DESIGN AND DEVELOPMENT OF A RASPBERRY PI-BASED CONTROL AND PROGRAMMING SYSTEM TRAINER BOARD ASA LEARNING MEDIA AT AVIATION POLYTECHNIC OF SURABAYA

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ABSTRACT
The importance of direct involvement in learning lies in its ability to enhance deeper and more relevant understanding. Teaching is not just about conveying facts and information to students but also about creating a learning environment that allows students to actively engage in their own learning process (learning by doing). In relation to this, this research aims to develop a Control System and Programming Trainer Board based on Raspberry Pi as a learning medium at Surabaya Aviation Polytechnic. This trainer board uses a Raspberry Pi microcontroller with sensors including ultrasonic, gas, temperature and humidity, LDR, and PIR sensors. In addition to sensors, there are actuators as outputs, namely a buzzer, LED, bulb, servo motor, and I2C LCD. A monitor, mouse, and keyboard are supporting devices in the program processing. This can facilitate cadets in understanding the courses on control systems and programming. The implementation of this Raspberry Pi-based trainer board is expected to make it easy for cadets at Surabaya Aviation Polytechnic to learn and understand the basic concepts and practical applications of control systems and programming. By using the Raspberry Pi platform, cadets can easily access various sensor and actuator modules and practice programming directly. This not only enhances their technical skills but also deepens their understanding of how electronic components work together in an integrated system. Additionally, this trainer board is designed to offer an interactive and immersive learning experience, motivating cadets to be more active in exploring aviation technology.

Keywords *: Trainer board, Raspberry Pi, control systems and programming, learning by doing*

1. INTRODUCTION

Education is a fundamental need for every individual. In general, education can be defined as a series of actions that enable the process of learning and development to occur[1]. Education can also be understood as an interaction that facilitates learning, which in turn stimulates growth. The most effective learning experiences are those that involve direct engagement, where individuals not only observe but also actively participate and take responsibility for the outcomes of the process. For example, in learning how to assemble electronic circuits, it is more effective if someone is directly involved in building the circuits, rather than merely watching or listening to explanations.

John Dewey emphasized the importance of direct involvement in the learning process[2] because it enhances understanding and the relevance of abstract concepts, while also developing critical thinking, problem-solving skills, and creativity. Educational approaches based on Dewey's principles focus on creating learning environments that allow students to actively engage in their own learning, such as through project-based and problem-based learning.

Instructors are not the sole source of learning, but they play a crucial role in designing or creating other learning resources to support an effective learning environment. Learning media, which can be used by instructors to deliver material to students, is an essential element in the teaching and learning process, especially in higher education, where graduates are expected to have skills relevant to their fields of study[3]. In the Department of Telecommunications and Air Navigation Engineering, for instance, mastering programming competencies is one of the essential skills that students must acquire.

However, the limited number of learning media, such as trainer boards, can be a barrier to practical activities. Based on a survey at the Surabaya Aviation

Polytechnic, it was found that the number of trainer boards for control and programming systems is very limited. Therefore, researchers plan to design a new trainer board that is expected to support teaching, learning, and practical activities more effectively.

Research conducted by Iqbal Anshary and Edidas in 2018 showed that the use of learning media, such as microcontroller trainers, can improve student learning outcomes[4]. Based on these findings, this study aims to develop a Raspberry Pi-based Control and Programming System Trainer Board as a learning tool at the Surabaya Aviation Polytechnic. This research also aims to understand how to use and operate the trainer board, emphasizing the importance of this research given that no similar trainer board is currently used as a learning tool at the Surabaya Aviation Polytechnic.

2. THEORETICAL FOUNDATIONS

There are several theoretical foundations needed in this research.

2.1 Design and Development

Design or designing is a crucial stage in the development of a system or product, involving a detailed definition of how the system or product will be created and implemented. This process involves several techniques and procedures depending on the type of system or product being developed[5]. According to Pressman (2009), design or designing is a series of procedures for translating the results of analysis and a system into programming languages to describe in detail how the system components are implemented. The design process may also involve the selection of appropriate technologies and tools for system implementation, as well as designing an effective and intuitive user interface. With good design, it is expected that the system or product produced will meet user needs efficiently and effectively, and can be successfully implemented according to the specified requirements.

Meanwhile, the word "build" in the context of "development" is an adjective that describes the activities or actions taken. In this context, "build" refers to the process of creating or constructing a new system, as well as replacing or improving an existing system, whether entirely or partially. This includes creating new systems, updating existing systems, or improving existing systems to enhance their performance. Therefore, "design and build" can be interpreted as an activity to apply or translate the analysis that has been conducted into a software package and to create a system or improve an existing system [6].

2.2 Trainer Board

A trainer board is a model in the form of an object that functions the same as real-world phenomena, created to enhance cognitive and psychomotor abilities in learning through practice-based education[7]. Trainer boards are very helpful in the learning process because they provide students access to conduct a series of experiments, thereby honing their thinking skills. In its use, the trainer board must be tailored to the students to be easily understood

2.3 Control Systems and Programming

A control system is a system for regulating or controlling one or more quantities (variables, parameters) so that they remain at a certain value or within a certain range of values[5]. In other terms, it is also known as control engineering, control systems, or control mechanisms. From an equipment standpoint, a control system consists of various physical components used to direct the flow of energy to a machine or process to achieve the desired performance.

On the other hand, computer programming, commonly referred to as a program, is a series of instructions written to perform specific functions on a computer. Essentially, a computer requires a program to function as a computer, usually by executing a series of program instructions within the processor. A program typically has a specific execution model so that the computer can execute it directly. The same program, in a human-readable code format, is called source code, a format that allows programmers to analyze and study the algorithms used in the program[8].

Source code is compiled by specific programming language tools to produce a program. Another way to execute a program is by using an interpreter, where the source code is directly executed by an interpreter of the programming language used. A computer can run multiple programs simultaneously, and the ability of a computer to run several programs at the same time is called multitasking. Computer programs can be classified according to their function as either system software or application software. There are many programming languages that can be used, such as C, C++, Java, Python, and others. Each language has a different style of usage, leading to different programming styles. This style of programming is commonly referred to as a programming paradigm.

2.4 Python Programming Language

Python is a widely used computer programming language for various purposes, including web development, software creation, data analysis, and task automation. Python is known for its versatility and ease of use, making it a top choice for many developers, including beginners[9]. Python was also the fourth most popular programming language according to the 2022 Stack Overflow developer survey, highlighting its widespread popularity and utility. Python has several advantages that contribute to its popularity, including ease of use, integration with various applications, and a focus on user-friendliness. Python is also frequently used in scripting and automation system development, making it an excellent choice for novice programmers or those new to scripting. Currently, Python code can run on various operating system platforms, including Linux/Unix, Windows, Mac OS X, Java Virtual Machine, Amiga, Palm, and Symbian (for Nokia products).

2.5 Microcontroller

A microcontroller is a small computer packed into a chip known as an IC (Integrated Circuit), designed to perform specific tasks or operations, such as receiving input signals, processing them, and then providing output signals according to the program loaded into the microcontroller[10]. Generally, the input signals for a microcontroller come from sensors, which provide information from the environment, while the output signals are directed to actuators that can perform actions on the environment. Thus, a microcontroller can be simply assumed to be like a brain within a device, capable of interacting with the environment.

2.6 Raspberry Pi

Raspberry Pi is a single-board computer (SBC) the size of a credit card that can be used to run office programs, computer games, and serve as a media player up to high-resolution videos[11]. The Raspberry Pi was developed by the nonprofit Raspberry Pi Foundation with the goal of teaching programming. The programming language for Raspberry Pi is Python, with a Linux operating system, which is widely developed due to its open-source nature. Figure 1 below shows the form of the Raspberry Pi with detailed pinouts. The GPIO pins can be set in software as input or output and used for various purposes.

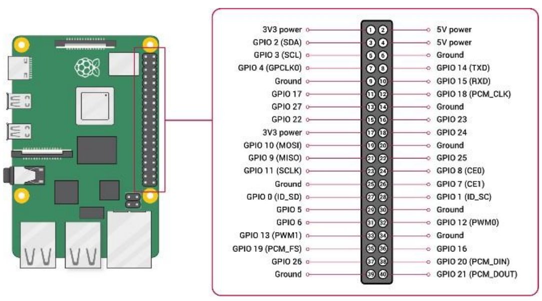

Figure 1 Raspberry Pi Pins

2.7 Sensor

A sensor is an electronic component that functions to convert mechanical, magnetic, thermal, light, and chemical quantities into electrical quantities such as voltage, resistance, and electric current. Sensors are often used for detection during measurement or control processes. In this research, several sensors are used, including a temperature and humidity sensor (DHT11), a light sensor (Light Dependent Resistor), PIR (Passive InfraRed) sensor, Gas Sensor, and an Ultrasonic Sensor.

2.8 Actuator

An actuator is a device that converts control signals into physical movement[12]. In the context of electronics and automation, actuators are often used to drive mechanisms or control other devices based on electronic signals. Examples include electric motors, servo motors, solenoids, and pneumatic or hydraulic actuators. For instance, in this project, a servo motor functions as an actuator that moves mechanical parts according to the signals received from electronic controls. In this research, the actuators used include an LED, relay, servo motor, I2C LCD, Bulb and buzzer.

2.10 Monitor, Keyboard, and Mouse

A monitor, keyboard, and mouse are hardware devices used for a computer or a single-board computer like the Raspberry Pi, which requires this hardware for operation. Therefore, this Raspberry Pi-based learning medium will be equipped with a monitor, keyboard, and mouse to maximize the functionality of the Raspberry Pi as a microcontroller with a Linux operating system and Python programming language. Adding these hardware components, similar to a regular computer, allows for monitoring, analyzing, designing, and integrating all the functions of the Raspberry Pi.

2.11 Raspbian

Raspbian is an operating system equivalent to Windows and is a derivative of Linux. This operating system is specifically designed for the Raspberry Pi, which is often referred to as a mini-computer with various types and features, including the Raspberry Pi 3B. Raspbian supports the Python programming language, which has a structured and simple writing style, making it easy to understand. In addition, Raspbian also has image processing capabilities integrated with the Pi Camera or a webcam. This capability allows Raspbian to be used for various activities, such as surveillance systems and face recognition/detection[13].

2.12 Power Supply

A power supply is a hardware device that provides electrical power to all the components in a computer system or electronic device[14]. Its function is similar to a power adapter, but the power supply in computers is generally more complex and designed to deliver power to various devices within the system unit. One of the main functions of a power supply is to convert electrical voltage from an external power source (usually household electricity) to the voltage required by components within the system, such as the motherboard, processor, and graphics card. Additionally, the power supply is responsible for regulating and maintaining voltage stability to match the device's specifications. The power supply used in this research is 220V AC with adjustable voltage.

2.13 Indicators for Eligibility Testing by Subject Matter Experts

To measure the eligibility of a product as a learning media, several important indicators can be considered. First, ease of use is the main focus, with indicators such as intuitive interface navigation, the availability of clear instructions, and the alignment of information structure with user logic. The supporting theory for this is the Technology Acceptance Model (TAM) proposed by Fred Davis in 1989, which shows that the easier a system is to use, the more likely users will accept and use it.

Next, content quality is crucial, with indicators such as the relevance of material to learning needs, clarity of content, and the connection of material to learning objectives. Constructivism theory in education, developed by figures like Jean Piaget and Lev Vygotsky, emphasizes the importance of relevant content to facilitate students' knowledge construction. Moreover, user engagement is measured through the level of interaction with content, emotional and cognitive involvement, and the appropriateness of challenges to the user's skill level, based on Mihaly Csikszentmihalyi's flow theory, which describes optimal experiences in challenging yet satisfying activities.

Learning effectiveness is also a focus, with indicators of achieving learning objectives, changes in knowledge or skills, and evaluations of understanding or abilities after using the product. Cognitive load theory, from John Sweller, highlights the importance of managing cognitive load so that students can process information effectively. Finally, the sustainability of use is measured through interest in continuing to use the product, intent to recommend it to others, and the alignment of product features with users' long-term needs, based on the TAM, which is also relevant for measuring the sustainability of product use. By considering these indicators, it can be ensured that the evaluation of the product's feasibility as a learning medium is carried out comprehensively based on relevant theories, resulting in a product that effectively enhances the learning experience.

2.14 Indicators for Eligibility Testing by Users

Indicators for product feasibility testing from users are based on various theories proposed by experts in their respective fields. For usability indicators, the theory used is the Usability Model by Jakob Nielsen, introduced in 1993. In his book "Usability Engineering," Nielsen outlines aspects of usability such as ease of use, efficiency, and user satisfaction, as well as heuristics for user interface design.
User satisfaction criteria refer to the User Experience (UX) Honeycomb developed by Peter Morville in 2004. Morville emphasizes the importance of user satisfaction in their overall experience when interacting with a product or service, including aspects of usability and desirability.

For effectiveness, the relevant theory is "Task Performance and Satisfaction in Human-Computer Interaction" by Ben Shneiderman, presented in 1987 in his book "Designing the User Interface: Strategies for Effective Human-Computer Interaction." Shneiderman emphasizes the importance of effectiveness in interface design, measured by users' ability to complete tasks with the help of computer systems.
Efficiency indicators refer to the "Time on Task and Cognitive Load" theory proposed by John Sweller in 1988. Sweller introduced Cognitive Load Theory, which refers to the amount of mental effort used in working memory. Efficiency here is measured by how quickly and efficiently users can complete tasks without excessive cognitive load.

The "Fit between Task and Technology" theory by Izak Benbasat and Ron Weber, presented in 1996, is used for suitability indicators. This theory emphasizes that technology should fit the task requirements to improve performance and effectiveness, measured by how well the product features meet the specific needs of the users.
For security indicators, the theory used is "Principles of Information Security" presented by Michael E. Whitman and Herbert J. Mattord in 2003. In their book, they discuss aspects of information security, including data protection and operational security, with an emphasis on maintaining data confidentiality, integrity, and availability.

Accessibility indicators refer to the Web Content Accessibility Guidelines (WCAG) developed by the World Wide Web Consortium (W3C) first published in 1999. WCAG provides guidelines on making web content more accessible to everyone, including users with special needs, with the latest version released in 2018. Finally, durability indicators refer to the theory of Reliability Engineering by Charles E. Ebeling, introduced in 1997 in his book "An Introduction to Reliability and Maintainability Engineering." Ebeling discusses the concepts of reliability and durability of products, both hardware and software, which refer to the product's ability to function properly over a long period. These indicators provide a solid framework for evaluating product feasibility from the user's perspective, based on theories from experts in their respective fields.

2.15 Research and Development Method Using the 4D Model

The 4D Model is one of the research and development methods. The 4D Model is used to develop learning tools. The 4D Model was developed by S. Thiagarajan, Dorothy S. Semmel, and Melvyn I. Semmel in 1974. As the name implies, the 4D Model consists of four main stages: Define, Design, Develop, and Disseminate[15]. The stages of developing learning tools using the 4D Model are:

Figure 2 4D Model

3. RESEARCH METHOD

This research is expected to facilitate students of the Air Navigation Engineering Study Program at the Surabaya Aviation Polytechnic in understanding the subjects of control systems and programming. The research employs the research and development (R&D) method using the 4D development model, which includes define, design, develop, and disseminate stages. This research and development method is closely related to the field of educational technology.

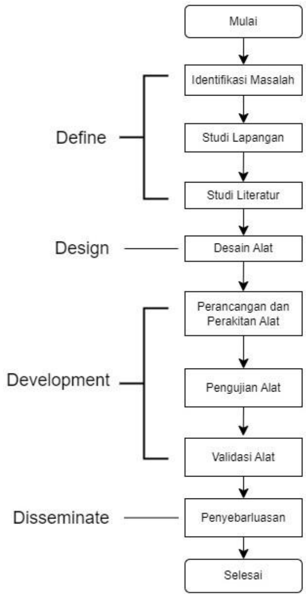

Figure 3 Device Design Flowchart

3.1 Define

In this stage, the following steps will be taken: This stage begins with problem identification through observation and syllabus analysis to gather data and information supporting this research. The observation process involves direct observation of the academic environment and an in-depth analysis of the syllabus used in the related study program. Accurate and comprehensive problem identification enables researchers to understand the specific context and needs that must be addressed in this research.

Field studies are conducted by interviewing several lecturers who have extensive experience and knowledge in relevant fields. These interviews aim to explore practical insights, perspectives, and challenges faced in implementing the current syllabus. Through these interviews, researchers can obtain rich and relevant qualitative data, which will be an essential foundation in formulating effective solutions based on real-world conditions.

A literature study is conducted to review previous research related to this topic and can be used as a reference for conducting this research. By examining various scientific sources, such as journals, books, and research reports, researchers can build a strong theoretical foundation and identify methods and approaches that have proven effective. This literature study also helps avoid research duplication and opens up opportunities to develop new innovations based on findings and recommendations from previous research.

3.2 Design

Creating a block diagram design is the initial step in the system design process. At this stage, the system's main components are identified and structurally arranged to provide an overview of how the system will function. Block diagrams help visualize the relationships between components, such as sensors, microcontrollers, and actuators. Having a clear block diagram allows a better understanding of the interconnections and interdependencies among system parts, ensuring that each component works harmoniously to achieve the end goal.

Additionally, the layout arrangement used on the Trainer Board is an important step to ensure that all components are placed efficiently and organized. This layout should consider accessibility, safety, and ease of use. Each component must be placed so that it is easy to access for testing and maintenance and avoids potential conflicts or interference between components. A good layout also helps minimize cable lengths and signal paths, improving system reliability and reducing electromagnetic interference. The following Figure 4 is the layout design of the Raspberry Pi-based control and programming system trainer board.

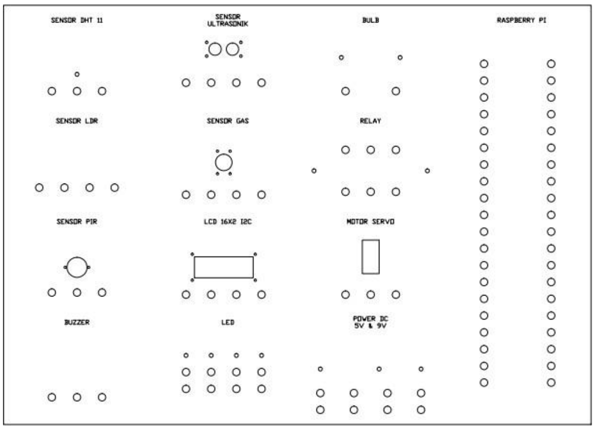

Figure 4 Trainer Board Layout

Creating a jobsheet and work instructions is the final step in the system development process. The jobsheet contains step-by-step guides on how to assemble and operate the trainer board. Work instructions must be written clearly and in detail, covering every aspect of the process, from initial setup to troubleshooting potential problems. These jobsheets and work instructions are important not only to ensure that everyone involved in the project has the same understanding of how the system should function but also serve as official documentation that can be used for future training and reference.

3.3 Development

The development stage involves creating and assembling tools; components gathered during the analysis and design stages are purchased and assembled according to the created design. A detailed cost breakdown in the trainer board assembly at this stage will be made to ensure that all financial needs required to conduct the research are identified and well-planned. Each component, such as sensors, microcontrollers, and actuators, is connected and arranged based on a pre-determined scheme. The assembly process requires precision to ensure that all components are installed correctly and meet specified specifications. Additionally, the arrangement of components must consider aspects of safety and ease of access for future maintenance.

After assembly, the tool testing phase is conducted to ensure that each part of the system functions as expected. This testing includes running various experiments and operational scenarios to check the tool's performance under different conditions. Every test result is recorded and analyzed to detect errors or discrepancies. If problems are found, repairs and retests are conducted until all components and tool functions work well and align with the initial design.

The final stage is tool validation, where the tested and proven tool is validated by subject matter expert lecturers at Surabaya Aviation Polytechnic. This validation aims to ensure that the tool functions well technically and meets the standards and needs in terms of its use. The subject matter experts will check whether the tool aligns with the intended learning or research objectives. This validation process ensures that the tool is suitable for use in the intended context and can provide maximum benefit to users.

3.4Dissemination

At this stage, the validated learning media are distributed to cadets of the Air Telecommunications and Navigation Engineering Study Program as users. User feasibility assessment questionnaires will be distributed. Additionally, dissemination can be conducted by writing articles about the tool and its usage. Proper dissemination will help others understand how to use and operate this trainer board.

4. RESULT

4.1 Define

The initial step in a project is to understand and clarify the problem or need that must be addressed. This stage involves needs analysis and information gathering. Referring to the curriculum of the Air Navigation Technology (TNU) diploma program of the Ministry of

Transportation, 2020, SK No. 177/BPSDMP-2020, for the control systems and programming course, there are course learning outcomes (CLOs) that include the ability to explain and perform programming of control devices and computer applications based on programs. More specifically, the sub-course learning outcomes (Sub-CLOs) state that students can explain and design devices with microcontrollers and can explain and design computer applications using programming languages (Visual Basic/C++/Java/Python/PHP). Based on this curriculum, the author analyzes the need to design a Raspberry Pi-based control system and programming trainer board as a learning medium at Surabaya Aviation Polytechnic.

To complete the necessary requirements, the author conducts interviews with several lecturers who have expertise in control systems and programming. These interviews yield data that will be used in the design process, where a trainer board requires input, a microcontroller, and output (actuators). The microcontroller used is the Raspberry Pi because currently, there is no Raspberry Pi-based trainer board available in the laboratory of the Air Navigation Technology study program. Temperature and humidity sensors, PIR sensors, ultrasonic sensors, gas sensors, and light sensors are the inputs used on the trainer board. These inputs focus on the needs for automation and smart building applications. Additionally, outputs include lights controlled using relays for switching, a servo motor for mechanical output needs, and an LCD for monitoring.

An LCD is the easiest display medium to observe because it produces a good and sufficient number of characters. A 16×2 LCD can display 32 characters, with 16 characters on the top row and 16 characters on the bottom row. A 16×2 LCD typically uses 16 pins for control, which can be quite inefficient if all 16 pins are used. Therefore, a special driver is used so that the LCD can be controlled with the I2C bus. Through I2C, the LCD can be controlled using just two pins, SDA and SCL.

In this trainer board, the practical exercises do not start with complex programming because learning should start from the basics. Therefore, several LEDs are included for initial programming practice. In programming, LEDs can be controlled in various modes, starting with the simplest, such as blinking LEDs, LEDs blinking alternately, and other variations. Therefore, the author has added LEDs as an initial learning step using a Raspberry Pi-based trainer board. Additionally, this trainer board will include an external DC power supply to supply DC voltage to the input equipment, ensuring that the DC input on the Raspberry Pi used is not easily damaged.

4.2 Design

Design is the product design stage. Tool design can begin by focusing on the selection of components to be used, software installation for the Raspberry Pi, and considering the tool's performance. In this research, this is done by designing the connection scheme between the hardware and software used. Below are the hardware and software components needed for this research.

The following is a list of materials needed for hardware components: Raspberry Pi 3 B+, Micro SD, Micro SD Adapter, Laptop, Micro USB Cable, LAN Cable, HDMI Cable, Monitor, Keyboard, Mouse, PIR Sensor, Light Sensor, Temperature and Humidity Sensor, LED, LCD with I2C, Banana Jack Jumper Cable, Bulb and Fitting, Banana Jack, Wire, Relay, Ultrasonic Sensor, Gas Sensor, 12VDC DC Source Power Supply, Buzzer, LM2596 DC Adjustable, and MCB. These components play a vital role in ensuring all aspects of the system can function properly. The Raspberry Pi 3 B+ will act as the main control center, while various sensors such as PIR, light, temperature, humidity, ultrasonic, and gas sensors will provide the necessary data for system operations. Various adapters and cables will connect all these hardware devices, while LEDs, LCDs, and I2C are used for output (actuators).

In addition to these materials, some supporting equipment is also required to assemble and operate the system efficiently. This equipment includes an Acrylic Cutting Machine, Acrylic, Drill, Drill Bits, Solder, and Screwdriver. The Acrylic Cutting Machine and acrylic are used to create casings or supports for hardware components, while the drill and drill bits are useful for making mounting holes. A soldering iron is needed to connect electronic components, and a screwdriver to tighten various connections. With this supporting equipment, the system assembly and maintenance process will be easier and more efficient, allowing the entire system to function optimally.

This Raspberry Pi-based trainer board uses acrylic to integrate it with banana jacks for simple jumper connections. Its construction requires equipment like a cutting machine or drill with drill bits, wire, electrical tape, soldering iron, and tin solder, among others. The trainer board uses black acrylic as it is less prone to dirt and easier to clean, requiring no special maintenance.

The software used is Raspbian. Raspbian is a Linux-based operating system specifically designed for Raspberry Pi single-board computers. It is built on the Debian Linux distribution and provides an optimal environment for Raspberry Pi hardware. Raspbian includes various programming tools and software that support learning, experimentation, and Raspberry Pi-based project development

4.3 Development

At this stage, the Raspberry Pi-based trainer board will be developed according to the previous design plan, which involves installing Raspbian software on the Raspberry Pi. Additionally, the trainer board has dimensions of 70x50x15 cm and serves as a medium for integrating components and connecting each module pin with banana jacks to ensure proper connectivity. All components will be carefully assembled to ensure that the trainer board can function optimally, in line with the initial design objectives. The total cost for the construction is IDR 2,375,148.

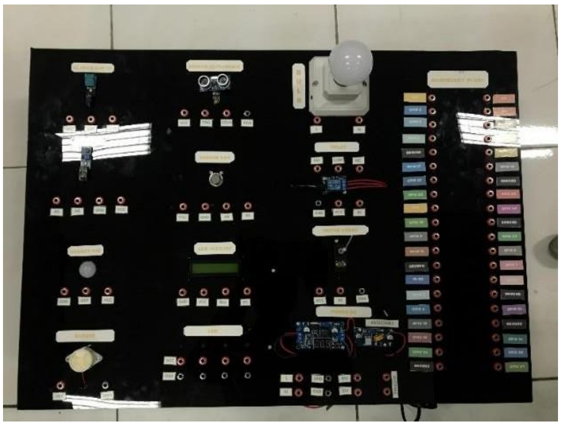

Figure 5 Raspberry Pi-based Trainer Board

After assembling all the components, testing is conducted on each module, including sensors, microcontrollers, and actuators, to ensure they perform their functions. Successful test results indicate that the system is ready to be used as a reliable learning tool that supports the teaching process for control systems and programming based on Raspberry Pi.

4.4 Dissemination

Disseminate is the stage of distributing the developed product. In this stage, validation tests are conducted with subject matter expert lecturers, and feasibility assessments are carried out by distributing questionnaires to students as users. The results of the validation by the subject matter expert lecturers received a score of 76%, which falls under the category of "highly feasible," with assessment indicators including ease of use, content quality, optimal experience in learning activities, learning effectiveness, and sustainability of use, and notes that it can be used as research material. Additionally, the feasibility assessment results by students received a score of 91%, also categorized as highly eligible.

5. CONCLUSION

Based on the research conducted, the following conclusions can be drawn:

1. The Raspberry Pi-based trainer board as a learning tool at the Surabaya Aviation Polytechnic was successfully designed using a Raspberry Pi 3B+ microcontroller with ultrasonic sensors, DHT11 sensors, LDR sensors, gas sensors, PIR sensors, and several actuators, including bulbs, LEDs, I2C LCDs, servo motors, relays, and buzzers. This design utilized the 4D method, consisting of Define, Design, Development, and Dissemination stages.

2. The Raspberry Pi-based trainer board as a learning tool at the Surabaya Aviation Polytechnic was designed using a Raspberry Pi 3B+ microcontroller with ultrasonic sensors, DHT11 sensors, LDR sensors, gas sensors, PIR sensors, and several actuators, including bulbs, LEDs, I2C LCDs, servo motors, relays, and buzzers. This trainer board is equipped with a mouse, keyboard, and monitor to run the program.

3. Validation results by subject matter experts showed a score of 76%, categorized as highly feasible, with the note that this tool can be used for further research. Additionally, assessments by the students yielded a score of 93.5%, also categorized as highly feasible. These figures indicate that the developed tool not only meets quality standards in terms of content but is also very well received by the end users, namely the students. This shows that the tool has great potential for effective use in learning at the Surabaya Aviation Polytechnic.

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