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User Interface Design for Arm Robot Controller Application using User-Centered Design Method as a Learning Media

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ABSTRACT: Arm Robot Controller is a controller that can be use to controlled wirelessly using Bluetooth based on an android application. Arm Robot Controller is designed as a learning media to help users(student) learn and understand material related to industrial robotic. This arm robot controller born because there is a need to facilitate student that have a large anthusiasm in understand industrial robotic. For that purpose they need a learning media of a controller that they can build with material that available in their surroundings to make it easier to explain on how the principle of controller works. The design method that use in this product are the User-centered Design (UCD) method. The UCD method has 5 stages, namely Plan the Human Centered Process, Specify the Context of Use, Specify User and Organizational Requirements, Produce Design Solutions and Evaluate Design against User Requirements. The design of the User Interface (UI) design follows the UI design principles of User Familiarity, Consistency, Minimal Surprise, Recoverability, and User Guidance. User Interface design uses a web-based designer application, namely MIT App Inventor which is open source. MIT app inventor can make it easier for users because programming uses blocks that are connected to each other. Evaluation of the design results uses the Overall Relative Efficiency method to measure the level of efficiency and error, while the System Usability Scale method is used to measure the level of satisfaction. The evaluation results show an efficiency level of 77.98% with an error rate of 18.6%. While satisfaction score is 79 so that the application can be categorized as acceptable.

KEYWORDS: Controller, User Requirement, User Interface, User-centered Design, Overall Relative Efficiency, System Usability Scale

INTRODUCTION

Technological developments over the past 10 years have been very rapid, one of which is in the industrial sector. Technological developments have now entered the era of the industrial revolution 4.0. The Industrial Revolution 4.0 is a term that refers to a combination of technologies related to physical, biological and digital dimensions that are difficult to separate and distinguish from this combination. [1]

Many changes have occurred as a result of this digitalization, such as the existence of an automation system. An automation system is a system that implements a combination of electronic, mechanical and computer systems to be able to control, monitor and control a company's production process. Automation systems are now widely using IoT because its application is wider and more concise for automation. So that the existence of this automation system will shift the role of humans in work, especially in jobs that are repetitive so that they require accuracy and speed but do not really need judgment [2]

In implementing an automation system, technology is needed to support the system, one of which is a robot. Robotics is a branch of science that transforms a form of human intelligence into a tool that can be adapted to human needs so that it can make work easier [3]

Human resources are the main factor in the development of Robotics technology. So it is necessary to increase education related to this robotics. Learning media is a device that is used to assist the academic process in clarifying the delivery of material and information so that the desired learning objectives are achieved [4]. Meanwhile, according to [5] states learning media is a medium or learning tool that can be used by facilitators during the learning process with the aim of increasing effectiveness and efficiency in achieving instructional goals. The Industrial Engineering Department of Diponegoro University itself has an Integrated Manufacturing system course which provides an overview of automation and industrial robotic processes.

However, nowadays still lack of learning media to facilitate student in introduce robotics principal. One of the supporting facilities is props. Teaching aids are a tool that is useful for conveying messages that can arouse students' attention, thoughts, feelings and desires so that they can improve the ease of the learning process [4].

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Based on this, the researcher intends to design robotics controller learning media. The controller of a robot arm that will be designed integrates computer programming, computer networks, data communications, and microcontrollers. So it is hoped that this learning media can unites various lessons, increases the interest and understanding of participants regarding robotics. The controller of a robotic arm will be designed with a Bluetooth communication system that can be connected via an Android application so that the robotic arm can be moved via a Bluetooth-connected device

METHOD

This research is development research, where the research is used to develop a product so that the purpose of its use is achieved, this research aims to design an Internet of Things-based Arduino Robot Arm controller application to become a useful teaching tool for building understanding of robotics in its use and design aimed at to Diponegoro University Industrial Engineering students, especially those taking courses on industrial robotics. Data collection to design development was carried out following the UserCentered Design (UCD) method. Data collection for application needs is carried out in the early stages using a questionnaire and application evaluation using Usability Testing.

The following is the flow of practical work research methods carried out:

1. Preliminary Study

In this study, there were two preliminary studies conducted, namely:

a. Field Study

This study was conducted by distributing questionnaires to related parties, namely Industrial Engineering Students who have an understanding of industrial robotics. The design of teaching aids as learning media arose because of student anxiety about understanding industrial robotics as a technology that is still too up-to-date, rarely found by students because it is only found in industrial factories, and is very difficult to make yourself. So that this reduces students' understanding of the industrial robotic material that has been taught. b. Study of literature.

This study was carried out after knowing the formulation of the problems that were known after field studies and then proceeding with searching for references to similar problems and implementing possible solutions.

2. Problem Formulation

The preliminary study illustrates that there are problems in students' understanding of industrial robotics. The problem that occurs is that there are no material props that can help students understand the material. So to solve this problem a possible solution is to design an Arm Robot controller application based on data communication via Bluetooth as a medium for industrial robotic learning.

3. Determination of Research Objectives is knowing the needs of users related to the Arm Robot application, designing the application, and evaluating the application.

4. Determination of Research Boundaries

Research limitations contain provisions to clarify the scope of the research to be carried out

5. Determination of the Design Method

The aspect that determines the scope of this research is based on the design method. The literature study that has been carried out forms the basis of the selection of this research design method. The method used in this study is the User-Centered Design method. This method is used to design an Arm Robot controller application based on user needs to design the application's user interface. User-Centered Design or UCD [6] has five main stages. The following is an explanation of each stage in this method:

a. Plan the Human Centered Process
b. Specify the Context of Use
c. Specify the User and Organizational Requirements
d. Produce Design Solutions
e. Evaluate Designs against User Requirements

6. Revision

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From the evaluation results at the last UCD stage, revisions are made if there are user requirements that have not been met or there are design principles that have not been met. Improvements can be made at the stages or phases where deficiencies are found according to the research flowchart

7. Analysis and Discussion

The analysis and discussion stage contains analysis related to the design of the application that has been designed and analysis of the design based on user interface design principles as well as analysis of the results of the evaluation in the previous stage so that the analysis can conclude whether the design meets user needs and the application can run properly.

8. Conclusions and Suggestions

After a review has been carried out on the application, if the application is declared to have met the user requirements and user objectives, the application is declared pass and is feasible. After that, conclusions are made to answer the research objectives and suggestions are given to provide recommendations to those who wish to develop this research further.

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RESULT AND DISCUSSION

Specify the Context of Use

This stage in UCD is useful for understanding the context of using the application to be made. At this stage it also determines potential application users with the aim of getting user needs in this application. This stage consists of several stages, namely: determining potential users, designing user requirements questionnaires, determining application users, and determining user personas.

Prospective users are determined based on demographic, geography criteria. Psychology, and behavior of prospective users. Based on these criteria, it is determined that users are Industrial Engineering students with special criteria based on behavior, namely those who have an interest in and understanding of industrial robotics.

Specify the User and Organisational Requirements

Data collection for user requirements was carried out by distributing questionnaires to 17 people who were Industrial Engineering students at Diponegoro University Class of 2020. The selection of user informants was based on the identification of potential users, namely students who have an understanding of industrial robotics (found in integrated manufacturing systems courses). The distribution of questionnaires was carried out in the Integrated Manufacturing Systems course class on June 3, 2022.

After obtaining the profiles of prospective users and the required data in the form of user needs, the researcher collects, concludes, and designs User requirements and functional requirements. User requirements are what users need, while functional requirements are what applications or systems need in designing a product. The result of interpretation of user needs from the results of the questionnaire that has been distributed can be seen in Table 1

Table 1. User Requirement and Solution Functional Requirement

Number	User Requirement	Solution Functional Requirements
1	Users want an interface that is user friendly and attractive	The design application conforms to good interface design standards and the placement of elements is readjusted according to function
2	Users want feedback in the form of the degree of the driven servo (83.3%)	The application provides feedback in the form of a number near the arrow (servo drive) which shows the servo degree information
3	The user wants the save position feature (100%)	The application has a save position feature to save the desired robot position

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4	Users need the use of symbols to make it easier to identify a function (88.9%)	The application is designed by providing symbols according to the function of a button (Symbols and descriptions)
5	Users prefer to use the type of arrow keys to move the servo (55.6%)	The application uses the arrow keys to use the servo and The application uses the arrow keys because it is more precise
6	Users prefer to use the menu position below (83.3%)	The application is designed with a save position, run and reset menu at the bottom
7	Users need a robot image in the application to make it easier for the user which part is moved on the robot (94.4%)	In the application there is a picture of a robot with connecting lines to the controller to identify which part is driven by the robot
8	Users need a tutorial on using the application so that users can understand how to use it the first time they use the application.	The application provides how to use and the sequence of using the application
9	Users want a feature that can save positions and can move positions according to the stored positions automatically	The application has save, run, reset features so that the robot can move automatically
10	Users need an explanation feature of each function in the application	The application provides a section that explains each function of a button in detail.

Produce Design Solutions

After obtaining user requirements through the previous stage, at this stage the researcher designs the application according to the functional requirements so that the application becomes a solution to the user's needs.

In designing the application design, the researcher determines the user flow and wireframe first as the initial design and design of the system and application design. The following is the result of collecting application structure data:

a. User Flow

User Flow is a series of steps required by the user to be able to carry out a function or feature from start to finish. User flow is useful for designers in designing user interfaces effectively and efficiently because userflow provides the order in which users run applications. The following Image 1 is the userflow for the Arm Robot controller application:

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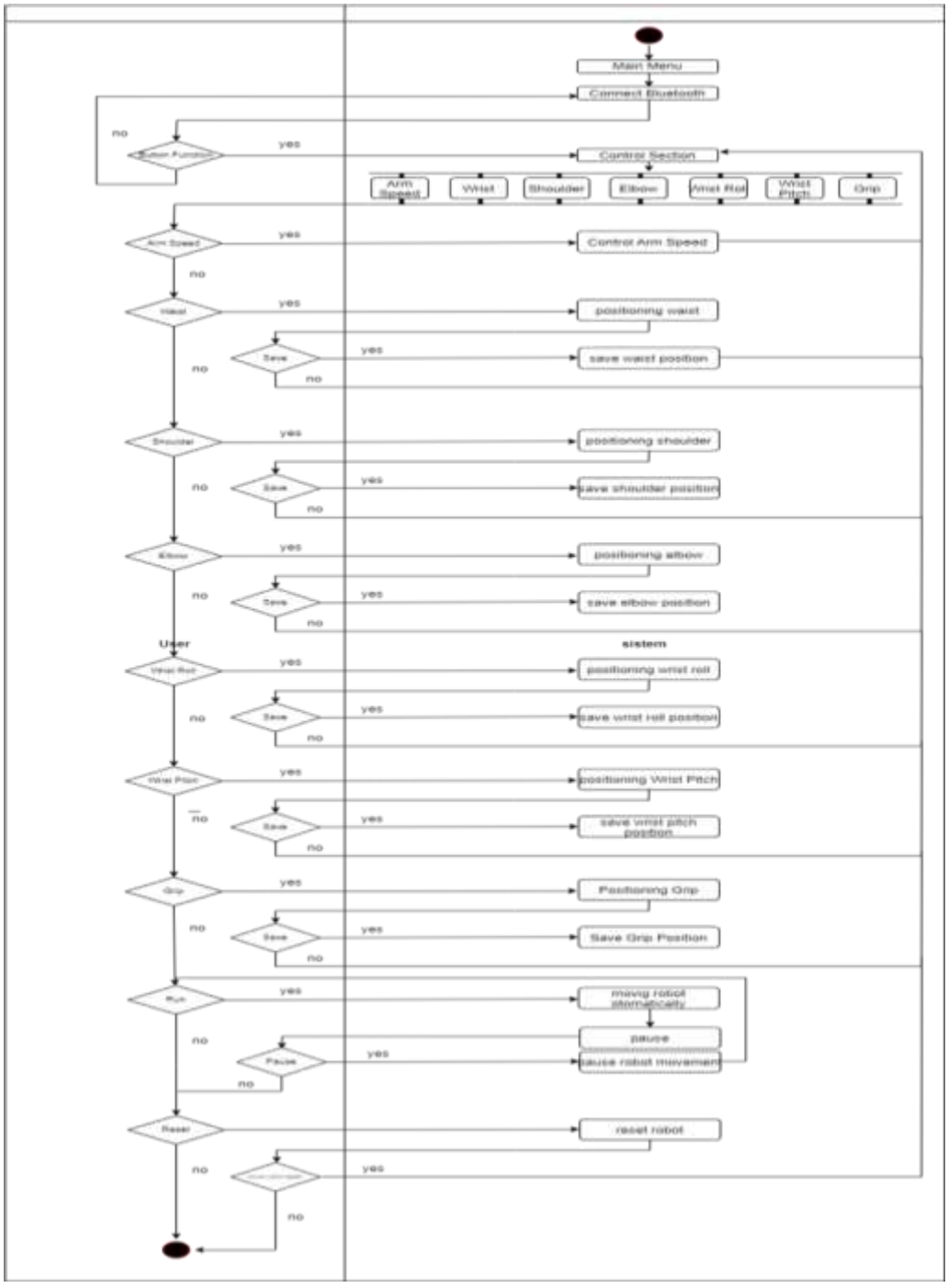

Image 1. User flow

b. Wireframes

Wireframes are a method used for web design to illustrate the appearance of a website sequentially [7]. The following is the wireframe used:

1. Main Menu

Here is the main menu wireframe: There are several sections, namely the Bluetooth section which contains to connect Bluetooth, controller. The wireframe for main menu can be seen in Image 2

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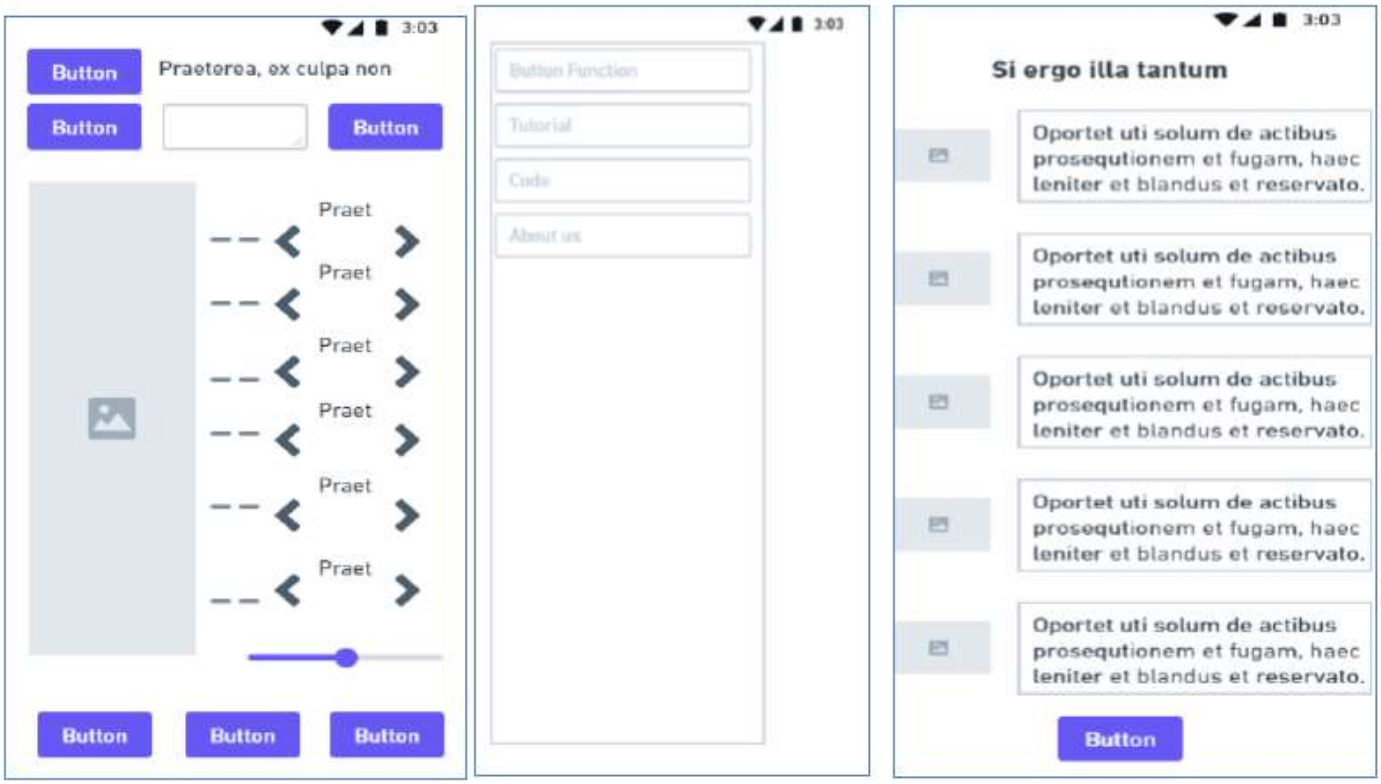

Image 2. Wireframe Main Menu Image 3. Wireframe Sidebar Image 4 Wireframe Button Function

2. Sidebars The Sidebar wireframe can be seen in Image 3
3. Button Function page. wireframe for Button Function can be seen at Image 4
4. Tutorial Page
5. Code Page
6. About Us Page.

c. Design implementation

In this phase, the user interface design for the Arduino Arm Robot application is implemented based on user requirements, user flow and wireframes. The following is the result of the implementation of the application's user interface design:

Evaluate Design Against User Requirements

After implementing the user interface design, the application is evaluated with the aim of whether the application and the system contained there are running well. Evaluation is carried out with two tests, namely system testing and usability testing. This stage involves 5 evaluators who have been adjusted to the previous user persona

This evaluation measures the level of efficiency, error, and satisfaction. The level of efficiency and error is evaluated through a testing system using the Overall Relative Efficiency method, the metric for the level of efficiency uses completion, namely the success of the evaluator in running the scenario. While the metrics for error rates use the number of errors, namely evaluator errors when running scenarios in the form of misclicks and click errors. This method uses a time indicator to complete tasks and competition tasks by giving a value of 1 for direct success and a value of 0 for a failed task and giving a value of 0.5 for an indirect success task. Overall Relative Efficiency using the formula:

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$$\overline{P} = \frac{\sum_{j=1}^{R}\sum_{i=1}^{N} n_{ij} t_{ij}}{\sum_{j=1}^{R}\sum_{i=1}^{N} t_{ij}} * 100\% \quad (1)$$

Explanation
P = Efficiency Level
N = Total tasks used
R = Number of Evaluators
nij = Result of task scenario i from evaluator j;(1 direct success, 0 fail, 0.5 Indirect success)

$$E = \frac{|B-S|}{B} * 100\% \quad (2)$$

Explanation
tij = time used by the evaluator j to complete the task i
E = Error Rate
B = Theoretical value
S = Trial value

Table 2 is the result of calculating Overall Relative Efficiency

Table 2. Overall Relative Efficiency Calculation Results

Participant	Completion Task	Duration (second)	Average Time (Second)	Theoritical Value	Error	Number of Steps	P	Error Rate
A	1	82	85,4	15	2	17	77,98%	18,6%
B	0,5	103			6	21		
C	1	80			2	17		
D	0,5	85			3	18		
E	1	77			1	16		

The level of satisfaction is evaluated using the system usability scale. Usability evaluation is a term used to assess a system in terms of function so that users are comfortable using the system [8]. This method is used to assess whether the application being evaluated is good based on the answers from the evaluator. This method is a method based on a questionnaire containing 10 questions filled out by the evaluator after conducting system testing. Table 3 are the results of the System Usability Scale (SUS) questionnaire obtained:

Table 3. SUS Calculation Results

Participant	Count Result Score										Total Amount	Total Satisfaction Score
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10		
A	3	3	3	2	4	4	3	4	3	3	32	80
B	4	3	1	1	3	4	3	4	2	4	29	72,5
C	4	3	4	4	4	3	3	3	3	3	34	85
D	3	3	2	1	3	3	4	4	2	4	29	72,5
E	3	4	3	3	3	3	4	4	3	4	34	85
Amount											158	395
Average Score												79

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Application Analysis

User interface design analysis was carried out based on two analyses, namely analysis based on design guidelines and analysis based on interface design principles. The design of application user interface designs uses design guidelines to make it easier to design applications. The following are the design guidelines used in the application design process:

User interface design analysis was carried out based on two analyses, namely analysis based on design guidelines and analysis based on interface design principles.

The design of application user interface designs uses design guidelines to make it easier to design applications. The following are the design guidelines used in the application design process:

The background color used is dark blue with code #101428. The choice of background color is due to the choice of using a dark user interface because in the application there are only buttons and images with only a little text to read

The selection of the derived color adjusts to the background-foreground combination so that the color is cyan with the code #43CEEA. Color combinations Dark background colors tend to be light and will go well with foreground high intensity cyan colors

The size of the button used follows the benchmark in subchapter 3.6.4.2, namely the recommended size is 32 px with a width that adjusts to the use of text and screens. This size is the recommended size to reduce the chance of the button not being pressed Design analysis was also carried out based on the 5 design principles used, namely:

1. User familiarity

Applications are designed using terms, symbols or buttons that are familiar to the user. One of the features that refers to this principle is the menu button in the application using the three line symbol at the top left to open the sidebar on the left screen. The image of Menu Buttons can be seen at Image 10

2. Consistency

Applications are designed to comply with the principles of consistency in designing application user interface designs. The feature that refers to this principle is the use of the home button which is always at the end of the page that directs to the main page. The image of home button can be seen at image 6

3. Minimal Surprise

This principle helps the user to be able to know the output of an operation the first time they use the application. One feature that refers to this principle is the connect and disconnect buttons that can been at Image 7

4. Recoverability

This principle helps the user to be able to cancel an ordered operation. The feature that refers to this principle is the reset feature which is used to delete all robot positions that have been saved via the save button that can seen at image 8

5. User Guidance

This principle requires the application to assist the user by providing useful information for the use of the application. One feature that refers to this principle is the Function Button menu that can be seen at Image 9

The next analysis is to analyze the results of the application evaluation. Evaluation of efficiency and errors using Overall Relative

Image 5. Design Guidelines

Image 6. Home Button

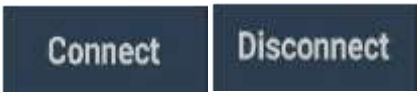

Image 7. Connect -Disconnect Button

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Image 8. Reset Button

Image 9. Function Buttons

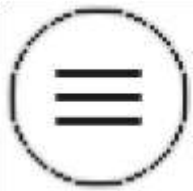

Image 10. Menu Button

Referring to ISO 9241-11, an effectiveness value above 78% can be said to be a very good application and an effectiveness value below 49% is the lowest quartile value. This shows that the application is good and acceptable but there are problems with the system because based on this test, it was found that the problem was in the user's error moving the robot part, namely the robot gripper. The solution is to redesign the gripper button with the following logo that can be seen at Image 11

Image 11. Gripper Button

Furthermore, based on the calculation results of the System Usability Scale questionnaire, an average value of 79 was obtained. The minimum score for an acceptable application is 70 [9]. So that the results of the SUS score for the application can be accepted and it is concluded that the application is user-friendly.

CONCLUSION

Researchers have completed all stages of designing the Arduino Arm Robot application based on the User-Centered design method. Identification of user requirements is carried out after determining the user persona and user goals. Identification of this user requirement using a questionnaire method to application users according to the user persona. The output of this stage is in the form of user requirements for the features needed in the application according to the User-centered design method.

The design of the Arduino Arm Robot application is carried out based on the user requirements that have been studied previously. The design of the application begins with creating a user flow to find out the flow of use and wireframes as a framework that helps as a researcher's initial view in designing applications. Application design follows the principles of user interface design so that the output of the application is better.

Evaluation was carried out using the Overall Relative Efficiency method and the System Usability Scale method. The Overall Relative Efficiency method is used to test whether the application can run properly and to measure how efficient the application is in achieving a goal. The results obtained are an efficiency rate of 77.98% with an error rate of 18.6%. The SUS method is used to measure the level of user satisfaction with the application. From the results of the SUS calculation, a SUS value of 79 is obtained so that the application can be categorized as acceptable.

User interface design analysis is carried out by examining the suitability of the design with the user interface design principles. The results of the analysis show that the application meets the user interface design principles.

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