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East Africa's Center of Excellence in Biomedical Engineering and E-Health (CEBE)

Master's Degree Program in Biomedical Engineer

Title: DESIGN AND PROTOTYPING A SMART WEARABLE SYSTEM TO MONITOR TEMPERATURE AND RESPIRATION RATE FOR TODDLERS. CASE STUDY MUHIMA HOSPITAL.

A Dissertation Submitted to the Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE), University of Rwanda as partial fulfilment of the requirements for the master's degree in biomedical engineering.

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Declaration

I, NYIRAHABINEZA Marie Louise, declare that this dissertation entitled “**Design and prototyping a smart wearable system to monitor temperature and respiration rate for toddlers**” is my original work based on research and prototype and has not been submitted for any other degree or professional qualification.

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CERTIFICATE

This is to certify that the project entitled “**Design and prototyping a smart wearable system to monitor temperature and respiration rate for toddlers**” is a record of original work done by NYIRAHABINEZA Marie Louise (Reference number: **222001115**), a MSc. Degree student in Biomedical Engineering.

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ABSTRACT.

This research project aims to design and prototype a smart wearable system to monitor temperature and respiration rate for under three years in Rwanda. The project will highlight some health problems faced by under three-year-old children including diseases like malaria, pneumonia and different infectious diseases which lead to mortality for under three-year-old babies in Rwanda. Most of the highlighted diseases are characterized by high fever and difficulties in breathing. In this work, a smart wearable device which integrates both temperature and respiration rate monitoring was designed and prototyped to be worn by the child. The suggested solution will use the wearable device that will monitor and communicate to the parent or caregivers in case of abnormal temperature or breathing difficulties. The system will communicate immediately via SMS alert so that the parent or healthcare giver brings the child to healthcare institutions in the early stage of the disease. The system is composed of body temperature sensor, respiration rate sensor, micro-controller, the GSM module, and the mobile phone.

Keywords: Arduino Uno; Cloud, GSM module, Body temperature sensor, respiration rate sensor.

LIST OF ACRONYMS

GSM: Global System for Mobile communication

SMS: Short Messaging Service

ADC: Analog to Digital Converter

SDA: Serial Data
SCL: Serial Clock
SDGs: Sustainable Development Goals
SIDS: Sudden Infants Death Syndrome
MCU: Microcontroller unit
Wi-Fi: Wireless Fidelity
STM32:ST Microelectronics 32 bits
IDE: Integrated Development Environment
MEMS: Micro Electromechanical Systems
BTMS: Baby Temperature Monitoring System
FTDI: Future Technology Devices International Limited
AC: Alternating Current
DC: Direct Current
FOW: Field of View
USB: Universal Serial Bus
LCD: Liquid Crystal Display
ICSP: In Circuit Serial Programming
EEPROM: Electronic Erasable Programmable Read Only Memory
ECG: Electrocardiogram

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CHAPTER 1: GENERAL INTRODUCTION

1. 1. Introduction

Rwanda is among countries who adopted the United Nations Sustainable Development Goals (SDGs). Goal three of the SDGs aims to improve maternal and child health outcomes. It is for that reason Rwanda's health sector tries to reduce the number of children dying under 3 years old. Even if different strategies took place in Rwanda, according to the Rwanda vital statistics report of 2020, the under three years' mortality rate was 37.1/1000 which is far from the SDGS target in 2030 [1].

Major causes of death among children vary by age. Children under 3 years old are especially vulnerable to infectious diseases like malaria, pneumonia, tuberculosis, and blood infections when not treated in early stages [2]. The main symptoms of the above infectious disease are high fever and difficulties in breathing [3]. Monitoring and taking care of children to detect those symptoms at an early stage becomes difficult for parents who also need a very big number of working hours.

Due to advanced technology, children under three years old need more care to reduce the risk of losing lives. One of the solutions that will help parents to take care of their babies and work long hours at the same time is by using remote communication and monitoring. The smart wearable system to monitor temperature and respiration rate will facilitate the remote monitoring and control of children' s vital signs, especially respiration rate and body temperature. If the rate of respiration exceeds the threshold values of a normal child, the system will send an alert message via GSM to parents and caregivers to quickly notify health care institutions. The system is composed of sensors, Arduino Uno as microcontroller that process the data from sensors and notifies the parent via GSM in case of abnormal sensor input.

1.2 PROBLEM STATEMENT

As referred to in the vital statistics report of Rwanda in 2020, the under three years' mortality rate is still at a high level compared to the target of SDGS [1]. Even if Rwanda Government provides all necessary facilities to eradicate the number of under three years dying children, as of

now, many parents are working far away from their homes and from that, it poses the following problems in toddlers:

- **Difficult in monitoring the health status for the parent.**
- **No health status information sharing between caregiver and parent in case there is abnormal detection.**
- **It is impossible to get the health status of the toddlers without taking consultation from nurses or doctors.**

After getting those problems from the community, the motive is to design and implement the smart wearable system that monitors temperature and respiration rate for children under three years old. This will connect the child and his parents remotely.

1.3. AIMS AND OBJECTIVES

1.3.1. AIMS

The aim of this project is to help in the reduction of the number of under three years old children being killed by infectious diseases which are not treated early due to lack of communication between children and their parents or caregivers. The caregivers or family members will see the notification alert via SMS that notifies the early stage of diseases.

1.3.2. General objective

The general objective of this project is to design and prototyping a smart wearable system to monitor temperature and respiration rate for toddlers in Rwanda.

1.3.3 Specific objectives

- To investigate deeply all problems faced by toddlers and provide the adequate solution.
- To design a system that monitors the temperature and respiration rate using temperature and oxygen sensors.
- To provide alert notification through SMS to the parents and to the caregivers once there is abnormal detection.

1.4 Research Questions

- How can we deeply investigate problems faced by toddlers and provide an adequate solution?

- b. Is there a designed system that monitors the temperature and respiration rate using temperature and oxygen sensors?
- c. Which technologies can be used to alert SMS to the parents?

1.5 Scope of the study

This study will be done with much focus on urban communities of Rwanda data will be collected from conveniently selected child mothers. On behalf of the operationalization of the system, it utilizes the microcontroller ATMEGA 328 to receive the signal from the sensors (DHT11 & oxygen breather sensors) and, therefore. It provides the output to the display and GSM for alerting. Moreover, the message alert must be given to the parent of the toddler as well as to the caregiver in case there is an abnormal detection made for both temperature and respiration rate. For temperature done by considering the body temperature rise, whereas the respiratory rate detected by exhaling the air upon the sensor.

1.6 Significance of the study

The project could help Rwandan infants live longer and have better health and wellbeing. Here are some possible advantages of the system: Reduced infant mortality: By monitoring vital signs and alerting parents if there is a problem, the system can aid in lowering infant mortality. By doing this, issues like sudden infant death syndrome (SIDS) and other health disorders may be avoided. Improved health and well-being: By giving parents peace of mind and assisting them in spotting and treating any health issues early on, the system can help to improve the health and wellbeing of infants. Increased access to healthcare: The system can help to increase access to healthcare for infants in Rwanda by making it possible for parents to monitor their child's health at home. This can help to reduce the number of unnecessary trips to the doctor or hospital. Reduced costs: The system can help to reduce costs for families and for the healthcare system by making it possible to monitor infants at home. This can help to reduce the number of unnecessary hospital admissions and the cost of healthcare.

1.7 Organization

This project thesis is made up of five chapters arranged as follows: chapter one: general introduction, problem statement, objectives of the study, research questions, scope of the study, significance of the study and organization of the study. Chapter two is literature review which is made by review of the research project and summary. Chapter three: Research methodology

describes the research instrument used in the project and therefore, it talks about the working principle, circuit diagram, component description and flow chart. Chapter four: Result of project implementation shows and interprets project result findings. The last chapter is the conclusion and recommendation.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Chapter two highlights what other authors have done on the wearable temperature and respiratory rate and then, the reviewed research was used to develop the improved smart wearable temperature and respiratory rate which leads to the provided summary and conclusion.

2.2 Review of Smart wearable temperature and respiratory rate system

With the advance in technology, remote communication and monitoring systems had emerged and facilitated the monitoring of children, particularly infant vital signs to address the number of children mortality rate. Many medical partners and researchers in different countries have worked on the project of smart wearable devices to control and monitor children's vital signs.

K. Mala et al. [4] Propose a novel, inexpensive ear-worn device which would noninvasively and not obtrusively monitor vital parameters like Respiration Rate, SpO₂ levels, Heart Rate, Body temperature of a child to enable rapid diagnosis wirelessly. Prototype developed was named Raksh consisted of sensors to monitor vital parameters like Respiration Rate, Heart Rate, Blood Oxygenation and Body Temperature. The data from the sensors are read by an STM32 Micro Control unit (MCU) and is transferred securely over Wi-Fi to a server. A 3.7 V, 240 Mah Lithium Polymer battery along with a power management circuit is used to power the system. The whole device sits comfortably behind the ear while being unobtrusive to the child.

Saada Tian et al. [5] developed a Low-cost infant monitoring and communication system. This paper proposes a low-cost, mobile-based monitoring and advisory system that continuously monitors the baby and remotely updates the mother on child status. This technology involves continuous measuring of the temperature, heart rate and motion and sends it to a server where the data is processed. The server analyzes the received data and sends the processed biological information of the baby to the mother and generates an alert system if the conditions of the baby are found abnormal. These alert messages are transmitted to support systems and nearby health clinics in emergency situations. Also, advisory first-aid information is sent to the mother to take immediate action. Thus, this ubiquitous system would enhance mother's awareness of their baby's health status.

Zhihua et al. [6] developed a Wearable Sensor Systems for Infants. The system proposed was composed of a wearable sensor system that senses infant vital signs and communicates via wireless communication to parents.

Madan Kumar S et al. [7] designed and developed Infant Monitoring using Smart Wearable System. The developed system monitors fundamental parameters like body temperature, pulse rate, growth of an infant, moisture content and CO₂ sensors to recognize the low oxygen level present around the infant's crib. By utilizing GSM and RF433 modules in this framework enables the system to communicate the sensor's output to their parent's lookout and make them initiate the possible control activities. The proposed framework utilizes a new simpler design which comprises relevant sensors attached to the microcontroller, and it is safely fastened with an infant. Moreover, the extracted fundamental parameters will be evaluated with a set of thresholds and the outputs are communicated to the parents through wireless communication modules that will make the system more compatible and user-friendly.

C. Lint et al. [8] developed the Sensory baby vest for the monitoring of infants. The developed sensory baby vest includes fully integrated sensors for the parameters respiration, heart rate, temperature, and humidity, to detect excessive sweating, for the continuous monitoring of infants under clinical and home conditions. It allows the early detection of potential life-threatening events calling for rescue as well as the recognition of the development or progression of diseases at an early stage. Health protection or even lifesaving thus will be enabled in time. A variety of principles for the measurement of the parameters has been assessed for the integration into garments. Prototypes have been manufactured incorporating the chosen sensing principles with textile and textile-compatible technologies. Currently, the prototypes are clinically tested for durability, handling, and signal quality.

Amr Abdelhamid and Ethan Webster. [9] proposed a paper on the Infant Monitor with Remote Temperature Sensor. In this project, they implemented a prototype for a contact-less temperature monitoring system using an infrared MEMS thermal sensor, the Omron D6T-8L-09, to be integrated in a smart infant monitoring unit. The implemented prototype was able to detect a high temperature situation which can be a fever and capture a photo of the object or subject and send it via email to notify the user. It showed promising results that can be extended to different

applications (i.e., security systems or energy management in home appliances). The performance of this proof-of-concept prototype was limited by the accuracy and precision of our infrared sensor. The results show the need for a more robust infrared sensor that has better accuracy and precision (a tolerance of about $\pm 0.5^{\circ}\text{C}$ is required). Also, a sensor with a wider field-of-view (FOV) and longer range might be used for a more practical monitoring system.

Majed A. Suhaim et al. [10] proposed the Baby Temperature Monitoring System (BTMS) is a parents' alerting system when a baby's temperature goes beyond or below certain degrees, according to the health standards of the body's temperature. The proposed BTMS will monitor the baby's temperature by receiving data from the physical components, which are going to collect the baby's temperature, analyze the data collected, and send the current baby temperature back to the App. Finally, alert the parents if the temperature is abnormal. The hardware tools need to be programmed, so they can collect the data, analyze it according to the standard criteria, and alert the parents in case the temperature is abnormal. This proposed system helps parents to control their children's body temperatures every second, which gives the parents the ability to take the procedures needed ahead of time. The results show the temperature of children at different time intervals.

M. Catrysse et al. [11] Presented a paper on textile sensors for the equipment of a wireless monitoring suit. In this paper wearable electronics and intelligent textiles are used for a medical application: continuous and long-term monitoring of children in a hospital environment. At present, monitoring, using conventional sensor techniques often cause problems: skin irritation, hampering wires. By integrating sensors, data processing, storage and transmission circuitry in clothing, the patient's comfort, mobility, and privacy is increased. Two physiological parameters, respiration rate and ECG, are measured, using dedicated textile sensors: The Respibelt and Tetrodes. The measured data is handled in a microprocessor and useful data can be stored in a serial EEPROM. If necessary, an alarm can be activated. An inductive link provides wireless power transmission to the suit, such that the battery can be recharged, and bi-directional data transmission.

2.3 Summary

The related work done is based on the respiratory rate monitoring and communication. Most of the system detects the respiratory rate value using a carbon dioxide sensor to read the oxygen level through inhalation and exhalation of the child. Others detect the respiratory rate by using temperature-based sensors and though the temperature sensed in the air, the respiratory rate value is recognized by measuring the amount of the voltage read from the system. For all developed systems, the temperature is monitored using temperature sensors. On the side of communication different communications were applied such as GSM, and NRF devices. The NRF communicates freely in smaller distance than GSM, but NRF requires to have receiver NRF as it is a transceiver device; though GSM communicates is done in longer distance with having airtime on the SIM card inserted in the slot of it.

After that, a smart wearable to monitor temperature and respiratory rate for toddlers is developed regarding the issues addressed by the previous works and provide a system which alerts parent or caregiver about the health of a child under normal or abnormal conditions.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter talks about the research instruments used for data collection during the design of the smart wearable system and the data analysis method. It also describes the system requirement for such software used to prototyping the system as well as the circuit diagram and working principle of the system. Furthermore, the components description used in prototyping were also explained in this chapter.

3.2 Data collection and Analysis

To collect data, the interview and questionnaire were used.

3.2.1 Interviews

Interviews were conducted to get clarification and in-deep understanding of the subject area under the study. The personal interview was conducted with the mothers of the children.

3.2.2 Questionnaire

The questionnaire with simple short questions was used to identify information regarding the life of children.

3.3 Data Analysis

Data obtained from the sensors was analyzed using an Arduino serial plotter.

3.4 System Requirements

3.4.1 System software design

My system was designed using a software called the proteus that offers a web-based platform that includes a simulator for Arduino software for simulating the system and Arduino IDE software for coding. Arduino IDE (Integrated Development Environment). The Arduino IDE is the official software tool provided by the Arduino project for programming and uploading code to Arduino boards. This is easy to write and compile in C, C++, and java to the board.

3.4.2 The system flowchart and Algorithm

The system works by following the algorithm explained thereof.

Step 1: Read the Body temperature sensor using DHT11.

Step 2: Read the respiratory rate value using a breath oxygen sensor.

Step 3: Count the real time using Real time clock DS3231.

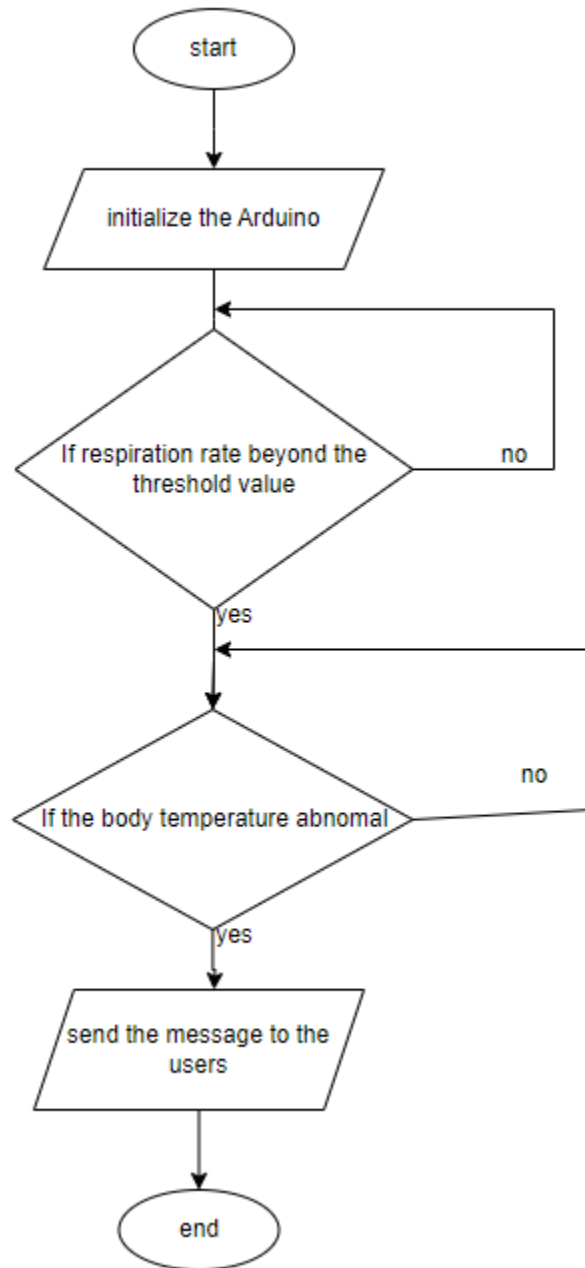
Step 4: Prints the detected and quantified value on the LCD display.

Step 5: If the Body temperature or respiratory value is normal, the GSM sends an SMS to the parents of toddlers with the set time in programming. i.e., The system alerts the health of the child to his /her parents.

Step 6: Otherwise, if the Body temperature or respiratory value is abnormal, the GSM sends an SMS to the parents of toddlers and to the caregiver immediately. i.e., The system alerts the health of the child is abnormal to his /her parents as well as to the caregiver.

Step 7: Stop.

Figure 1 The system flowchart and Algorithm



3.5 Components Description

The system was designed and prototyped using Arduino Uno, DHT11, Respiratory rate sensor, GSM Module, Rechargeable power supply, LCD, and Mobile phone.

3.5.1 Arduino Uno

Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

The board has the following new features: 1.0 pinout: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible both with the board that uses the AVR, which operates with 5V and with the Arduino Due that operates with 3.3V. The second one is a not connected pin that is reserved for future purposes. Stronger RESET circuit. At mega 16U2 replaced the 8U2

Figure 2 Arduino Uno photo



3.5.2 DHT11

DHT11 sensor is a sensor module that measures humidity and temperature. Its analog voltage output allows it to be further processed by a microcontroller. The sensor is low power

consumption, excellent precision, high integration, compact size, and affordable pricing. The Arduino Uno is utilized in conjunction with the DHT11 sensor. The OTP program memory contains calibration coefficients, which are used by this module to include temperature and humidity values in calculations when the internal sensor picks them up.

Figure 3 DHT11 photo



DHT11 uses Single-bus data for communication between MCU and DHT11, it costs 5mS for single time communication. Data consists of integral and decimal parts; the following is the formula for data. DHT11 sends out higher data bits firstly! DATA=8-bit integral RH data+8-bit decimal RH data+8-bit integral T data+8-bit decimal T data+8-bit checksum If the data transmission is right, checksum should be the last 8 bit of "8-bit integral RH data+8-bit decimal RH data+8-bit integral T data+8-bit decimal T data". When MCU sends the start signal, DHT11 changes from low-power-consumption-mode to running-mode. When MCU finishes sending the start signal, DHT11 sends a response signal of 40-bit data that reflects the relative humidity.

Table 1 DHT11 Technical specifications

Parameters	Conditions	Minimum	Typical	Maximum
Humidity				
Resolution		1%RH	1%RH	1%RH
			8 Bit	
Repeatability			± 1%RH	
Accuracy	25°C		± 4%RH	
	0-50°C			± 5%RH
Interchangeability	Fully Interchangeable			
Measurement Range	0°C	30%RH		90%RH
	25°C	20%RH		90%RH
	50°C	20%RH		80%RH
Response Time (Seconds)	1/e(63%)25°C , 1m/s Air	6 S	10 S	15 S
Hysteresis			± 1%RH	
Long-Term Stability	Typical		± 1%RH/year	
Temperature				
Resolution		1°C	1°C	1°C
			8 Bit	8 Bit
Repeatability			± 1°C	
Accuracy		± 1°C		± 2°C
Measurement Range		0°C		50°C
Response Time (Seconds)	1/e(63%)	6 S		30 S

3.5.3 Respiratory rate sensor

The respiratory rate sensor measures changes in the electrical impedance of the person's thorax caused by respiratory or breathing. During the respiration there is a change in respired air temperature, moisture, chemical composition of the air, and in its volume. The breathed-out air is hotter than the air that is breathed in by around 2-3°C much of the time. The breathed in air is at room temperature which is normally around 25°C (70°F), and the breathed-out air has a temperature of around 28°C (82.4°F). If the inspired air is warmer, then the heat lost from the body during the respiration process is lesser. Breathes in air contain dihydrogen monoxide vapor yet is rarely immersed. The breathed-out air is approximately immersed for the temperature at which it leaves the body.

In this way, the breathed-out air picks up dihydrogen monoxide vapor and carts it away from the lungs. Breathing builds up a transmutation in the chemical composition of the air. Breathed in air embodies around 20.947% of Oxygen (O₂) and 0.033% of Carbon Dioxide (CO₂) by volume, though the breathed-out air contains 15.4% of Oxygen (O₂) and 4.3% of Carbon Dioxide (CO₂) by volume. Breathed air contains unstable natural substances in immensely minute amounts.

The resistor 1k Ω is added in series with the Thermistor 10k and the voltage of 5V is supplied across the resistors R₁ and Thermistor R₂. The voltage across the Thermistor is taken as V_{R2} and is measured using the Voltage divider formula given below.

$$V_{R2} = \frac{5.R2}{R1 + R2}$$

3.5.4 GSM

A6 Module provides a serial port to communicate via GPRS, sending text messages and phone calls. The GPRS functions can be used for IoT projects which do not require Wi-Fi connection conditions. The GSM functionality of the module provides more ways to send commands to your IoT device.

Figure 5 GSM photo



3.5.5 LCD

A 16×2 LCD display is a liquid crystal display that can show 16 characters in each of its two rows, providing a total of 32 characters of information. It's commonly used to display alphanumeric information in various electronic devices. A 16×2 LCD display works by controlling the liquid crystals to either block or allow light to pass through, creating characters and symbols on the screen. It's controlled by sending data and commands to its controller, which in turn manages the display of information.

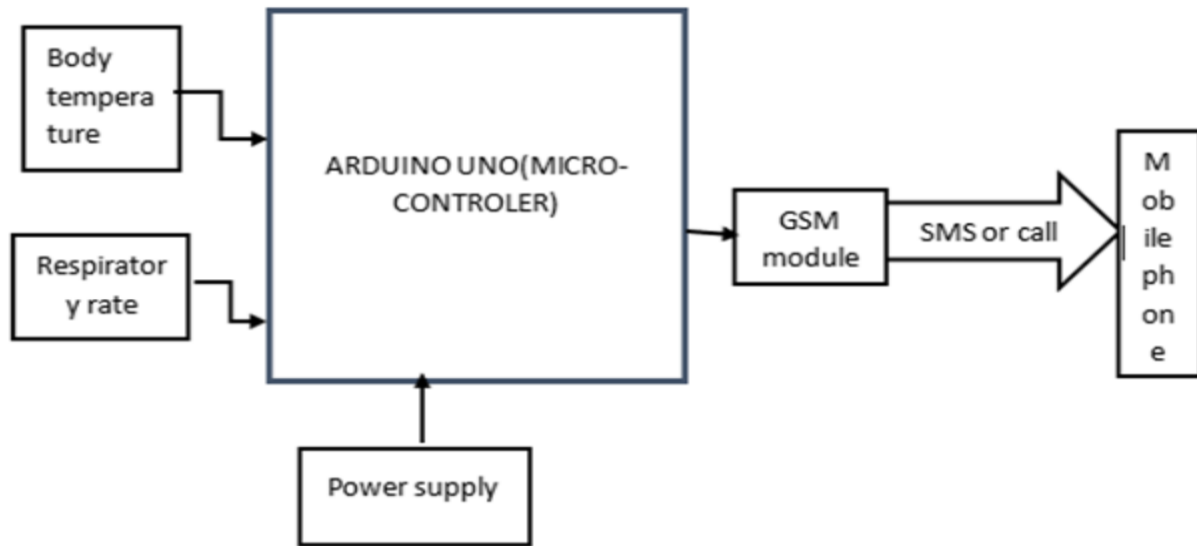
Figure 6 LCD photo



3.6 System block diagram

The system is composed of a microcontroller at mega 328, respiratory rate sensor, GSM, LCD, power supply, mobile phone and DHT11.

Figure 7 system block diagram



Microcontroller is the brain of the entire prototype because it governs all components interfaced to it. It therefore holds Arduino programming used to read the input signal and execute the output.

Respiratory rate sensor is for measuring the air breathed by a child through inhalation and exhalation worn at the arm of the child. The respiratory rate sensor sends the collected data to an Arduino microcontroller.

DHT11 is for measuring the body temperature of the toddler.

GSM: is for communicating the health status of a toddler over SMS to the parent / caregiver.

DS3231: is for calculating the timing for sending SMS when the health of a toddler is normal.

Mobile phone: is for receiving the incoming message from GSM.

Power supply: provide the required voltage to run the system.

CHAPTER 4: SYSTEM SIMULATION, PROTOTYPE, RESULTS AND DISCUSSION

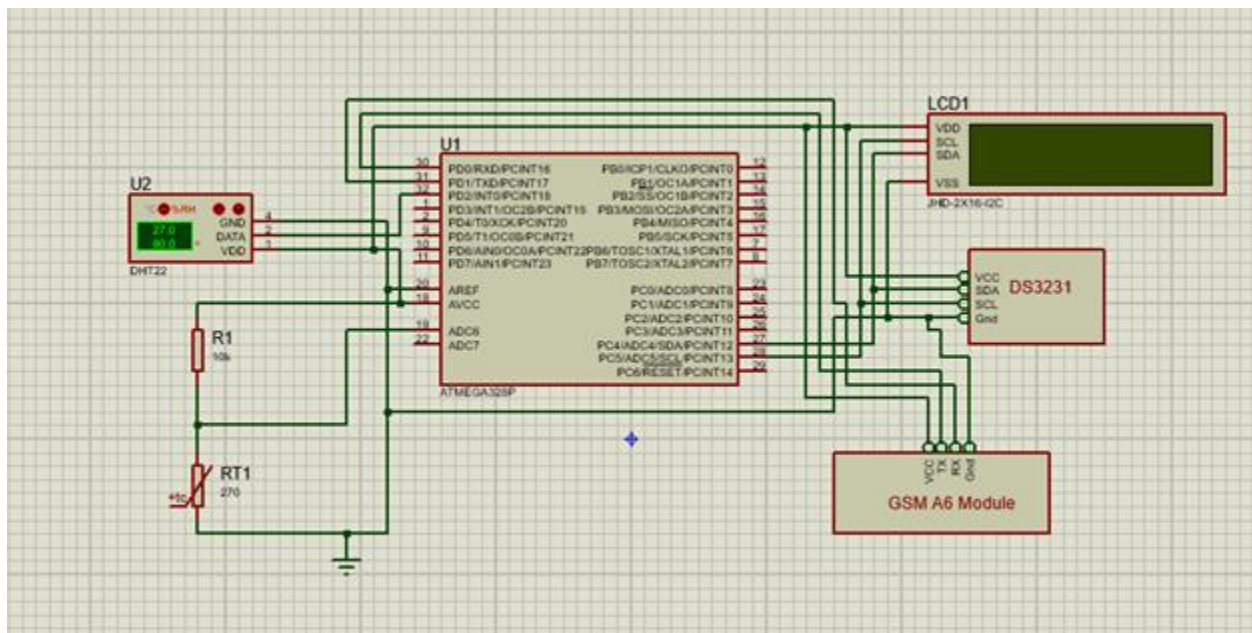
4.1 Introduction

Chapter four describes the results obtained after implementation of the system; it is therefore taken on temperature sensor and respiratory rate sensor. The measured value of the temperature sensor and respiratory rate values were analyzed using an Arduino serial plotter. All this data is taken via the implementation system which provides the notification (SMS) to the parents or caregiver over GSM. Prototyping is also the part of this chapter whereby the picture of the implemented system is attached in this report.

4.2 System simulation and prototyping

The circuit (wiring) diagram of temperature and respiratory rate monitoring system of toddlers is presented in Figure xxx which was simulated in PROTEUS software.

Figure 8 Circuit Diagram of temperature and respiratory rate monitoring system of toddlers



Working principle of temperature and respiratory rate monitoring system of toddlers

A smart wearable system to monitor temperature and respiration rate for toddlers is implemented using body temperature sensor (DHT11) and carbon dioxide sensor. All the sensors are interfaced to the Arduino microcontroller at mega 328 operating as the processing unit of the system; Arduino

uno is programmed using Arduino code to read the body temperature and respiration value of toddlers; therefore, it sends the measured value temperature and level of respiratory value to the mobile of parents using GSM A6 module.

The SMS is sent every one hour to the parents; if the health of toddlers is normal, it means that the body temperature is in the range of 36.1 and 37 centigrade, whereas the respiratory rate sensor of the system is between 23 to 29 mill mole per liter. If the temperature and respiratory rate of the toddlers becomes abnormal, the GSM communicates to the parent and caregiver immediately to let know the health of his /her child is in abnormal condition.

4.2 Prototyping of temperature and respiratory rate monitoring system of toddler

Figure 9 Prototyping of temperature and respiratory rate monitoring system of toddlers



4.3 Results and Interpretation

4.3.1 Temperature result

Under normal health of the child the body temperature of toddler varies based on the time illustrate in table below

Table 2 Body temperature detected using DHT11.

S/n	Measured body temperature	Time
1	36.8	10:13 AM 11/04/2024
2	36.2	11:13 AM 11/04/2024

3	36.1	12:13 PM 11/04/2024
4	37.2	1:13 PM 11/04/2024
5	36.2	2:13 PM 11/04/2024

Figure 9 Result of Temperature measured by DHT11

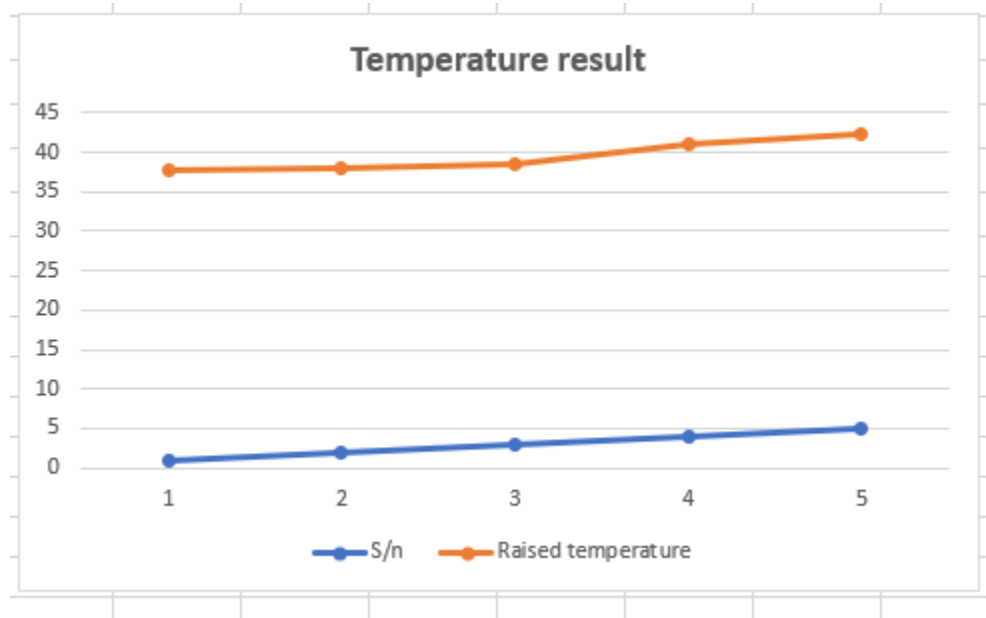


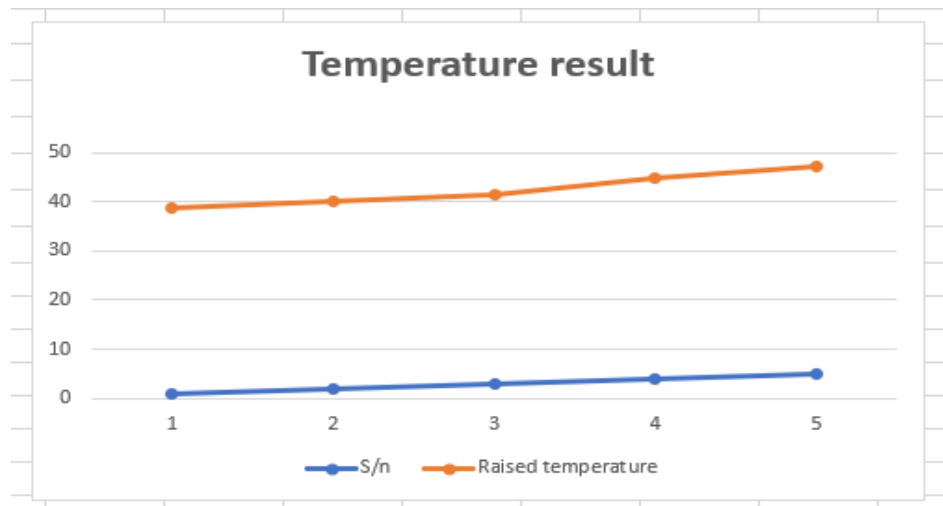
Figure 9 shows the temperature being measured on the DHT11 and therefore, the system sends the SMS to the declared number of the parents for monitoring the health of the toddlers. The SMS is sent after one hour whereas the timing is calculated using a real time clock interfaced to the microcontroller and conditioning GSM to send the SMS after an hour. To raise the temperature above the normal body temperature for this sensor, DHT11 of a smart wearable temperature and respiratory rate system is placed in the body of a toddler and therefore, the temperature is raised as it is illustrated in the figure below.

Table 3 temperature under abnormal condition

S/n	Raised temperature	Time
1	37.8	2:13 AM 11/04/2024
2	38.1	2:13 AM 11/04/2024
3	38.6	2:14 PM 11/04/2024

4	41	2:16 PM 11/04/2024
5	42.3	2:17 PM 11/04/2024

Figure 9 Result of Temperature measured by DHT11.



From table 3, the temperature rose sharply, as soldering iron rises its temperature quickly and thereby, the GSM sends the SMS at time the measured temperature becomes greater 38 centigrade.

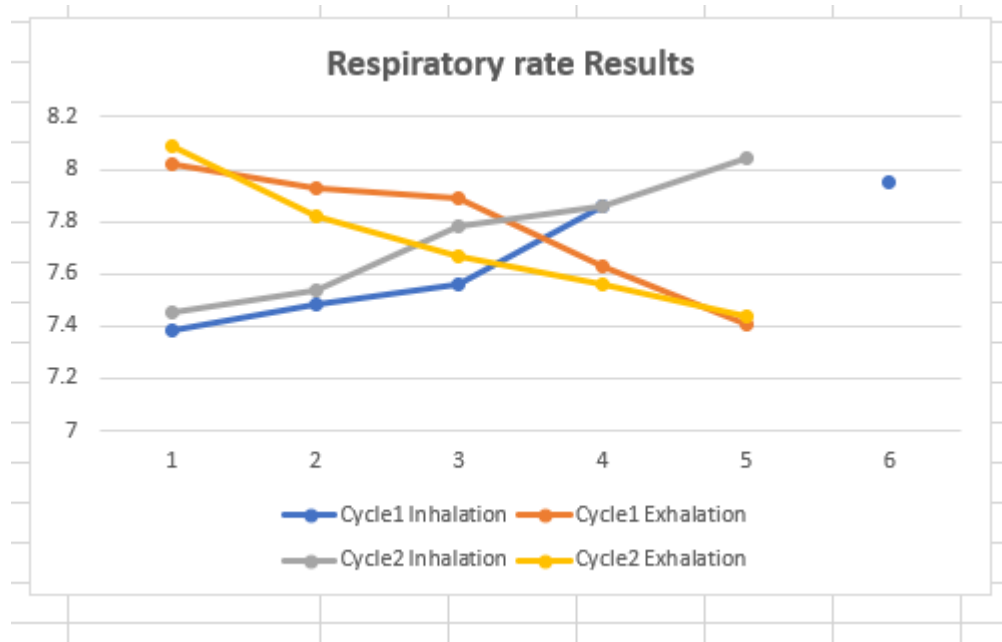
4.3.2 Respiratory rate Results

During inhalation and exhalation there is a minimum change in sensor voltage. This small change of voltage is not enough to be understandable by the ADC of the microcontroller. So, the sensor voltage is amplified using an amplifier. The current work uses a differential amplifier to obtain an appropriate amplified voltage signal. During the respiration process, there will be a sudden change in the resistance. I.e., during exhalation phase the resistance goes low from 9kΩ to 7.32kΩ and during the inhalation phase the resistance goes high from 7.32kΩ to 8.2kΩ as shown in table 4.

Table 4 Change in thermistor resistance during two phases of respiration for 2 cycles

Cycle1		Cycle2	
Inhalation	Exhalation	Inhalation	Exhalation
7.38	8.02	7.45	8.09
7.48	7.93	7.54	7.82
7.56	7.89	7.78	7.67
7.86	7.63	7.86	7.56
7.95	7.41	8.04	7.44

Figure 11 Respiratory result through inhalation and exhalation cycle



Stage II Stage 2 gives the voltage during the Respiration. The voltage across the sensor pin can be measured in the voltage divider circuit. The voltage change across the sensor output pin is

very less i.e., from 4.19V to 4.21V for inhalation and from 4.2V to 4.19V for exhalation phase as shown below.

Table 5 Change in thermistor voltage during two phases of respiration for 2 cycles

Cycle1		Cycle2	
Inhalation	Exhalation	Inhalation	Exhalation
4.19	4.2	4.2	4.2
4.2	4.19	4.21	4.2
4.21	4.19	4.21	4.19

Table 6 Change in ADC output value during two phases of respiration for 2 cycles

Cycle1		Cycle2	
Inhalation	Exhalation	Inhalation	Exhalation
198	204	197	204
200	201	209	200
206	196	193	194

CHAPTER V: CONCLUSION AND RECOMMENDATION

5.1 Introduction

Chapter five describes the conclusion and recommendation based on the findings.

5.2 Conclusion

The smart wearable system for temperature and respiratory rate monitoring of toddlers is designed and prototyped based on the objectives set. The objectives made were achieved because the system was designed based on data collected from the parents and nurses. The prototype of the system detects temperature and respiratory rate and thereby, lets the parents know the health status of the toddler under normal health status and therefore, it lets the caregiver and parents know under abnormal health status. Moreover, the system is made by a wearable sensor that must be attached to the infant's arm. The sensor collects data on the infant's vital signs, including respiratory rate, and body temperature. Under normal conditions, the temperature of a toddler varies between 36 and 37 centigrade however, for abnormal conditions, the temperature varies beyond 37 centigrade whereas for respiratory rate, its value varies between 23 up to 29 mill mole/ liter under normal conditions.

Further, the designed system is low-cost, easy to use, and can be easily deployed in urban areas. It will have the potential to reduce the number of infant deaths and improve the quality of life for infants and their families.

5.2 Recommendation

The smart wearable system to monitor temperature and respiratory rate of the toddler was implemented using a breather oxygen sensor and DHT11 sensor. DHT11 processes temperature data slowly with the duration of 2 seconds and it therefore operates under the principles of resistance variation. Secondly, there is an error in GSM communication happening in time SMS sent to more than one person, whereby the message reaches the receivers at different times; this happens especially when GSM sends more messages. Thirdly, the respiratory value detected by oxygen sensor where it is the only parameter used herein to get the respiratory status of toddler

though, there are respiratory sensors that read the other particles like turbidity situated in inhaled and exhaled air. I am here to recommend using a temperature sensor that responds quickly with high responsiveness as well as a GSM that operates using 4G network. In addition to that, the respiratory sensor with more than parameters shall be used for further improvement.

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APPENDICES

1.The questionnaire sample

Section 1: Demographic Information

1. What is your age?

. 18-24

. 25-34

. 35-44

. 45

2. What is your gender?

. Male

. Female

3. What is your level of education?

- . Primary school
- . Secondary school
- . postgraduate education
- . Bachelor's degree

4. Do you have children?

- . Yes
- . No

5. If yes, how many children do you have, and what are their ages?

- . Open-ended

Section 2: Current Monitoring Practices

6. How do you currently monitor your child's health (temperature, respiration, etc.)?

- . Manual checks (thermometer, etc.)
- . visits to the doctor
- . Using wearable devices

7. How often do you check your child's temperature?

- . Daily
- . Weekly
- . Only when they appear unwell.
- . Never

8. Have you experienced any challenges with your current monitoring methods?

- . Yes (please explain): _____
- . No

Section 3: Technology and Wearables

9. Are you familiar with wearable health monitoring devices?

. Yes

. No

10. Have you used any wearable health devices for your child?

. Yes

. No

11. What features do you consider most important in a smart wearable device for toddlers? (Select all that apply)

. Temperature monitoring

. Respiration rate monitoring

. Real-time alerts/notification

. Data sharing with healthcare providers

Section 4: Attitudes and Preferences

12. How concerned are you about your child's health in terms of temperature and respiration monitoring?

. Very concerned

. Somewhat concerned.

. Neutral

. Not very concerned

. Not concerned at all

13. How much would you be willing to pay for a reliable smart wearable system for your child?

. Less than \$20

. \$20 - \$50

. \$51 - \$100

. More than \$100

Section 5: Final Thoughts

15. **What concerns do you have about used a smart wearable device for monitoring your child's health?**

. Open-ended

16. **Any additional comments or suggestions regarding the design and features of a smart wearable system for toddlers?**

. Open-ended

2.Arduino code of the smart wearable system to monitor temperature and respiration rate for toddlers

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <SoftwareSerial.h>
#include <Wire.h>
#include <DS3231.h>
#include "DHT.h"
#define DHTPIN 3
RTClib myRTC;
#####define DHTTYPE DHT11 // DHT 21 (AM2301)
DHT dht (DHTPIN, DHTTYPE).
LiquidCrystal_I2C lcd(0x27,20,4); // set the LCD address to 0x27 for 16 cars and 2-line display.
int sensor=A0.
float respiratory value=0.
SoftwareSerial my Serial (3, 2).
void setup ()
{
  lcd. init ();      // initialize the lcd
```

```
lcd. in it ().
// Print a message to the LCD.
lcd. Backlight ().
lcd. set Cursor (0,0); lcd. set Cursor (0,1).
lcd. Print ("TEMPERATURE ");
lcd. Print ("RESPIRATORY RATE ");
delay (3000).
lcd.clear();
lcd. set Cursor (0,0);
lcd. Print ("MONITORING ");
lcd. set Cursor (0,1);
lcd. Print ("SYSTEM FOR TODDLER ");
delay (3000).
lcd. Clear ();
lcd. setCursor (0,0);
lcd.print("BT:").
  lcd. set Cursor (8,0);
lcd.print("RR:").
  lcd. set Cursor (0,1);
lcd.print("RS:").
  Serial.begin(9600).
mySerial.begin(9600).
  Serial.println("Initializing...").
delay (1000).
  Wire.begin().
  delay (500).
  Serial.println("Nano Ready!").
  dht.begin();
```

```

sms();
}
void loop ()
{
  timing ().
  res ().
}
void timing () {
  delay (1000).
  DateTime now = myRTC.now();
  Serial.print(now.year(), DEC);
  Serial.print('/').
  Serial.print(now.month(), DEC);
  Serial.print('/').
  Serial.print(now.day(), DEC);
  Serial.print(' ').
  Serial.print(now.hour(), DEC);
  Serial.print(':').
  Serial.print(now.minute(), DEC);
  Serial.print(':').
  Serial.print(now.second(), DEC);
  Serial.println().
  /* lcd.setCursor(5,1);
  lcd.print(now.hour(), DEC);
  lcd.print(":");
  lcd.print(now.minute(), DEC);
  lcd.print(":");
  lcd.print(now.second(), DEC);*/

```

```

Serial.print(" since midnight 1/1/1970 = ").
Serial.print(now.unixtime());
Serial.print("s = ").
Serial.print(now.unixtime() / 86400L);
Serial.println("d").
    temperature ().
}
void temperature () {
    delay (1000).
    float h = dht. readHumidity();
    // Read temperature as Celsius (the default)
    float t = dht. read Temperature ();
    // Read temperature as Fahrenheit (is Fahrenheit = true)
    float f = dht. read Temperature(true);
    lcd. set Cursor (3,0);
    lcd.print(t*19.5).
    lcd.print("*C ");
    // Check if any reads failed and exit early (to try again).
    if (isnan(h) || isnan(t) || isnan(f)) {
        Serial.println(F ("Failed to read from DHT sensor!"));
        return.
    }

    // Compute heat index in Fahrenheit (the default)
    float hif = dht.computeHeatIndex(f, h);
    // Compute heat index in Celsius (Fahrenheit = false)
    float hic = dht.computeHeatIndex(t, h, false);

```

```

Serial.print(F ("Humidity: ")).
Serial.print(h).
Serial.print(F ("% Temperature: ")).
Serial.print(t).
Serial.print(F ("°C ")).
Serial.print(f).
Serial.print(F ("°F Heat index: ")).
Serial.print(hic).
Serial.print(F ("°C ")).
Serial.print(hif).
Serial.println(F("°F")).
}
void res () {
  respiratory value=analogRead(sensor).
  lcd.setCursor(3,1);
  lcd.print(respiratory value);
}
void sms(){
  mySerial.println("AT"); //Once the handshake test is successful, it will back to OK.
  updateSerial();
  mySerial.println("AT+CMGF=1"); // Configuring TEXT mode
  updateSerial();
  mySerial.println("AT+CMGS=\"+250789956386\""); //change ZZ with country code and
xxxxxxxxxxxx with phone number to sms
  updateSerial();
  mySerial.print("temperature is normal"); //text content.
  updateSerial();
  mySerial.write(26).

```

```
}  
void updateSerial()  
{  
  delay (500).  
  while (Serial.available())  
  {  
    mySerial.write(Serial.read()) ;//Forward what Serial received to Software Serial Port  
  }  
  while (mySerial.available())  
  {  
    Serial.write(mySerial.read()) ;//Forward what Software Serial received to Serial Port  
  }  
}
```

3. BUDGET

Table 7 System budget

ITEMS	Units	Price/Unit	Total prices
Arduino uno	1	50000 Rwf	50000 Rwf
DS18B20 temperature Sensor	1	8000 Rwf	8000Rwf
Respiratory rate sensor	1	20000 Rwf	20000 Rwf
GSM module	1	70000 Rwf	70000 Rwf
Mobile phone	1	100000 Rwf	100000 Rwf
Rechargeable power supply	3	30000 Rwf	30000 Rwf
Jump wires	10	20000 Rwf	20000 Rwf
Communication and internet		100000 Rwf	100000 Rwf
Printing		10000 Rwf	10000 Rwf
TOTAL	-	-	408,000 Rwf