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Design and Development a Learning Media for Dialyzer Reprocessing System Based on Arduino

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ABSTRACT

This study aims to design an Arduino-based learning media simulating the Dialyzer Reprocessing System as an educational tool for Electromedical Engineering students. The media is developed to simulate the reprocessing steps of a dialyzer, including cleaning, rinsing, and sterilization, which are typically performed in hemodialysis procedures. The system is built using an Arduino Mega 2560 microcontroller, a DS18B20 temperature sensor, three water pumps, a 20x4 LCD module, and three push buttons as user input controls.The testing methods used in this study include functional testing (black box), material expert validation, and media expert validation. The results of the functional test show that all components operate properly as designed. The temperature sensor accurately reads the liquid temperature in real time and displays the result on the LCD. Product validation was carried out by three material experts and three media experts. The validation results showed a feasibility score of 100.00% from material experts and 90.00% from media experts, both categorized as "Highly Feasible" based on Arikunto's (2009) criteria.In conclusion, the Arduino- based Dialyzer Reprocessing System learning media is highly effective and feasible for use as a practical educational tool in Electromedical Engineering learning and vocational training environments.

Keywords:
Arduino , Dialyzer , Learning Media, Reprocessing , Validation .

الملخص:

تهدف هذه الدراسة إلى تصميم وسائط تعليمية قائمة على أردوينو تُحاكي نظام إعادة معالجة جهاز غسيل الكلى كأداة تعليمية لطلاب الهندسة الطبية الكهربائية. طُوّرت الوسائط لمحاكاة خطوات إعادة معالجة جهاز غسيل الكلى، بما في ذلك التنظيف والشطف والتعقيم، والتي تُجرى عادةً في إجراءات غسيل الكلى. بُني النظام باستخدام متحكم أردوينو ميجا **2560**، ومستشعر درجة حرارة **DS18B20**، وثلاث مضخات مياه، ووحدة شاشة **LCD** مقاس **20×4**، وثلاثة أزرار ضغط كعناصر تحكم لإدخال المستخدم. تشمل طرق الاختبار المستخدمة في هذه الدراسة الاختبار الوظيفي (الصندوق الأسود)، والتحقق من صحة خبير المواد، والتحقق من صحة خبير الوسائط. تُظهر نتائج الاختبار الوظيفي أن جميع المكونات تعمل بشكل صحيح كما هو مُصمم. يقرأ مستشعر درجة الحرارة درجة حرارة السائل بدقة في الوقت الفعلي ويعرض النتيجة على شاشة **LCD**. تم التحقق من صحة المنتج من قِبل ثلاثة خبراء في المواد وثلاثة خبراء في الوسائط. أظهرت نتائج التحقق درجة جدوى بنسبة **100.00**٪ من خبراء المواد و **90.00**٪ من خبراء الوسائط، وكلاهما مصنف على أنه "ممكن للغاية" استنادًا إلى معايير **Arikunto** (2009). وفي الختام، فإن وسائط التعلم الخاصة بنظام إعادة معالجة الغسيل الكلوي المستند إلى **Arduino** فعالة للغاية وممكنة للاستخدام كأداة تعليمية عملية في بيئات التعلم والتدريب المهني للهندسة الطبية الكهربائية.

الكلمات المفتاحية: أردوينو، جهاز التحليل، وسائط التعلم، إعادة المعالجة، التحقق.

Design and Development a Learning Media for Dialyzer Reprocessing System Based on Arduino

I. INTRODUCTION

Hemodialysis is a kidney replacement therapy that filters metabolic waste and excess fluid from the blood of patients with chronic kidney failure. A vital component of this procedure is the dialyzer, which can be reused after undergoing a reprocessing process—cleaning, rinsing, sterilization, and membrane leak testing—before being reused on the same patient.[1] Substandard reprocessing can pose a risk of cross-infection, allergic reactions, and even poisoning due to residual sterilization chemicals.[2]

In vocational education, learning about dialyzer reprocessing is crucial to equip electromedical students with an understanding of sterility, device validation, and infection control principles, as stipulated in the 2017 Indonesian Ministry of Health and the 2016 WHO regulations. However, limited costs and access to authentic hemodialysis equipment drive the need for alternative learning media. Therefore, The use of microcontroller technology such as Arduino is considered effective and affordable for simulating a dialyzer reprocessing system in a practical manner.[3]

The design of this Arduino-based learning media is expected to improve students' understanding of technical aspects and patient safety, while also serving as an educational solution for mastering electromedical skills.

Problem Formulation

Based on the above background, the researcher is interested in conducting a study entitled "Design and Construction of Arduino-Based Dialyzer Reprocessing System Learning Media."

II. PREVIOUS STUDIES

There have been some studies that have investigated the application of Arduino system technology for the haemodialysis process. For instance, Aminah A. Sulayman et al. (2024) Arduino Microcontroller-Based Real-time Monitoring of Haemodialysis Process for Patients with Kidney Disease. They showed that Arduino microcontrollers can be used for the remote online monitoring of the haemodialysis process using the combined functionality of temperature, conductivity, and weight measurement. This research contributes to the development of healthcare technology but not specifically for the purposes of simulating haemodialysis. Nonetheless, these research results confirm the reliability of the Arduino microcontroller system for use in simulating the reprocessing system for the dialyzer in the field of vocational training for the healthcare industry[4].Additionally, there is another research that does not directly relate to the reprocessing of the dialyzer but is significant from the point of view of this research. There have been many researchers and engineers who have contributed to enhancing the safety of patients during hemodialysis through Arduino-guided monitoring systems. [M. Marin, C. Roșu, F. B. Marin (2024). An Intelligent System Based on Arduino for Blood Leakage Detection during Haemodialysis] proposed the design of an intelligent blood leakage detection system using the Arduino Nano board with photoelectric sensors and the IoT model for data communication. This research article showed how the Arduino microcontroller can efficiently ensure safety-related systems in the field of hemodialysis. Technological progress helps researchers develop Arduino-guided educational content for simulating critical hemodialysis operations. [5]

III. RESEARCH METHOD

This study employed a Research and Development (R&D) method with a quantitative approach, as described by Sugiyono (2015) .[6] The aim was to design and test Arduino-based Dialyzer Reprocessing System learning media. The prototype was developed using an Arduino Mega 2560, a DS18B20 temperature sensor, three water pumps, a relay module, a 20x4 LCD, and push buttons as input. Testing was conducted using the black-box testing method to ensure the cleaning, rinsing, sterilization, and temperature reading functions worked as designed. Validation was conducted by subject matter and media experts to assess the appropriateness of the content, display, and effectiveness of the media in supporting the learning of electromedical engineering students. The conceptual framework of this research is shown in Figure 1.

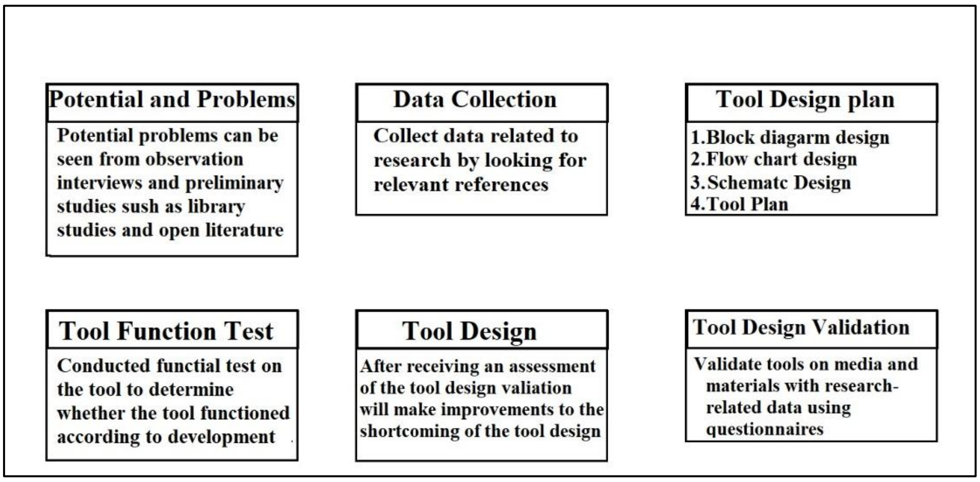

Figure 1. Research Conceptual Framework

For designing the block diagram shown in Figure 2.

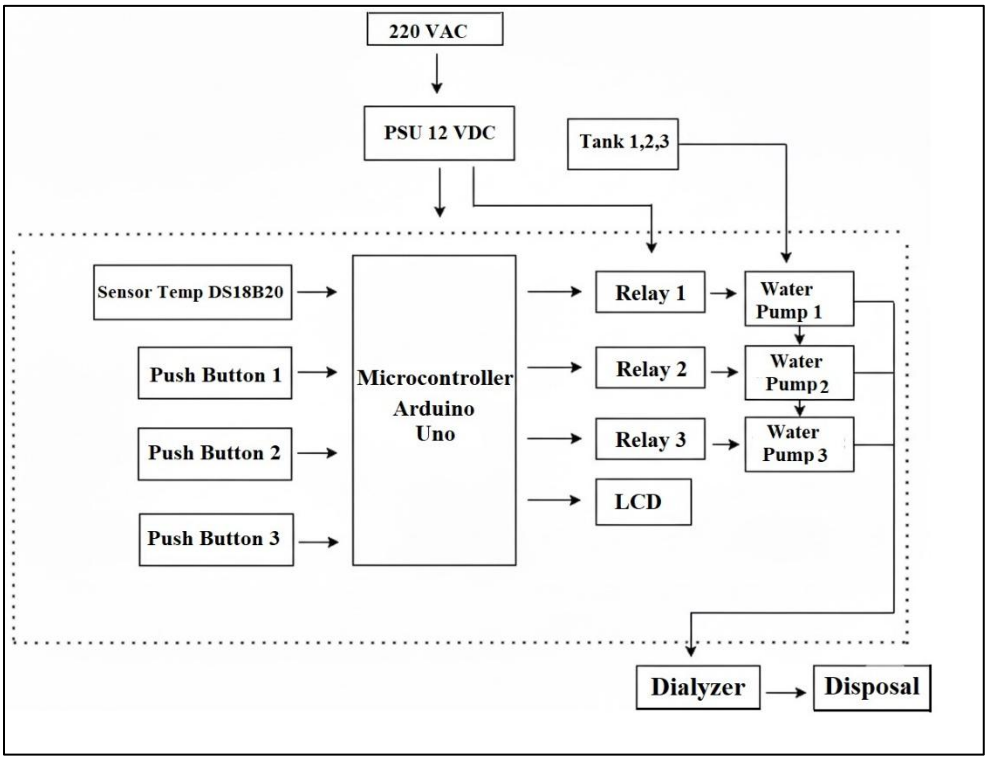

Figure 2: Tool Block Diagram

Based on the flowchart in Figure 3, the flowchart explains the workflow of the Start tool, then enters the System Initialization stage, where the Arduino, sensors, pumps, and other components are activated and prepared for operation. Next, the system faces a logical decision to determine whether to run the Wash + Sterilization process or just Rinse. If the Wash + Sterilization process is selected, the system will run a thorough cleaning and sterilization stage of the dialyzer before entering the Reprocessing Process stage. Alternatively, if Rinse is selected, the system goes directly to the Reprocessing stage after the rinsing is complete. After the reprocessing process is carried out, the system will check the reprocessing results. If the results meet standards, the system will provide a notification that the reprocessing was successful and the process is declared complete. However, if the process fails, the system will display a failure notification, and the user will be directed to check the condition of the tool. After checking and repairs, the system can return to the initialization stage to restart the process. This flowchart shows the flow of system automation that not only runs the main process but also equipped with decision-making logic and error management.

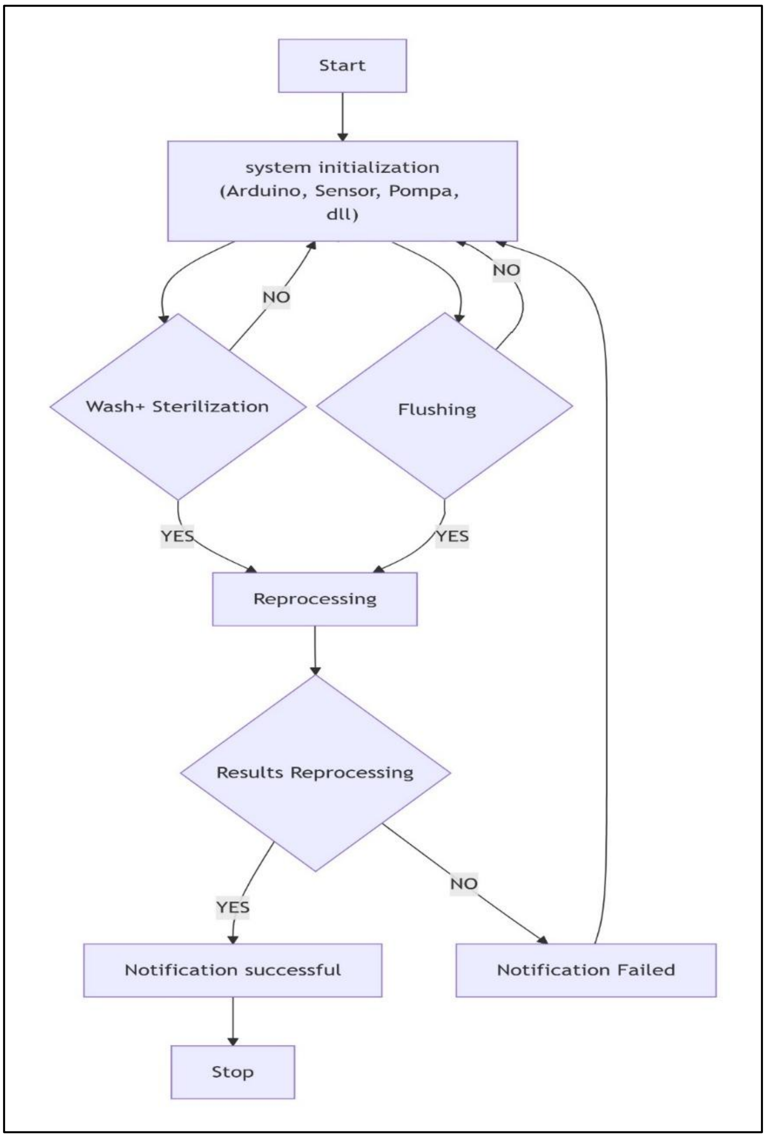

Figure 3: Tool Flowchart

IV. FIGURES OF DESIGN AND CONSTRUCTION OF ARDUINO-BASED DIALYZER REPROCESSING SYSTEM LEARNING MEDIA

Modification of Narcotics Storage Cabinet with RFID-Based Security System and Biometric Technology using several components, namely Arduino UNO, DS18B20, Solenoid Valve, Power Supply, LCD 20x4, and Relay.The product image shown in Figure 4 demonstrates the complete development of the tool and represents the physical implementation of the tool from the front and back.

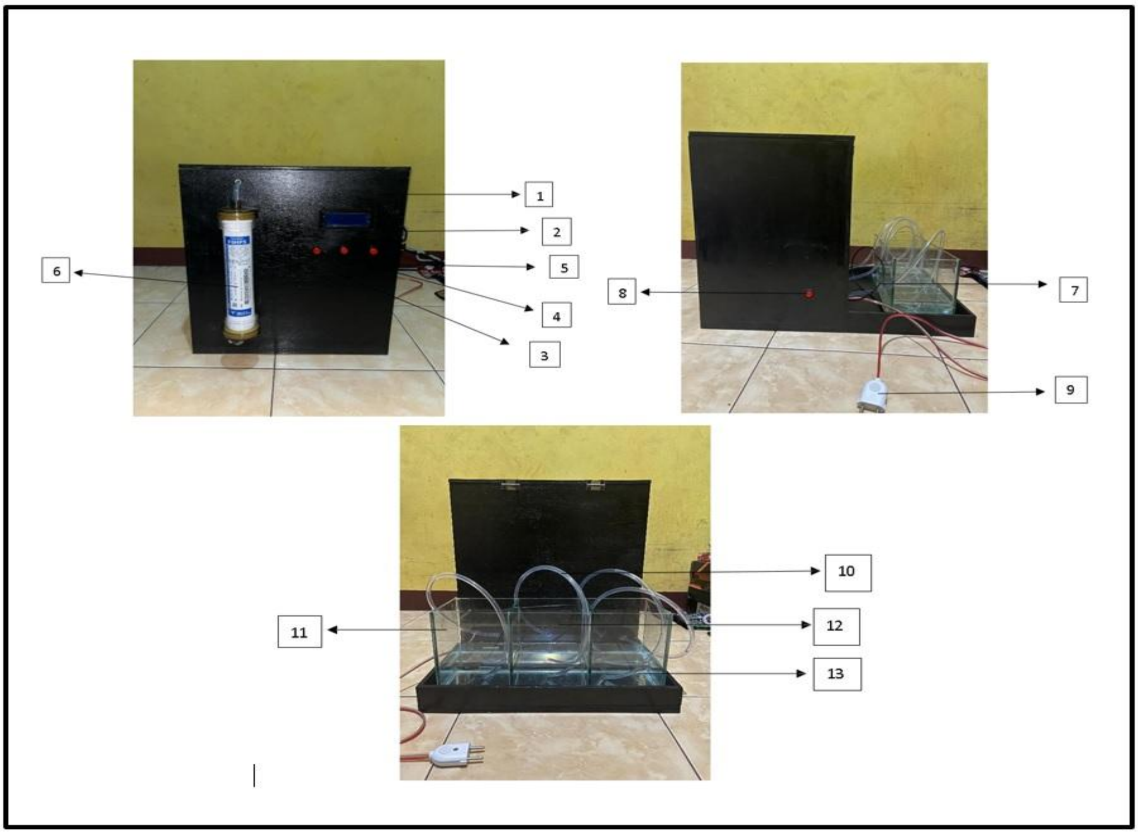

Figure 4: Implementation of "Design and Construction of Arduino-Based Dialyzer Reprocessing System Learning Media

The following is a description of figure 4:

1. The device's casing protects the electronic components (Arduino, sensors, pumps, and other actuators) from dust, water, and physical impact.
2. The 20x4 LCD serves as the main interface for displaying system information to the user.
3. Push Button 1 serves as a momentary switch to start the cycle in cleaning mode.
4. Push Button 2 serves as a momentary switch to start the cycle in rinsing mode.
5. Push Button 3 serves as a momentary switch to start the cycle in sterilization mode.
6. The dialyzer is the main part of the hemodialysis machine, functioning as an artificial kidney to filter waste and excess fluid from the blood.
7. The DS18B220 sensor measures the temperature of the fluid.
8. The on/off switch functions to turn the device on/off.
9. The power cable provides electrical power to all components in the device.
10. The hose delivers fluid to the dialyzer.
11. The cleaning tank supplies fluid for cleaning.

12. The Rinsing Tank serves to provide fluid for rinsing.
13. The Sterilization Tank serves to provide fluid for sterilization.

V. RESULTS

1. Software Testing Results

Software testing is conducted using the black-box method, which refers to the evaluation of the functional requirements of the software to ensure that the application program produces output that meets expectations and fulfills its intended function. In this testing, the focus is on the developer conducting functional testing. The software testing results can be seen as below. Testing a 20x4 I2C Liquid Crystal Display (LCD) using the Arduino IDE shown in figure 5.

```
// === INISIALISASI SENSOR & LCD ===

OneWire oneWire(ONE_WIRE_BUS);

DallasTemperature sensors(&oneWire);

LiquidCrystal_I2C lcd(0x27, 20, 4);


void tampilkanMenu() {

  lcd.clear();

  // Suhu tetap tampil di baris 0 (akan di-refresh di
loop)

  printCenter(1, "1. Pembersihan");

  printCenter(2, "2. Pembilasan");

  printCenter(3, "3. Sterilisasi");
```

Figure 5: Application View of Testing a 20x4 I2C Liquid Crystal Display (LCD) using the Arduino IDE

Expected Results is Liquid Crystal Display (LCD) I2C 20x4 can be run through Arduino IDE .. the conclusion is [√]Succeed. Testing a DS18B20 sensor shown in figure 6.

```
#include <OneWire.h>
#include <DallasTemperature.h>

// === INISIALISASI SENSOR & LCD ===
OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);
LiquidCrystal_I2C lcd(0x27, 20, 4);


// === TIMER & STATUS ===
unsigned long startTime = 0;
const unsigned long duration = 300000; // 5 menit
bool timerActive = false;
int currentRelay = 0;
bool menuTampil = false;
}
```

Figure 5: Application View of Testing a DS18B20 sensor

Expected Results is The DS18B20 sensor can be run through the Arduino. The conclusion is **[√]Succeed**

2. Power Supply Testing

A power supply is a device that supplies electrical power by converting alternating current voltage to direct current, which is then distributed to other components.

Table 1: Power Supply Test Results

Measurement of the	Expected Voltage (Volts)	Rated Voltage (Volts)	*Error*	*Error* (%)
1	12V	12,22V	0,22	0,01%
2	12V	12,22V	0.22	0,01%
3	12V	12,24V	0,24	0,02%
4	12V	12,24V	0,24	0,02%
5	12V	12,24V	0,24	0,02%
6	12V	12,24V	0,24	0,02%
7	12V	12,24V	0,24	0,02%
8	12V	12,24V	0,24	0,02%
9	12V	12,24V	0,24	0,02%
10	12V	12,24V	0, 24	0,02%

[redacted]		
1.	Average voltage measurement	12.24 V
2.	Error	0,24
3.	Accuracy/Error(%)	0,02%

Source (Personal Documentation, 2025)

Based on the test results, the average output voltage measurement was 12.24 VDC. The measurement error value was 0.24 VDC with an error accuracy of 0.02%.

3. Testing Arduino UNO

The purpose of testing the Arduino UNO is to determine the output voltage on the pins used. If 5 VDC is detected at the output during the test, the test is considered successful. If the result exceeds the tolerance limit, it can damage the Arduino microcontroller. The test results are listed in Table 2.

Table 2 Arduino UNO Test Results

Measurement of the	Expected Voltage (Volts)	Rated Voltage (Volts)	*Error*	*Error* (%)
1	5V	5,050V	0,005	0,01%
2	5V	5,050V	0,005	0,01%
3	5V	5,050V	0,005	0,01%
4	5V	5,050V	0,005	0,01%
5	5V	5,050V	0,005	0,01%
6	5V	5,050V	0,005	0,01%
7	5V	5,050V	0,005	0,01%
8	5V	5,050V	0,005	0,01%
9	5V	5,050V	0,005	0,01%
10	5V	5,050V	0,005	0,01%

[redacted]		
1.	Average voltage measurement	5,050V
2.	Error	0,005
3.	Accuracy/Error(%)	0,01%

The average output voltage measurement is 5.050V VDC. The measurement error value is 0.005 VDC with an error accuracy of 0.01%.

4. Water Pump Testing

Water pump testing is carried out to ensure whether the water pump can function properly or not according to its specifications, namely 12 VDC.

Table 3 Water Pump Test Results

Testing of the	Expected Voltage (Volts)	Measured Voltage (Volts)	Error	Error (%)
1	12V	12.00 V	0	0%
2	12V	12.00 V	0	0%
3	12V	12.00 V	0	0%
4	12V	12.00 V	0	0%
5	12V	12.00 V	0	0%
6	12V	12.00 V	0	0%
7	12V	12.00 V	0	0%
8	12V	12.00 V	0	0%
9	12V	12.00 V	0	0%

10	12V	12.00 V	0	0%
[redacted]				
1	Average Voltage Measurement			12.00 V
2	Error			0
3	Percentage Error %			0%

Source (Personal Documentation, 2025)

The results of the Water Pump test and the results of the Water Pump output voltage measurements in Table 4 show that the average output voltage measurement is 12.00 VDC. The measurement error value is 0 VDC with an error accuracy of 0%.

5. DS18B20 Sensor Testing

Testing was conducted to ensure the DS18B20 temperature sensor functioned properly in reading the fluid temperature in the system. The temperature readings were displayed on a 20x4 LCD screen and compared with a digital thermometer for comparison. Detailed test results are shown in the table below, which can be seen in Table 4 below.

Table 4: DS18B20 Sensor Test Results

Testing of the	Measurement Results Using a Thermometer (°C)	Measured Temperature (°C)	Error	Error (%)
1	30.2°C	30.1°C	0,1	0.003%
2	30.2°C	30.1°C	0.1	0.003%
3	30.2°C	30.1°C	0,1	0.003%
4	30.2°C	30.1°C	0,1	0.003%
5	30.2°C	30.1°C	0,1	0.003%
6	30.2°C	30.1°C	0,1	0.003%
7	30.2°C	30.1°C	0,1	0.003%
8	29.7 °C	29.6 °C	0,1	0.003%
9	29.7 °C	29.6 °C	0,1	0.003%
10	29.7 °C	29.6 °C	0,1	0.003%
[redacted]				
1	Average Voltage Measurement			30.2°C
2	Error			0,1
3	Percentage Error %D			0.003%

Source (Personal Documentation, 2025)

The average temperature measurement obtained was 30.1°C. The measurement error value was 0.1°C with an error accuracy of 0.003%.

VI. CONCLUSION

Based on the research results, it can be concluded that the Arduino-based Dialyzer Reprocessing System learning media was successfully designed and developed in accordance with the proposed problem formulation. This prototype is able to simulate the process of cleaning, rinsing, and sterilizing the dialyzer automatically with the support of Arduino Mega 2560 components, DS18B20 temperature sensor, three water pumps, relays, push buttons, and a 20x4 LCD as an information display. The results of black-box testing showed that all components functioned well, indicated by accurate temperature readings and the pump workflow according to the design. The validation of the material expert gave a score of 100% and the media expert 90% with the category of "very feasible", so this media is considered effective as an educational tool in improving the understanding of electro medical engineering students regarding the principles of dialyzer reprocessing.

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