for data collection and feedback purposes. These data and feedbacks were collected through ratings and reviews from Google Play Store that can be observed also by the developer in Google Play Console. The google form is also used to collect the users' opinions on the different aspects of the mobile application, ELA.

The data and feedback collected from both mediums are later been analysed and discussed with the conclusion. The ratings were discussed with the criteria of application evaluation such as the design of UI, Engagement, Learning Content, User Experience (UX). On the other hand, the reviews were discussed with the categories of reviews received such as "Satisfaction", "Recommendation", "Complaints and Bugs".

2.1 System Block Diagram

Block diagram is used to visualise the operation or screen navigation of the whole system of mobile application ELA. The simple block diagram in figure 2 shown the main UI existed in ELA, which are main menu, submenu 1 "Intro", submenu 2 "Comparison", submenu 3 "Application", and submenu 4 "About the App".

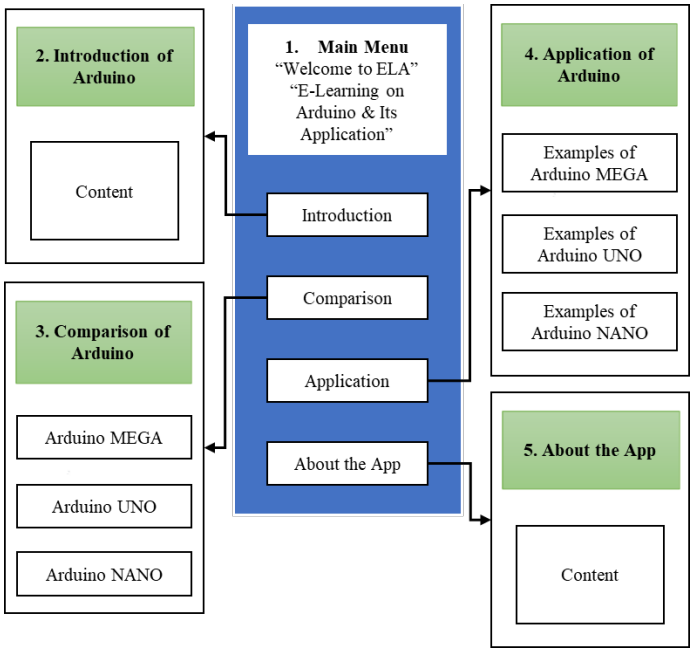

Figure 2: Simple system block diagram of ELA

The content presented in submenu 1 "Introduction" included the histories of Arduino, introduction of Arduino hardware (Arduino board) with suggested link to buy Arduino board in Malaysia; introduction of Arduino software (Arduino IDE) provided with official download links, introduction of

schematic diagram and wiring connection software provided with download links (Proteus and Fritzing); guidance videos on the software installation steps, steps on how to add Arduino library into Proteus, steps on implementation of Arduino code to Proteus, steps to run Arduino in details etc.

The content presented in submenu 2 "Comparison" compared 3 types of popular Arduino boards such as MEGA, UNO, NANO with the pin's configurations of these Arduino board; manual or specifications for these Arduino boards; suggested project for each Arduino boards.

The content presented in submenu 3 "Application" included the examples of electronic projects implemented with 3 Arduino boards (MEGA, UNO, NANO). These examples are provided with the list of components or hardware needed; the software needed, the schematic diagram that plotted with Proteus Professional; the wiring connection of the whole electronic project which plotted with Fritzing; the Arduino coding which written in C++ programming language. There are also comment feature existed for each example to allow the users to leave their comments or exchange their opinions about the examples that had been presented.

The content presented in submenu 4 "About the App" included the importance of the mobile application ELA, manual on how to use ELA and what ELA can teach to users.

2.2 Android Studio IDE

Throughout the mobile application development lifecycle, the tools or software that used to develop ELA is Android Studio IDE. It is an official Integrated Development Environment (IDE) for Android development and it is based on JetBrain's IntelliJ but with Android Development Kit (ADK) [7]. Android Studio utilized Java SE Development Kit 9 (SDK 8) which it can used to develop the mobile application that targeted different Android version of devices [8]. The Android SDK (Software Development Kit) provides with a set of API (Application Programming Interface) that are enable development of applications with Android Studio. [9]

From the programming languages available in Android Studio IDE for Android app development, Java is chosen between Java and Kotlin as the Android Studio IDE supports on JDK (Java Development Kit) was deemed better for Java compared to Kotlin [10]. In this mobile development process, Java is used to code the functionalities, interaction, and operations such as screen navigation of the mobile application.

Meanwhile, XML (eXtensible Markup Language) is used to design the User Interface (UI) of the mobile application ELA. XML is used to define the rules for encoding documents which the formats can be read and understand by both human and machine. XML file is the layout file that contains the definitions of UI elements [11].

On the other hand, the real-time database Firestore is used to store the data that submitted by users in comment feature. It is act as the database to store the comments submitted by users and display it synchronously to users in ELA. The implementation of Firestore in ELA is developed with Java coding. Firestore stores data in documents that organized in collections, and it is similar to JSON (JavaScript Object Oriented) [12].

2.3 Google Play Store

The developed mobile application ELA is then published to the Android application market, Google Play Store with store name of "ELA: E-Learning of Arduino & Its Application". The ratings and reviews in Google Play Store can be collected by developer through Google Play Console. The data analysis on installation also analysed by Google Play Console where the "Reach and Devices" section analysed the install based on Android version, RAM, System on Chip, CPU, and GPU.

2.4 Google forms

Throughout the data collection, Google forms were used to collect the users' information such as gender, range of age, identity categories. Other than the ratings and reviews also collected in this Google form, the users' experiences on the educational mobile application also been investigated whether they heard about Arduino before, installed an educational mobile application before, installed an educational mobile application that teaches Arduino. On the other hand, the criteria of app evaluation towards ELA are collected through users' opinion on ELA's design of User Interface, Engagement, Learning Content, User Experience (UX) after consideration between parameters between design, engagement, learning or educational content, functionality, technical characteristics [13], [14].

3. Results and Discussion

Google Play Store, Google Play Console and Google forms had used to collect the data about mobile application that is developed, ELA after the ELA was published into Google Play Store. Google Play Console is the terminal where Android developers upload or publish their Android app to Google Play Store, while users may download and install these Android app with Google Play Store.

Throughout the whole project, the Google Play Console had collected and analysed the reviews and ratings collected, the pre-launch report for open testing, the installation based on different parameters such as Android version, RAM (Random Access Memory), system on chip (SoC), CPU (Computer Processing Unit), and GPU (Graphic Processing Unit).

3.1 Results of Open Testing (Beta)

The result of open testing had done with the data collection through Google Play Console which it included ratings and reviews in "Testing Feedback" section, and "Pre-Launch Report". The proportion of ratings were divided from 1-Star to 5-Stars and the data is visualised in figure 3.

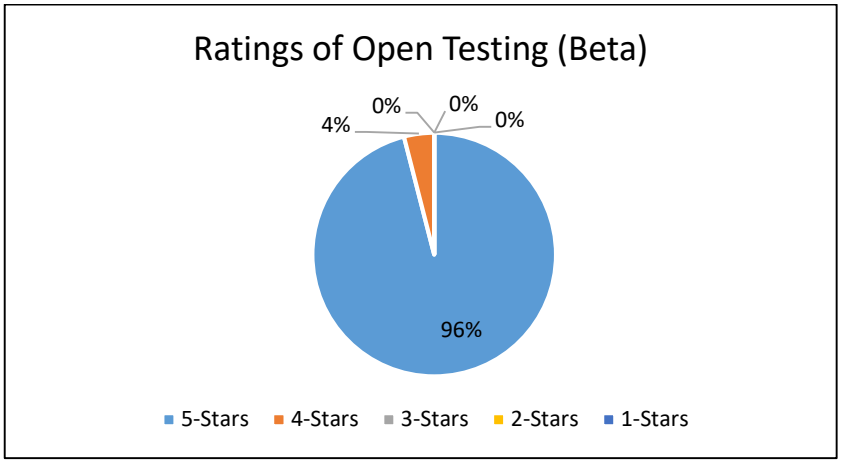

Figure 3: Ratings of Open Testing (Beta)

It is found that 24 out of the total 25 open testing users had assigned 4-Stars to ELA, while one of them assigned 1-Star to ELA in open testing. According to [15], the average ratings of open testing is calculated as 4.96.

According to [16], the reviews of Google Play Store can be categorized into categories such as recommendations, innovative ideas, user requirement, complaints & bugs, satisfaction, interface, pricing, , updates problem and others. In this project, the reviews were categorized into Recommendation, Satisfaction, Complaints & Bugs. The proportion of reviews categories were visualized as in figure 4, there were 21 of the users had assigned reviews that is categorized as

satisfaction while 4 of the total 25 open testing users assigned reviews that is categorized as recommendation.

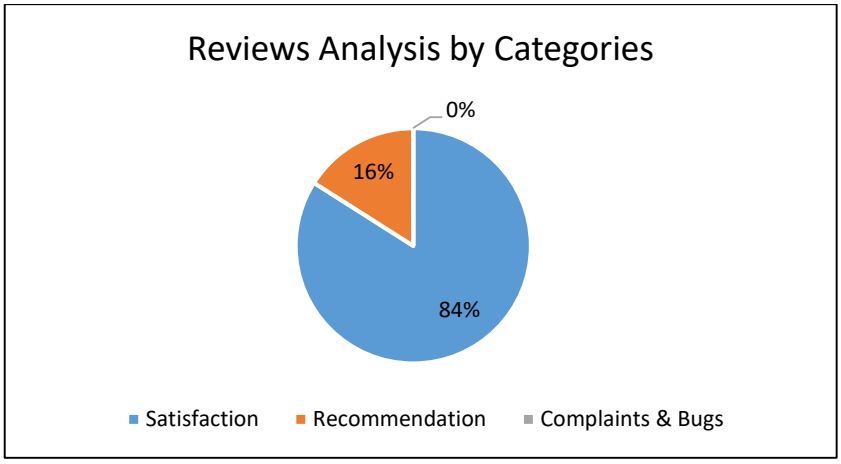

Figure 4: Reviews of Open Testing (Beta)

The pre-launch report of open testing reported the minor issue on the stability and performance of ELA in the virtual machine devices such as Samsung Galaxy S9 and Nokia 1. The stability issue faced was it is unable to draw image file with large size over $2.83MB$ in these 2 devices with Android SDK version of 7.0 and 8.1.

3.2 Official Launch (Production)

After the data collection in open testing, improvements on the User Interfaces, implementation of the suggestions on fixing some minor bugs, the educational Android app ELA had officially launched in Google Play Store. Throughout the design and revision of UI, the final UI of ELA can be seen from Figure 5 to Figure 11.

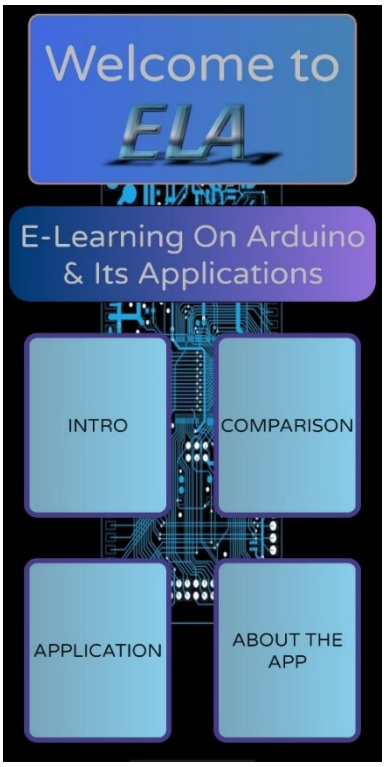

Figure 5: UI of Main Menu

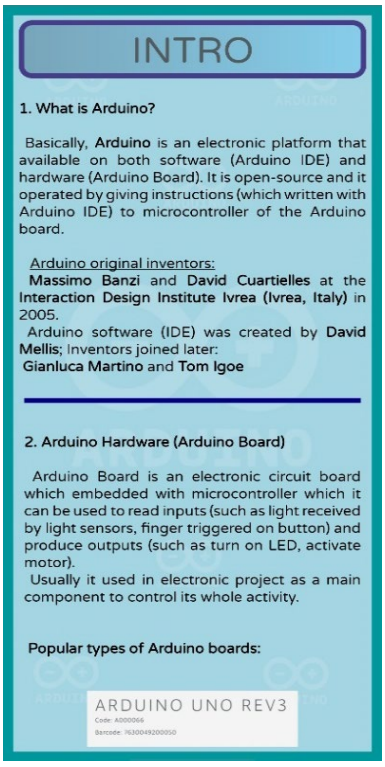

Figure 6: UI of Submenu1 (INTRO)

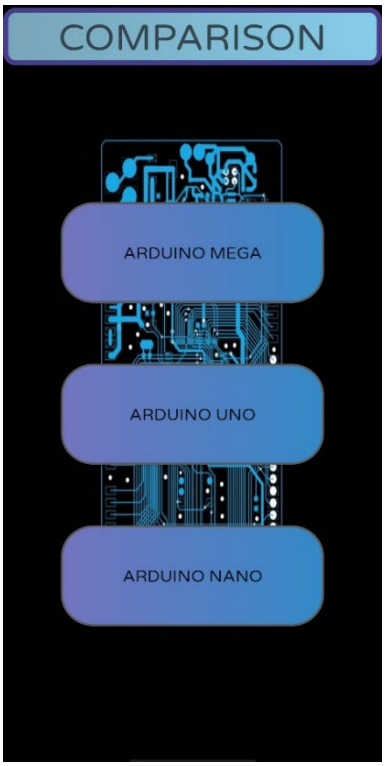

Figure 7: UI of Submenu2 (COMPARISON)

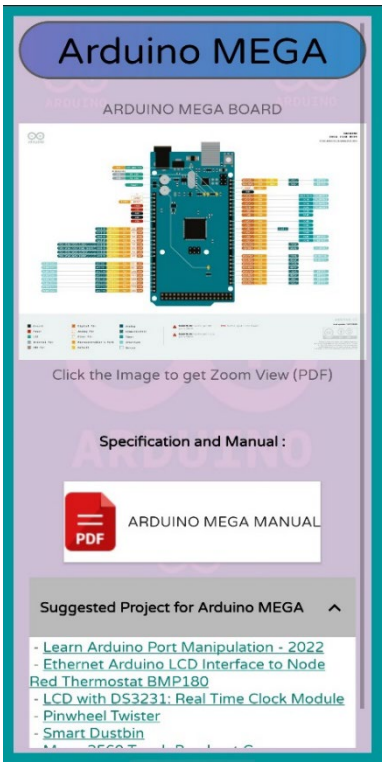

Figure 8: UI of Submenu2.1 (Arduino MEGA)

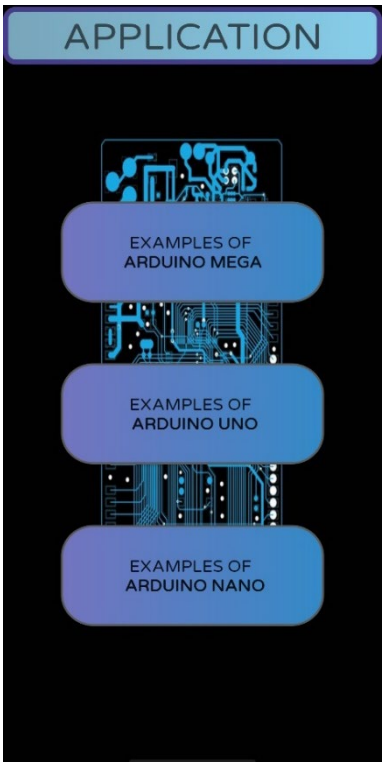

Figure 9: UI of Submenu3 (APPLICATION)

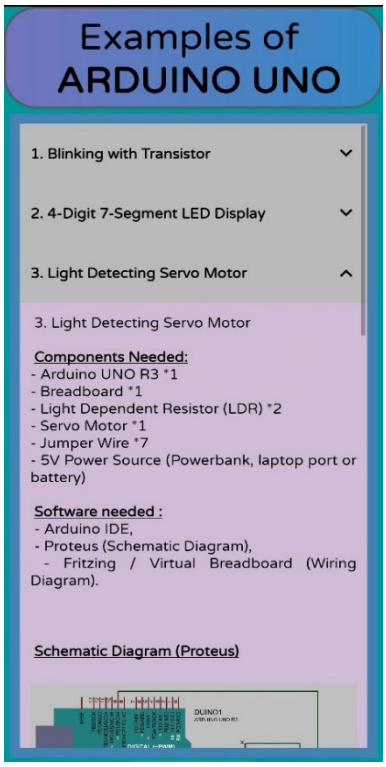

Figure 10: UI of Submenu3.2 (Examples of Arduino UNO)

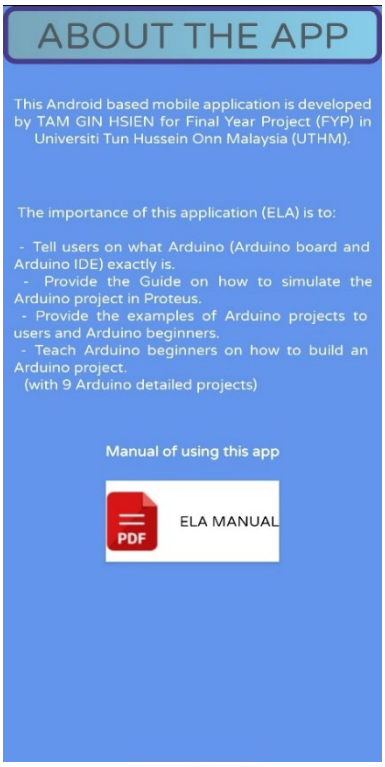

Figure 11: UI of Submenu4 (About the App)

The result of official launch had collected and analysed with Google Play Console and Google forms. The Google Play Console collected and analysed the total installation number, the ratings, and

reviews; the proportion of install base on Android version, RAM, SoC, CPU, GPU. The Google forms is used to collect and analyse the data regarding to users' information, experiences, and opinion regarding the app evaluation of ELA.

The data of total downloads of ELA in Google Play Store had been collected through Google Play Console where the total downloads reached 150 users in official launch (Production). It is viewed by the overall view of Google Play Console as shown in figure 12.

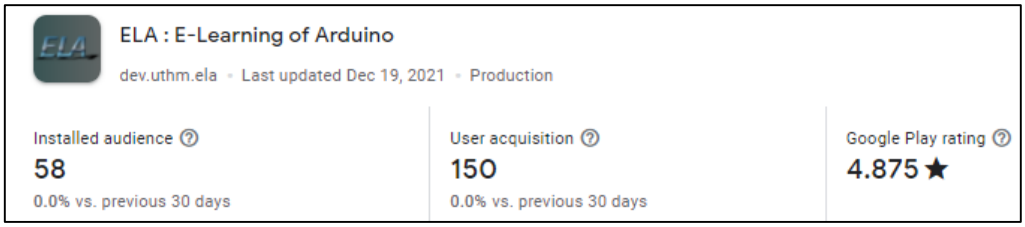

Figure 12: Total Download of ELA through Google Play Console

The ratings received in official launch were collected through Google Play Store and Google Play Console. The total rating received were 80 users where only 60 of them assigned reviews in Google Play Store. According to data analysis, there were 76 users had assigned 5-Stars, 2 users had assigned 4-Stars and 2 users had assigned 1-Star as shown in figure 13. The average ratings of ELA in open testing is calculated to be 4.96 with the formula according to [15]:

$$Ratings = \frac{sum\ of\ all\ the\ individual\ ratings\ assigned\ to\ the\ app}{total\ number\ of\ user\ assigned\ ratings} \qquad Eq.1$$

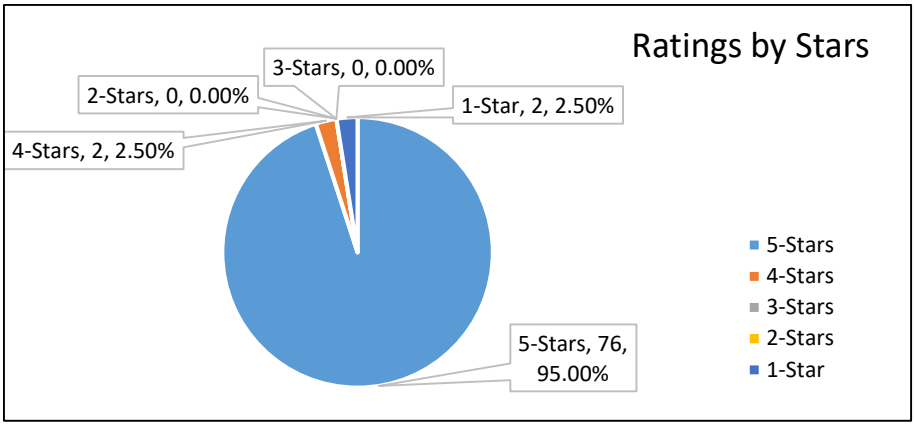

Figure 13: Ratings of ELA in official launch (Production)

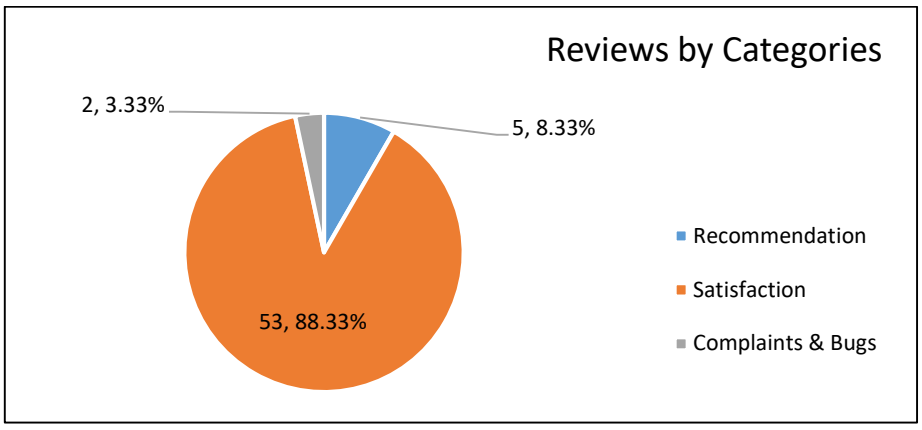

Figure 14: Reviews of ELA by categories in official launch (Production)

The reviews of ELA in official launch collected through Google Play Console shown that there were 53 users had assigned the reviews that were categorized as satisfaction, 5 users had assigned the reviews that were categorized as recommendation, and 2 users had assigned the reviews that were categorized as complaints & bugs. The data is visualised in pie chart as shown in figure 14.

The installation of ELA based on Android version, RAM, System on Chip (SoC), CPU, and GPU were analysed by Google Play Console in the section of "Reach and Devices". It is found that the most used Android version is Android 11, the most devices' RAM is 5-6GB, the most used SoC are Qualcomm SM8250 & HiSilicon KIRIN 980, the most used CPU is ARM Cortex-A53, the most used GPU is ARM MALI G72.

Throughout the data collection and analysis of Google forms that involved the 60 users which had assigned the reviews to ELA in Google Play Store, it is found that there were 32 of them is Female, 28 of them is Male. 41 of them were aged between 18 to 25 years old, 10 of them aged between 13 to 17 years old, and 9 of them were aged above 25 years old. Throughout the 60 users, there were 35 of them is pre-U or university students, 15 of them is adult public that has been working, and 10 of them is secondary school students.

On the other hand, the users' experiences on educational mobile application also been collected and analysed through Google forms towards the 60 users that had assigned reviews on Google Play Store. It is found that 39 of them have not been heard about Arduino before the utilization of ELA, 21 of them have been heard about Arduino. There were also 42 of them have been installed an educational mobile application before the installation of ELA, 18 of them have not been installed any educational mobile applications. In addition, all these 60 users have not been installed any educational mobile application that teaches Arduino.

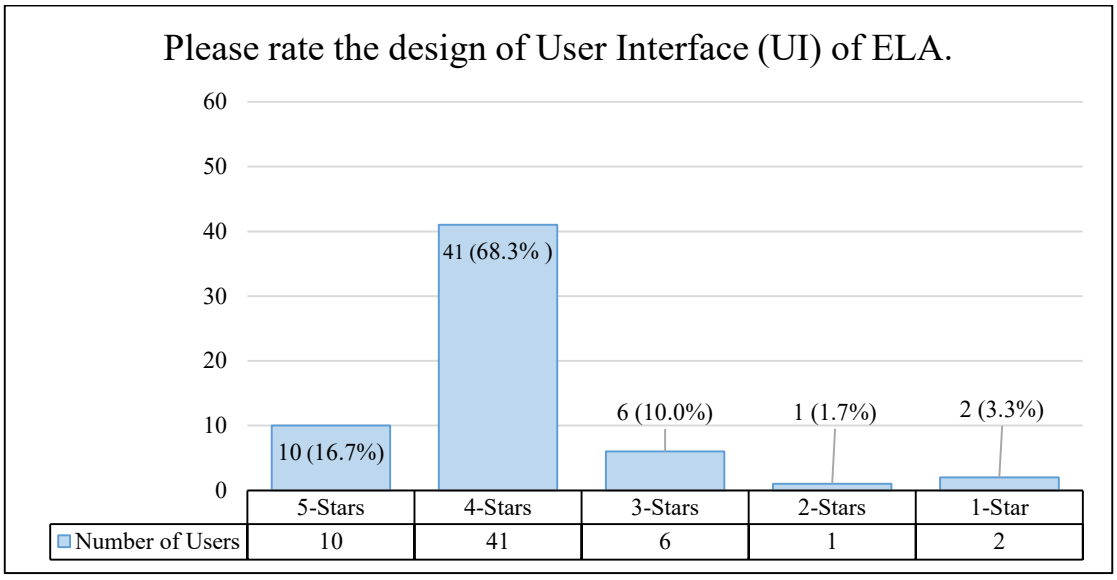

Figure 15: Users' opinion on the design of User Interface (UI) of ELA

Furthermore, the data about mobile application evaluation is collected and analysed with Google forms such that the users' opinions about ELA were collected. The first criterion or element that used to evaluate the mobile application ELA is design of User Interface (UI). As shown in Figure 15, most of the users assigned 4-Stars ratings to the design of UI of ELA. The average rating for the design of UI is calculated to be 3.933 with the formula of $Eq.1$.

The second criterion or element that used to evaluate the mobile application ELA is "Engagement" of ELA. This emphasized on the user interaction with ELA, how often they activate ELA, the duration of usage, did the ELA really aroused users' interest on knowledge about Arduino and thus making them

wanted to learn more with ELA. As shown in figure 16, there were almost same proportion of users assigned 4-Stars and 5-Stars ratings to the engagement of ELA. The average rating for the engagement is calculated to be 4.183 with the formula of $Eq.1$.

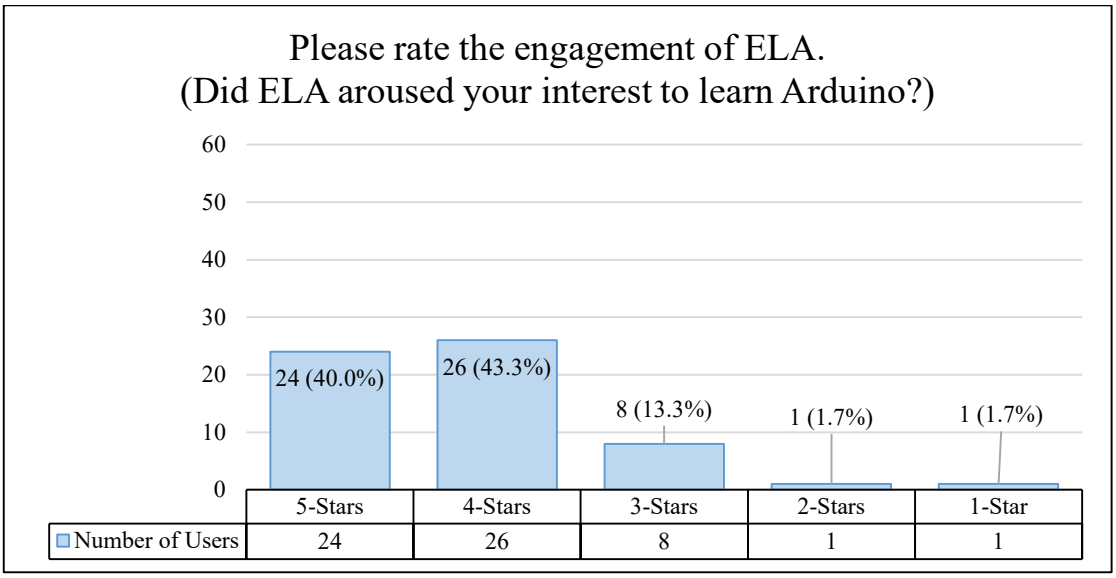

Figure 16: Users' opinion on the Engagement of ELA

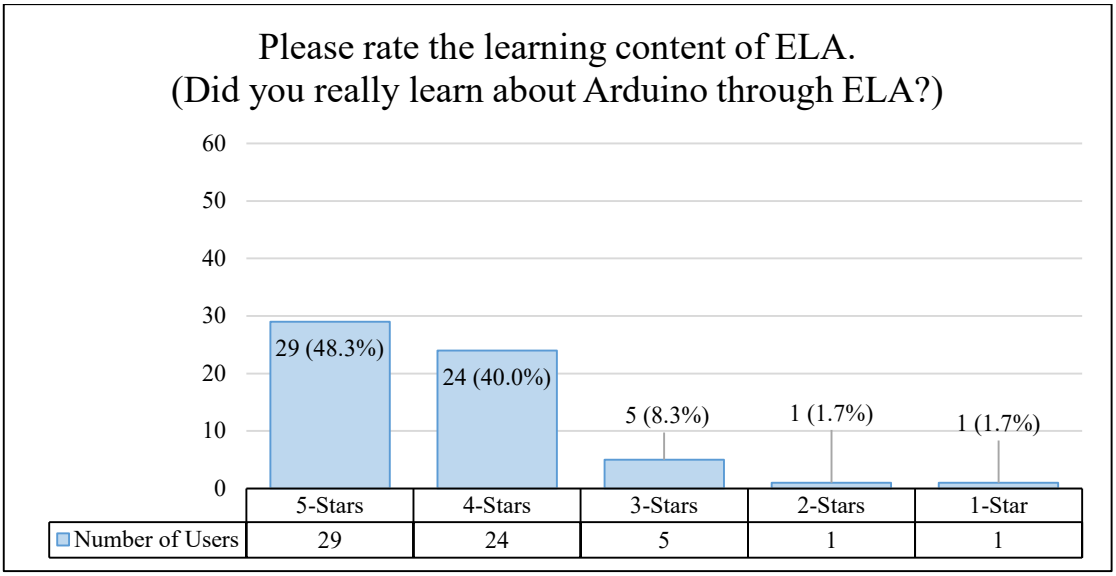

Figure 17: Users' opinion on Learning Content of ELA

Moreover, the third criterion or element that used for application evaluation of mobile application ELA is "Learning Content" of ELA. This referred to anything about the knowledge presented in ELA which included the knowledge package appropriateness, error correction or feedback provision, learning provision, bias free, accuracy of learning content. As shown in Figure 17, there were almost same proportion in the number of users that assigned 4-Stars and 5-Stars ratings to the learning content of ELA. The average rating for the learning content of ELA is 4.317 as calculation with formula of $Eq.1$.

The fourth criterion or element that used to evaluate the mobile application ELA is "User Experience (UX)". UX referred to the end-to-end experience of users, set of interactions users experienced, navigations, and the feeling in usage of ELA. As shown in Figure 18, there were 30 users

had assigned 4-Stars and 28 users had assigned 5-Stars to UX of ELA. The average rating for the User Experience (UX) of ELA is 4.383 as calculated with formula of $Eq.1$.

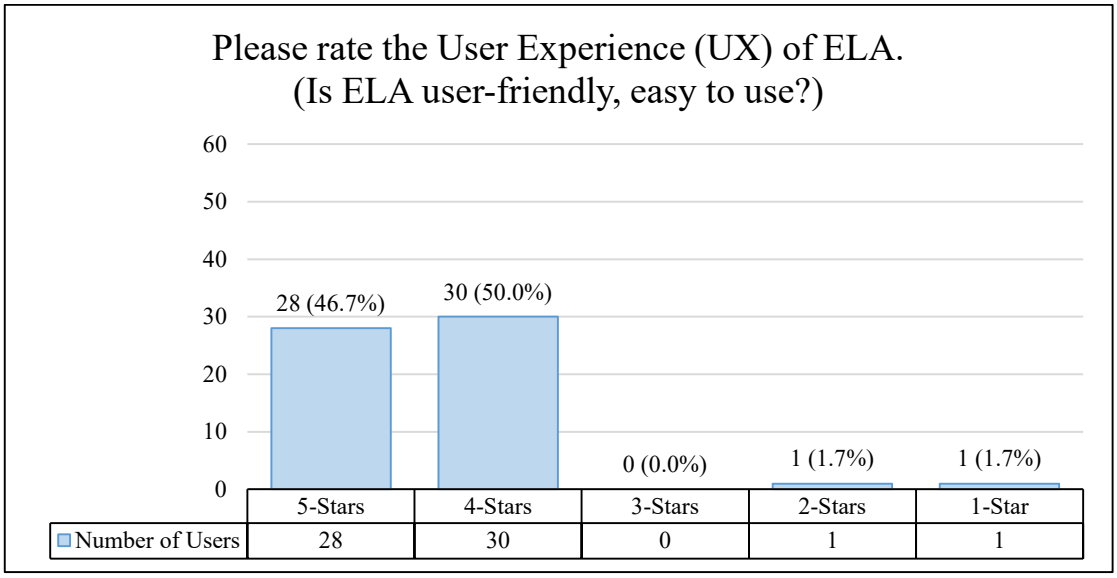

Figure 18: Users' opinion on User Experience (UX) of ELA

4. Conclusion

Throughout the project paper, the Android based educational (e-learning) mobile application has been developed with Android Studio IDE, Java, XML, real-time database Firestore. This Android app namely "ELA" is then published to Android application market, Google Play Store with the store name as "ELA: E-Learning of Arduino". There 2 launching for this app which are open testing (Beta) and official launched (Production).

The results were collected through Google Play Console and Google forms which the ratings and reviews were analysed and discussed with different ways. Reviews were analysed with categories such as "Recommendation", "Satisfaction", "Complaints & Bugs". Google forms had used to collect the users' basic information (gender, range of age, identity categories), users' experiences (whether users had heard about Arduino, had installed educational mobile app, had installed educational mobile app that teaches Arduino), users' opinions (ELA's design of UI, Engagement, Learning Content, UX).

In short, this project had achieved all the objectives and scopes as the ratings received for the official launch (Production) were 4.875 for the average ratings of ELA. ELA that developed with Android Studio in APK & AAB format then published to Google Play Store had successfully presented the knowledge about Arduino (introduction, comparison, application of Arduino) in beginners' level, provide examples of its use, and some easy-to-use applications.

4.1 Impact of Engineering Technology Solutions

Meanwhile, the development of this mobile application ELA had also contributed some impacts of the engineering technology solutions on the aspects such as environmental sustainability, safety & health, and economy. According to [17], WEEF (World Engineering Education Forum) had addressed that the engineering, technology and industry had relationships with the impact of influencing global economy, pace of life, university's role in innovation, interdisciplinary mindset, environmental sustainability, and safety & health.

The development of ELA had impact on the environment sustainability in both positive and negative ways. For positive impacts, ELA had encouraged the learning process through utilization of educational or e-learning mobile application. This had significantly reduced needs of learning process

through physical materials such as books, foolscap paper etc. For the negative impacts, the knowledge taught in ELA which are knowledge related to Arduino had encouraged the implementation of Arduino boards in IoT (Internet of Things) electronic projects that will increase the physical material wastes. The Arduino board that has been used or broken normally will be thrown to dumpsite or junkyard. This will increase the number of electronic wastes that cannot be process and recycle. According to [18], there are around 700,000 official Arduino boards registered in the world, and it is estimated that there will be at least 1 clone board for every official board.

Moreover, the development of ELA also contributed impacts of engineering technology solutions in aspect of safety and health. Users of ELA that learned Arduino through ELA would face the safety risk when they are building the IoT electronic projects with Arduino boards. As an example, the incorrect connection of relay may lead to the explosion of relay which may harm users' safety. Therefore, it is recommended that the users of ELA follow every hardware installation step presented in ELA.

Furthermore, the development of ELA had contributed some impacts of engineering technology solutions in aspect of economy. As stated previously, the encouragement of utilization of Arduino boards in building IoT electronic projects in ELA may increase the usage of Arduino boards, thus increasing the consumption, buying and sales of Arduino boards. This had increased the spending ability of customers (or users) and generated income for the sellers of Arduino boards.

4.2 Recommendations

Throughout the development process of Android mobile application ELA, there are some recommendations are suggested to implement in the development process and the output product.

The first recommendation was that the implementation of encryption or obfuscation method on resources and data of the app, ELA. R8 or ProGuard were suggested to implement in ELA to prevent the anonymous to obtain ELA source code with reverse engineering method such as extract APK with APK Extractor to obtain the resource, DEX (Dalvik Executable) files and manifest files of ELA. R8 or ProGuard able to protect the source code of ELA by convert the names of packages, methods, and classes inside ELA by substituting them with obscure name [19].

The second recommendation was addition of interactive section such as exercise, Q&A sessions, or Quiz sessions. The recommended Quiz session could be the "True or False" quiz or the multiple-choice questions quiz. The third recommendation is that the function of Arduino compiler that found in Arduino IDE was recommended to implement in the mobile application ELA. It is suggested that ELA can improved such that it can compile and upload Arduino coding through mobile's Type-C or USB ports.

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