CHAPTER III

METHOD

3.0 Introduction

Research is to be the more formal, systematic intensive process of carrying as the scientific method of analysis. It involves more systematic structure of its investigation usually resulting in some sort of formal record of procedures and a report of results or conclusions (John.W.Best, 1996).

Methodology means as the logic of methods but not only in order to justify their use for defined purposes in specified situation and circumstance (Rob Walker, 1985).

Selection of appropriate methodology provides clear direction to the researchers with regard to the various steps to be followed in carrying out the research successfully. The present chapter outlines the Site description, Description of the sample, Sampling technique, Variables of the study, Design of the study, Construction of the tool, Data gathering procedure and Data analysis procedure

The method of the present study has two stages

Stage I: Design and Development of Science Lab Talking Device (SLTD)

Stage II: Study the Effectiveness of Science lab Talking Device

SLTD was developed to support students with visual impairments in performing the Science Lab Experiments independently which they have been deprived of the existing Lab settings.

In order to study the effectiveness of the SLTD, the students with visual impairments who are the end user were selected to perform the experiments using the Device

To substantiate the effectiveness of the device, the teachers for the students with visual impairment were involved to get their rating about the device

3.1 Stage I: Development of Science Lab Talking Device (SLTD)

Science Lab Talking Device has been developed using the hardware called Arduino Mega 2560. The Arduino Mega 2560 is a microcontroller board based on the mega 2560 (datasheet). It has 54 digital input/output pins, 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller. The developed device can function with AC to-DC adapter power. The critical part of the Arduino Mega 2560 is that it is compatible with all sensor operations.

Arduino Mega 2560 directly runs the programme in micro controller which in turn converts the sensor reading with minimum time and maximum speed. The investigator used six sensors connected to the Arduino Mega 2560. The sensors used for various science experiments include: Temperature, Colour, Light Detection & Current Measurement sensor, Volte Measurement, and Weight sensor. For each sensor operation, separate push buttons have been fixed on the board. The device works with embedded C program. The Embedded C program interface technology is used for real time data collection and converting the output in voice reading to enable students with visual impairment to get the real time data in voice form. The voice output is read both in Tamil and English language. The output is heard through an ear phone/head phone connected with the device.

3.2 Life Cycle of Science Voice Talking Device Development

Science Voice Talking Device (SLTD) Development Life Cycle is the process of design, implement and test the system in order to remove bugs, defects and uncertainty in the system and also to achieve reliability.

Our proposed system has FIVE phases in life cycle of SLTD development. They are analysis, designing, implementation, testing and deployment. For each of these phases, the output of one phase is the input of another phase.

Fig 3.1Life Cycle of SLTD Development

During the process of developing SLTD development life cycle, an expert committee is formed and involved in all the framework process. The committee consists of researcher, supervisor, technical expert, subject expert along with the student with visually impairment. The committee analyses the various requirements of the framework till STLD development lifecycle of 13 months. The main challenge faced during the development of SLTD is unclear user requirements. This was overcome by analysis phase.

1. Analysis phase

In analysis phase, the entire SLTD's possible requirements are analyzed and listed. The development team had a discussion with the stakeholders to figure out requirements of the science teacher and end user who is the student with visually impairment. The team listed out both functional and non-functional requirements. The checklist includes:

- Analyze the problem statement
- Analyze the requirements of the targeted user i.e., Students with visual impairment
- Analyze the risk involved in the similar system development
- Analyze the hardware and software components needed
- Analyze the man power involved
- Analyze the time taken to complete the entire project
- Analyze the cost of the project
- Analyze the ways to convert visual output to non-visual output

All requirements must be clearly documented. Analysis phase is too important to avoid the defect during the development phase or deployment phase. The difference between error and defect are error can be recovered but defect cannot be recovered. Defects lead the system rendered useless. Table 3.1 describes the gantt chart for software project development. The gantt chart shows the time taken to complete the project which includes both hardware and software completion. The total time taken to complete the project is 13 months. The time duration taken by the analysis phase is 3 months as shown in table 3.1.

2. Design phase

The blue print or prototype of the device was developed. Acquiring the data from the previous phase i.e., hardware and software specification, the overall architecture of the system was created. Based on this prototype, the device was developed. The technical expert will design the prototype based on the discussion taken place in analysis phase. The design phase also stated about the input and output of the system. The checklist includes

- Design principles of Arduino and Sensors
- Arduino pin connectivity to the Sensors
- Architecture development of Arduino and Sensors
- Basic study material for Embedded C
- Input and output of the system.
- Testing tools

The time duration taken by design phase of the project is 2 months after completion of analysis phase. The challenge faced during this phase is changing of user requirement which takes excess of time period in SLTD development lifecycle.

3. Implementation phase

The entire device was developed based on the blue print created in the previous phase. The entire implementation procedure was developed into various modules called units, and each module/unit was developed in the allocated time.

- Hardware implementation : implementation of Arduino with sensors
- Software implementation : implementation of Embedded C coding
- Install the code to Arduino Mega 2560

After the successful completion of analysis and design phase, implementation is done based on the prototype. It took next 4 months to do both hardware and software implementation. Implementation phase faced two challenges. First, linking of software and hardware. Secondly, the budget allocated to the spare parts of STLD had grown high compared to the expected budget allocated during analysis phase.

4. Testing phase

Testing has to be done on both hardware and software of the system. The development team established a continuous testing of both hardware and software to find out the defects and errors that was previously identified in the analysis phase. On the software side, the team ensured that the code quality metrics are achieved. Cyclomatic complexity, class coupling, line of codes and depth of inheritance comes under the metrics of code quality. This helps to reduce code complexity.

On the hardware side, the team ensured the connectivity of the device, and reliability of the system in various environments. Reliability stands for failure free software function in a specified environment at time varies.

- Unit testing is performed to test the Embedded C codes as the modules are divided into various units
- Testing the prototype if the system fails to give the desired output
- Finally verification and validation are done to the final device

Testing was done in 11^{th} and 12^{th} month of the project. It is necessary for the researcher to ensure that the device is error free.

4. Deployment phase

Deployment is the last phase in the system development life cycle. The developed device or system is deployed in the user environment. The product was released to the targeted user i.e., students with visual impairment into the real world. Maintenance can also be done at this stage if the end user i.e., visually impaired students needs any amendment charges in the product.

Deployment is done at the 13^{th} month of the life cycle of system development.

Table 3.1 Gantt Chart for Software Project Development

Months	1	2	3	4	5	6	7	8	9	10	11	12	13
Analysis													
Design													
Implementation													
Testing													
Deployment													

The framework had been completed on time and the Science Lab Talking Device had been deployed to the students in order to identify the efficiency and versatility. Following pilot study in chapter 3.2.10 discuss about feedback received nearly 30 teachers about the physical features, usability and accessibility of SLTD device. It is observed from the feedback that the device is performed well based on the requirements, versatility and user friendliness. The detailed pilot study is discussed in chapter 3.2.10.

External layout of the Science Lab Talking Device

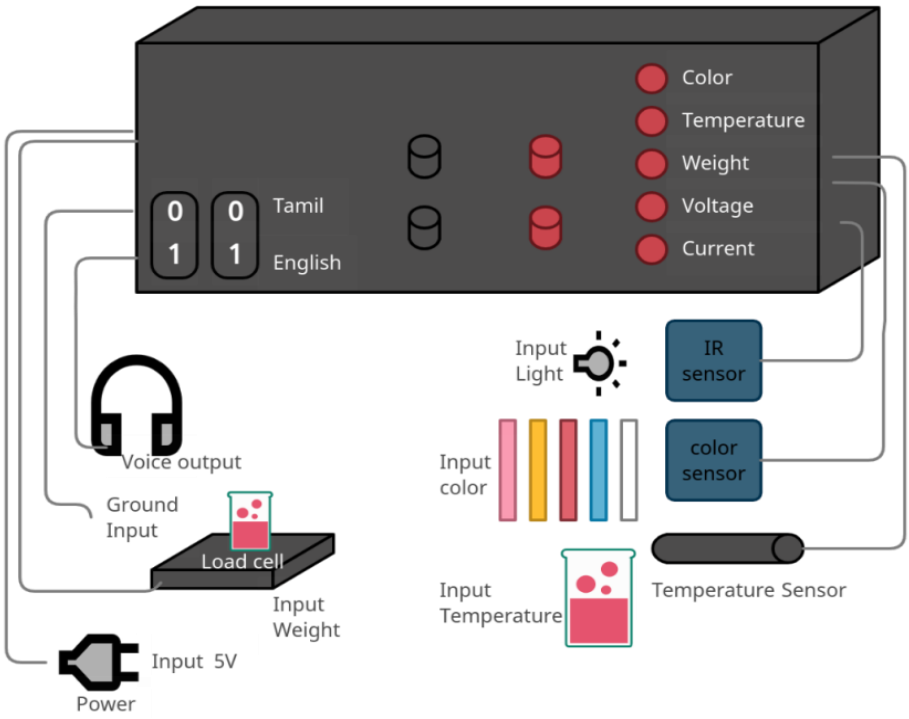

Fig 3.2 (a) External layout of the Science Lab Talking Device

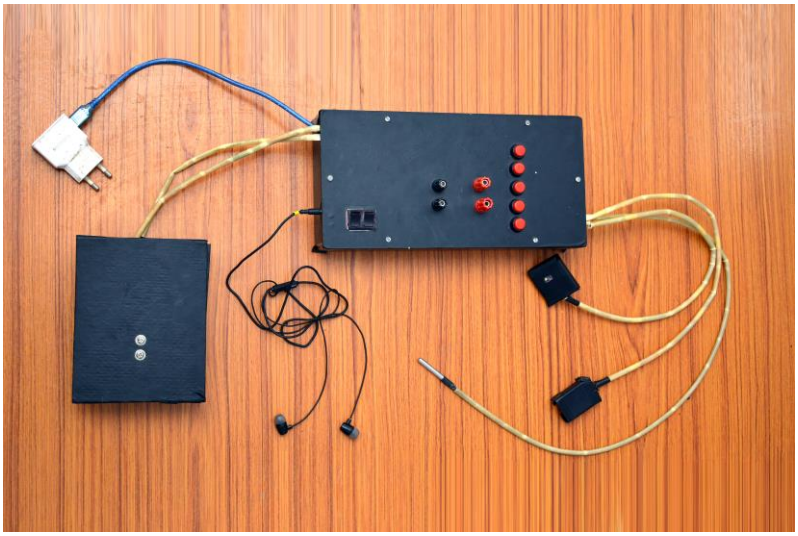

Fig:3.2 (b) Science Lab Talking Device

After development of the device, its efficacy was analyzed with the introduction of the device for experiments. For this purpose, samples have been selected and the procedure for finding out the effectiveness of the device is detailed below.

Description of the Device

The device consists of

1. Arduino Mega 2560
2. INA219 based Current Sensor with LDR
3. Voltage Sensor
4. Load Cell Sensor with HX711 ADC converter
5. TCS3472 Colour Sensor
6. DS18B20 Temperature Sensor and
7. Micro SD Card

3.2.2 Arduino Mega 2560

Ardunio defines an open- source electronic platform or board used to perform it. Arduino has a microcontroller and a software or IDE (Integrated Development Environment) that runs on the system. It helps to write the computer programming language and upload the programming codes in the microcontroller.

Micro controller (MCU) is also called as microprocessor (MPU) is an integrated circuit that is a chip that consists of volatile (ROM) and nonvolatile memory (RAM),

input output control unit (I/O unit) and a timer. In the beginning micro controller is called as “system - on -chip”.

Arduino mega 2560 is a micro controller board having 54 digital input/output pins, 16 analog inputs, 4UARTs hardware serial ports, 16MHz crystal oscillator, USB connection, ICSI header and a power jack. Arduino can connect with another Arduino or a computer or a micro controller. It has four UARTs hardware and TTL serial communication. SPI communication uses SPI library. Arduino allows textual data to and from micro controller. The output can be either text or voice. Regarding Arduino software, it allows the user to upload the codes by pressing the upload button in the Arduino environment. In this study methodology, the software coding was written in Embedded C language.

The method of designing , as shown in fig 3.3(a), it describes the hardware architecture, Arduino Mega 2560 is connected with various sensors say current sensor, voltage sensor, load cell sensor and colour sensor. The sensed data will be a voice output. All the recorded of voice output will be stored in memory SD card, which in turn connected to Arduino Mega 2560. The voice output will be either in Tamil or English language depends upon the user’s requirement. Fig 3.3(b) describes the circuit diagram of overall circuit of the methodology.

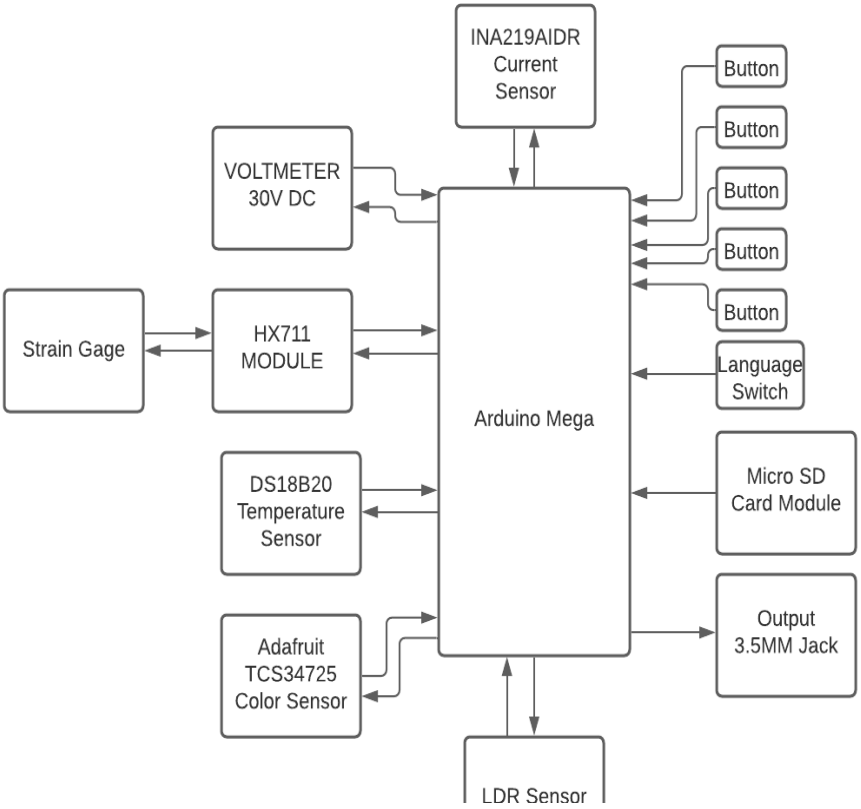

Fig 3.3 (a) Hardware Architecture of SLTD

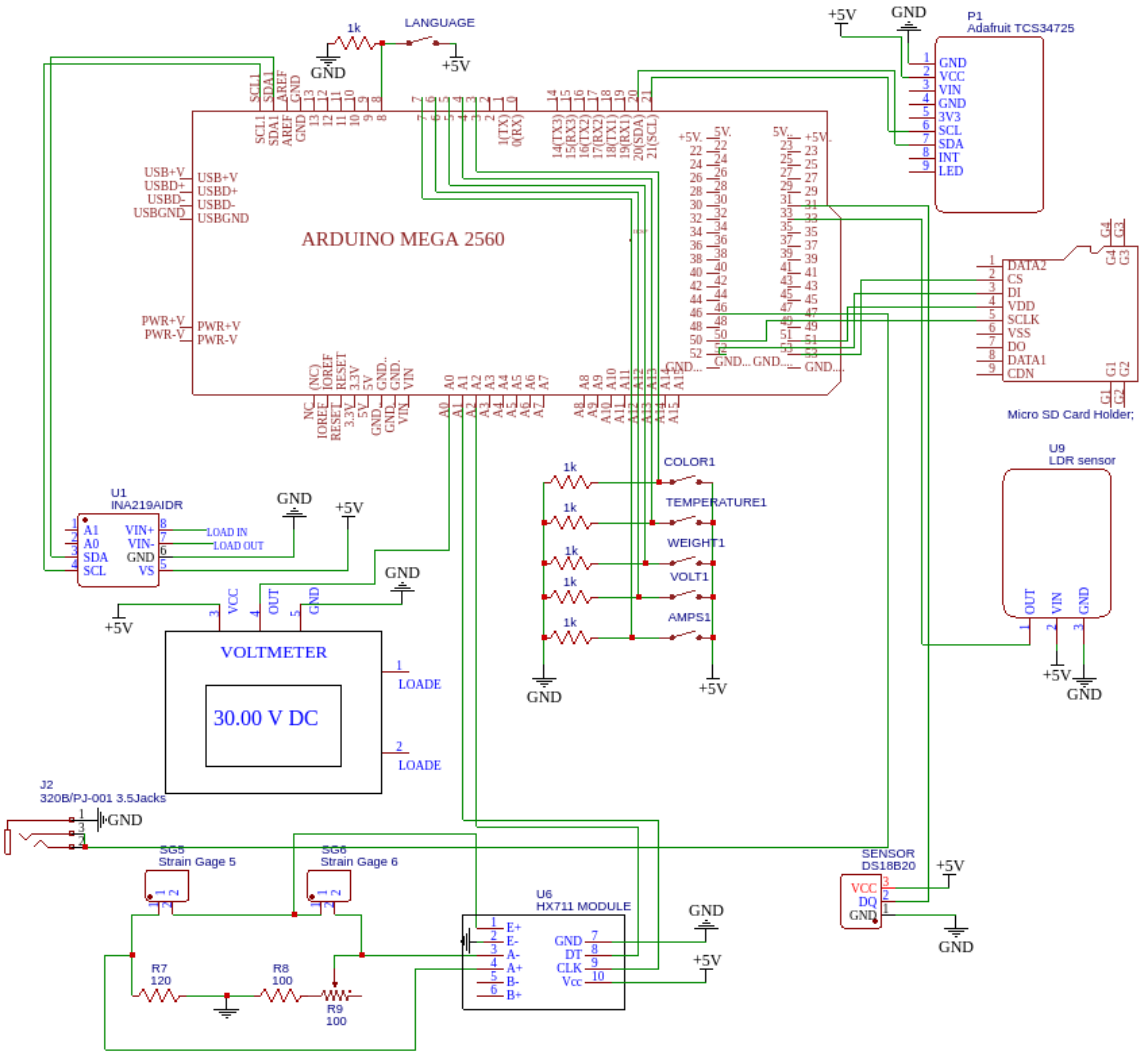

Fig 3.3 (b) Circuit Diagram of SLTD

Sensor

Sensor is a device or a subsystem which helps to detect the changes or events taken place in the environment. In other words, it responds to a physical stimulus like light, heat, pressure, sound etc and transmits the data to the controller. Different types of sensors are available for different purposes. In the present study, load cell sensor, current sensor, voltage sensor, colour sensor and temperature sensor were used.

3.2.3 INA219 based Current Sensor and LDR

INA219 based Current Sensor module CJMCU 219 is an I2C interface based zero drift and bi- directional current or power monitoring module. It is used to sense current, voltage, power and shunt voltage at the same time. The 128 sample averaging

data is submitted through I2C protocol. The main purpose of INA219 is power monitoring and also converts the measured current into amplifier as is has 12 bit ADC convertor. The sensing range will be +or - 3.2A and0.8mA resolution.

LDR stands for light dependent resistor which has a resistance which helps to change with the light intensity that falls upon it. It is used along with dark and light activated switching circuit and also with sensor circuit. LDR is also called as photoresistor or photoconductor.

Sample coding for current sensor

if(digitalRead(ldr)==HIGH){

Serial.println("lite is on");

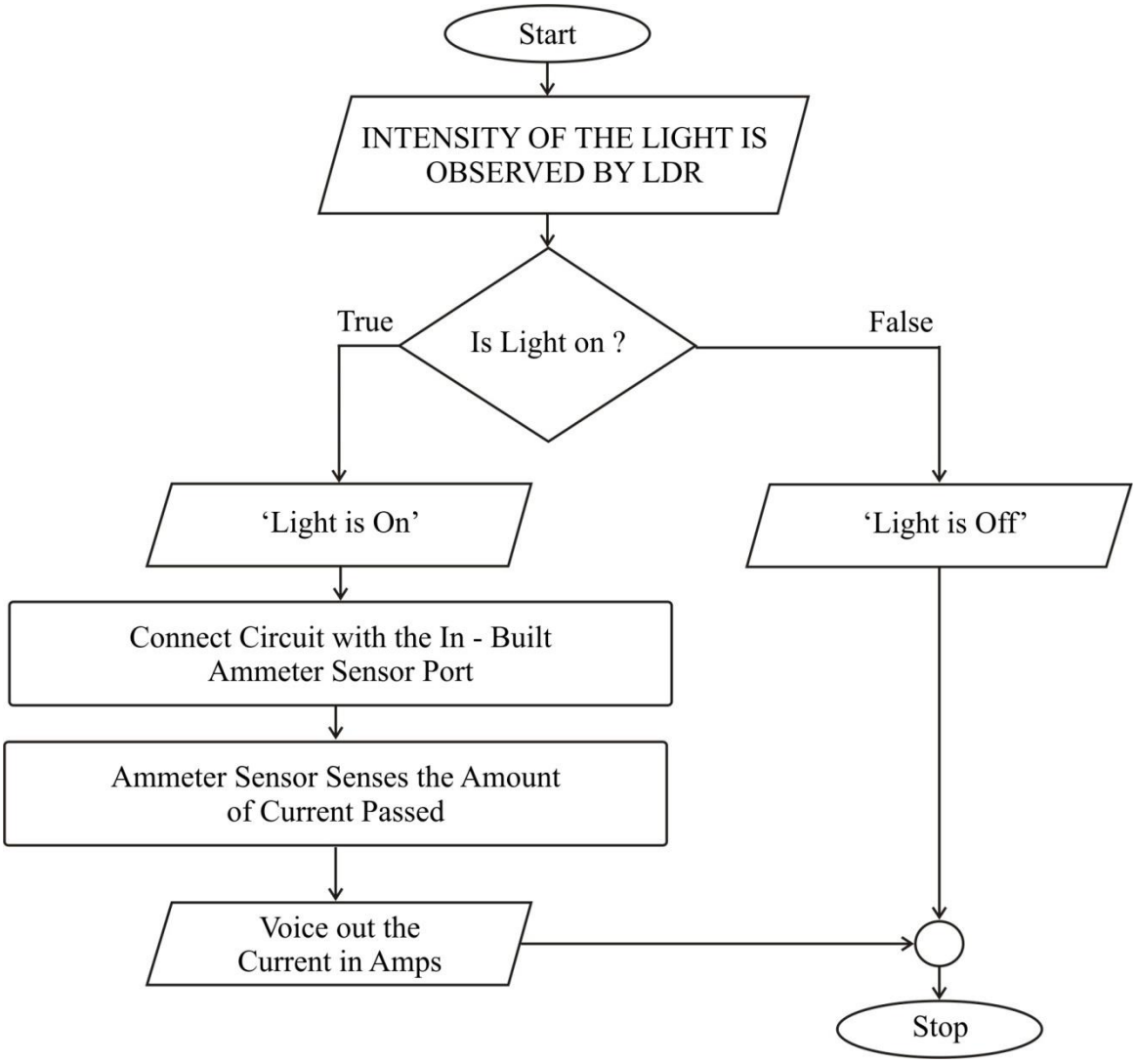

Fig 3.4 (a) Flowchart of Current Sensor with LDR

The operation of current sensor with LD is shown in fig 3.4(a). LDR observes the intensity of light and loud out whether the light is on or off. Circuit wire is connected with the ammeter that calculates the amount of current passed in the circuit wire and loud out it with amps. The corresponding circuit diagram with LDR is shown in fig 3.4(b).

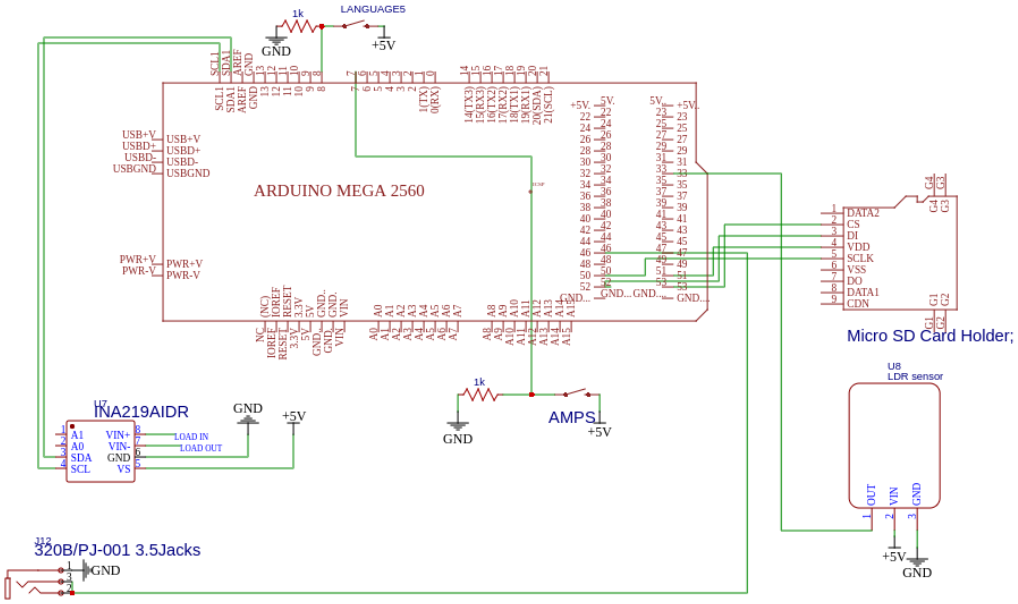

Fig 3.4 (b) Circuit Diagram for Current Sensor

Sample coding for Ammeter

```
if(digitalRead(lang)==HIGH)
{
  sayNumbera(aIN);
  tmrpcm.play("amps.wav");delay(1000);
 }
```

The if part describes whether the language is Tamil. The current in volt is read and displayed using a voice message.

3.2.4 Voltage Sensor

Voltage sensor is used for measuring voltage. It is a low cost sensor that has resistive voltage divider design. The advantages of voltage sensor are it does not need any external component and easy to use with microcontroller. The input voltage ranges from 0 to 25V and has analog voltage resolution of 0.00489V.

Sample coding for Volt meter

```
if(digitalRead(lang)==HIGH)
{
   sayNumbera(vIN);
   tmrpcm.play("tvolt.wav");delay(1000);
 }
```

The if part describes whether the language is Tamil. The Voltage is read and displayed using a voice message.The operation of voltage sensor with LD is shown in fig 3.5(a). Similar to ammeter, LDR plays a vital role in voltmeter. LDR observes the intensity of light and loud out whether the light is on or off. Circuit wire is connected with the voltmeter that calculates the amount of current passed in the circuit wire and loud out it in volts amps. The corresponding circuit diagram of voltage sensor with LDR is shown in fig 3.5 (b).

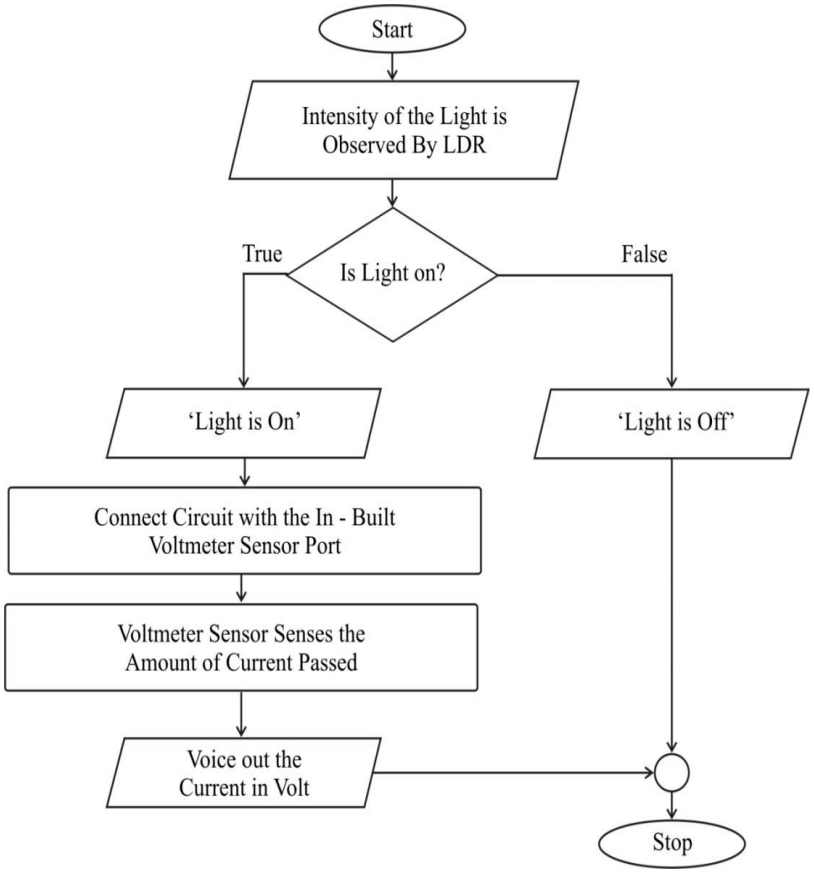

Fig 3.5 (a) Flowchart for Voltmeter

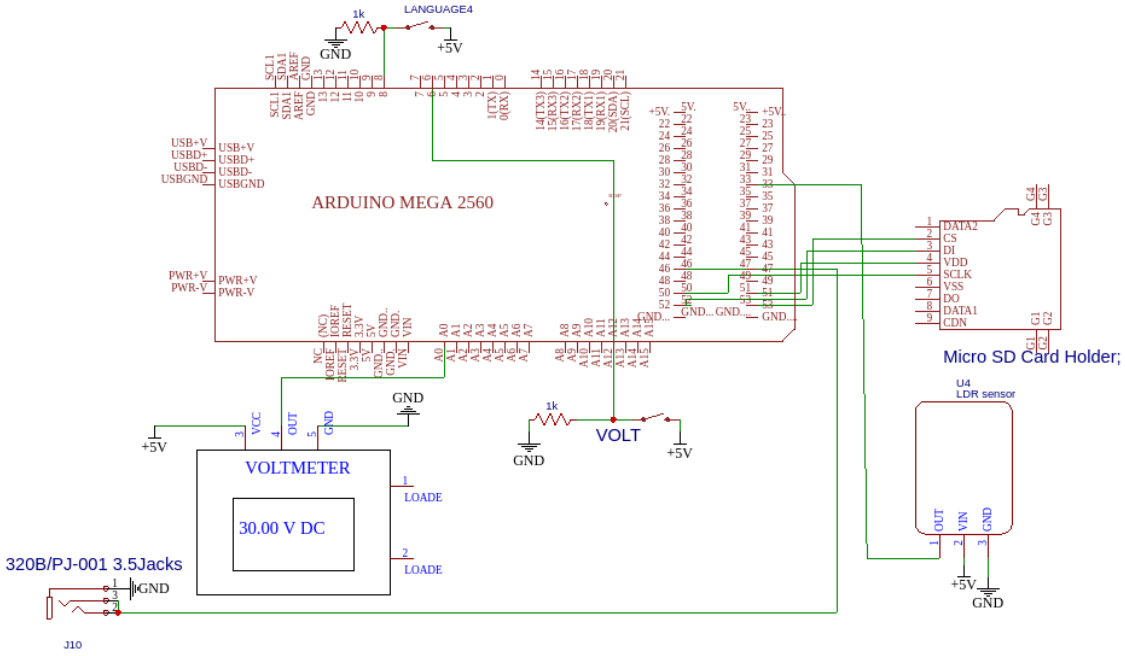

Fig 3.5(b) Circuit Diagram for Voltmeter Sensor with Arduino

3.2.5 Load Cell Sensor

Load Cell Sensor is also called as strain gauge as it could translate up to 1 kilo gram of pressure into signal. The load cell helps to measure the electrical resistance and the objects are measured using gauge.

Formula to calculate load voltage

loadvoltage = busvoltage + (shuntvoltage / 1000);

Bus voltage is the total voltage between power and ground. It is the sum of the load voltage and the shunt voltage

Shunt voltage is the voltage at shunt resistor terminals

Bus voltage is measured between IN and GND in INA219 sensor

Load voltage is the voltage present in the load.

3.2.6 Coding for Weight Sensor

The coding for both load cell sensor and temperature sensor are same. Except the temperature sensor sounds the word Celsius along the value. But load cell sensor sounds gram along the value. A separate file is included to sound either gram or Celsius.

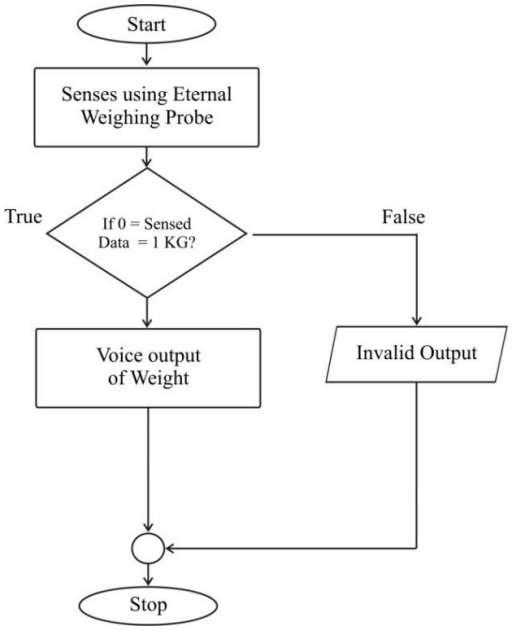

Fig 3.6 (a) Flow Chart of Loadcell Sensor Functionality

The above flow chart in fig 3.6 (a) describes the working principle of load cell sensor. The external probe which helps to weigh is connected to arduino. It checks whether the value is between 0 and 1 kg. If the value exceeds, the audio output sounds invalid. If the value lies between the range, it converts the decimal value into binary using ADC. The digital value is compared with the audio files stored in the memory SD card. The respective audio file is taken and the voice output of the weight sounds to the user. Fig 3.6 (b) shows the circuit diagram of loadcell sensor.

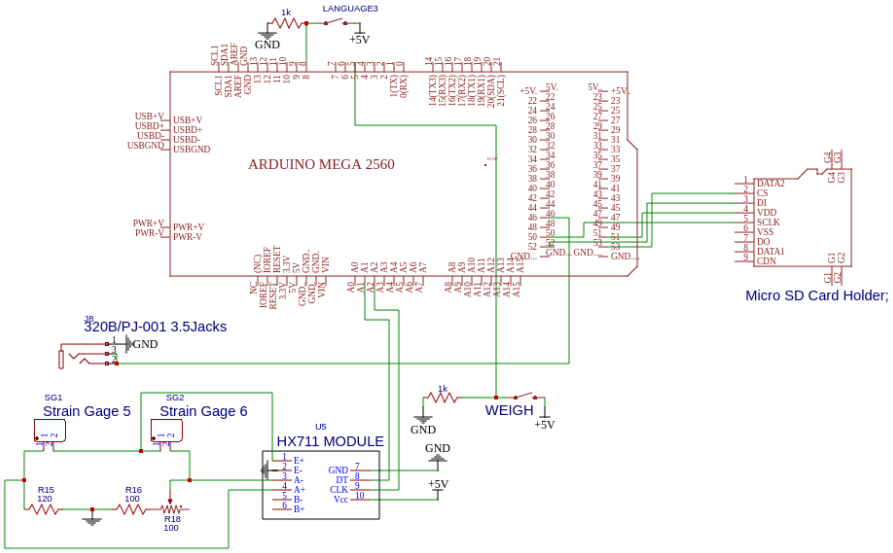

Fig 3.6 (b) Circuit Diagram of Loadcell Sensor and ADC with Arduino

3.2.7 HX711 24 Bit Analog to Digital Converter (ADC)

HX711 has a 16 pin which is built to convert the analog signal into 28 bit long digital signal. It is contains in built preamplifier which amplifies low voltage signals. Here, in HX711, the input is the voltage signal and the output is the digital signal i.e., 0's and 1's in millivolts. Two analog channels say And B are present in the chip where A has a constant gain of 128 or 64 but B has a constant gain of 32. It also has an in built oscillator that helps to avoid the usage of external components. Channel A and B are called as input channels and the output data rate can be controlled. The data rate is 10Hz when the pin is low; on the other hand it is 80Hz when the pin is high. The connectivity of 24 bit analog to digital converter (ADC) with loadcell sensor is shown in the fig 3.4 (b).

3.2.8 TCS3472 Colour Sensor

TCS3472 Colour Sensor helps to identify the RGB colours (i.e., red, green, blue) with the clear light sensing values. The objective of TCS3472 Colour Sensor is to minimize the Infra-Red spectral component and Ultra Violet spectral component of incoming light in order to measure the colour accurately. For this purpose, an integrated IR blocking filter is used. It also minimizes the transient errors. This type of sensors mainly used in medical diagnostic equipment.

Sample Coding to find the RGB colour

```
if(int(red)>=96 &&int(red)<=103 &&int(green)>=85 &&int(green)<=92
&&int(blue)>=56 &&int(blue)<71)

{
    Serial.println("red");
    if(digitalRead(lang)==HIGH)

{
      tmrpcm.play("sivapu.wav");delay(1000);
    }
   else

{
      tmrpcm.play("red.wav");delay(1000);
   }
 }
```

The given valueof RGB red >= 96 &&<=103 &&; green>=85 &&<=92 &&; blue >=56 &&<71 indicates the colour is RED. For every colour, the RGB value changes. The output will be displayed either in Tamil or English. The value HIGH indicates that the selected language is Tamil.

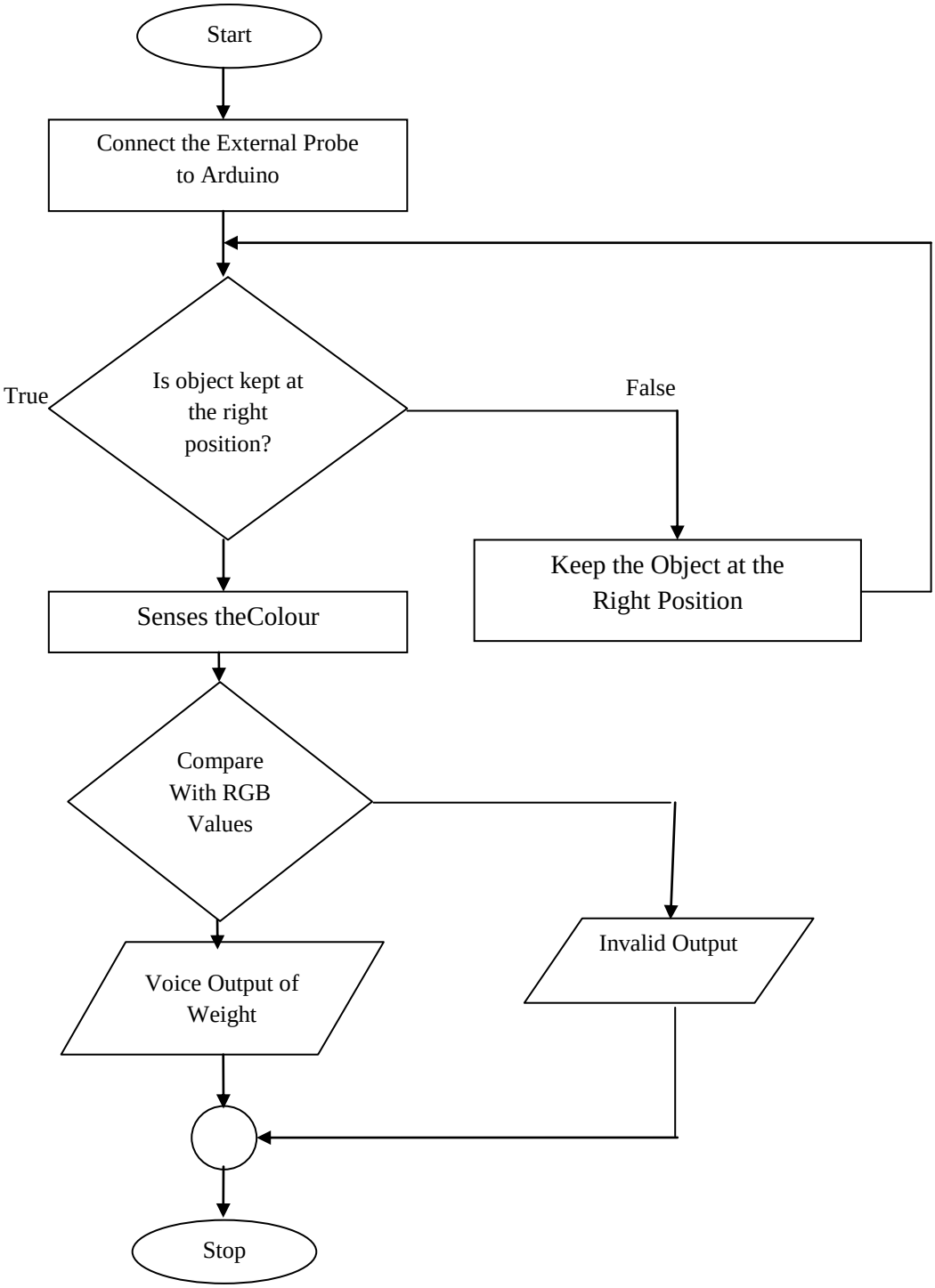

Fig 3. 7 (a) Flow Chart of Colour Sensor

From figure 3.7 (a), the external probe colour sensor senses the colour of the given object. State of the object is litmus paper. The sensed data from the colour sensor is send to the Arduino Mega 2560. Every colour is the combination of R (Red), G (Green), B (Blue) values. Memory SD card contains R.G.B values of every colours. The Arduino compares the RGB value of litmus paper with the list of RGB values presenting the memory card. The matches indicate that the exact colour of the paper. Figure 3.7(b) shows the circuit diagram of colour sensor connected with Audio Mega 2560.

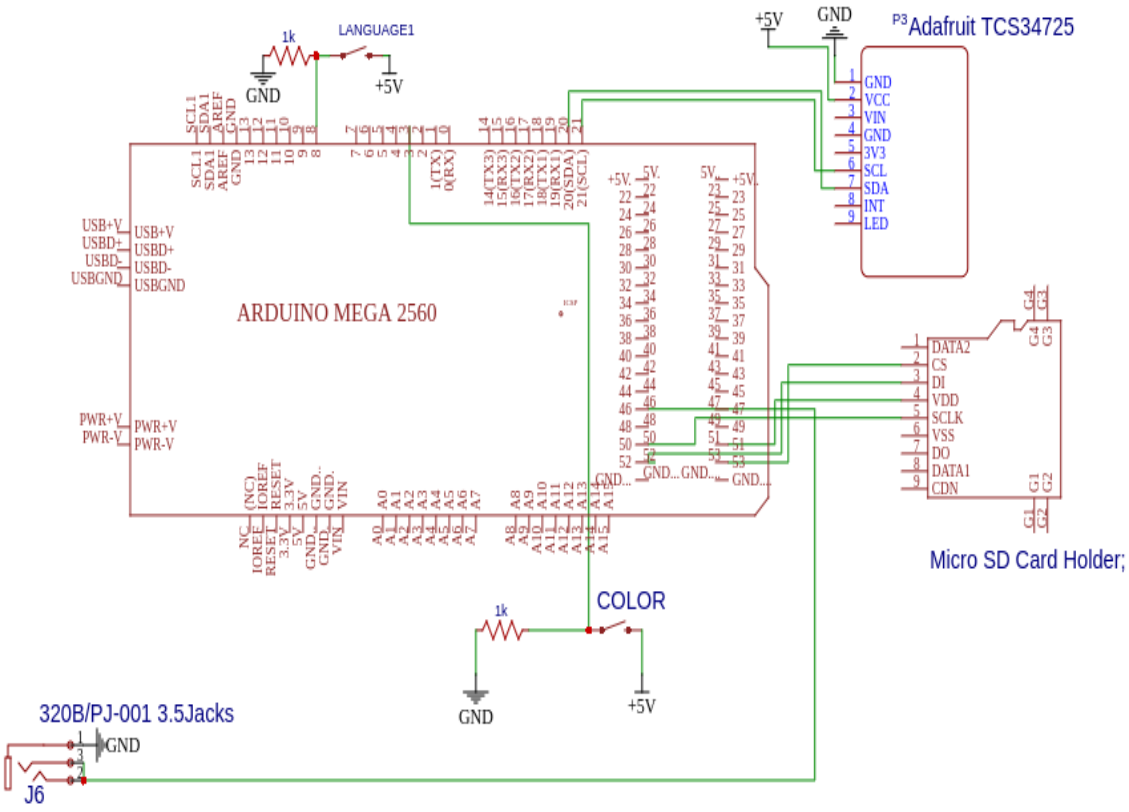

Fig 3.7 (b) Circuit Diagram for Colour Sensor with Arduino

3.2.9 DS18B20 Temperature Sensor

Temperature Sensor is a programmable digital temperature sensor that is used to communicate 1 - wire method from maxim integrated. It means 1 wire method is used to sense the data. DS18B20 temperature sensor helps to measure the temperature in the chemical environment and stored in 2 Byte register which is present inside the sensor. ROM command and function command are used to read the values. It measures the temperature ranges from -55 degree to +125 degree and the operating voltage will be

3V to 5V. The micro controller is connected to data pin along with pull up resistor and the next two pins are used for power. The accuracy will be equal to + to - 0.5 degree C. The output resolution ranges from 9 bit to 12 bit and takes a conversion time of 750ms at 12bit.

Formula to convert Celsius to Fahrenheit

tempFahrenheit = tempCelsius * 9 / 5 + 32;

Temperature can be either in Fahrenheit or in Celsius. Initially the input of the temperature will be in Celsius. The above formula helps to convert the temperature from Celsius to Fahrenheit if the user wants to know temperature in Fahrenheit.

Sample coding for finding the temperature.

```
 if (n>=100)
{
    int hundreds = n / 100;
    sayNumber(hundreds);
    tmrpcm.play("hundred.wav");delay(1000);
    n %= 100;
  }
```

If the input temperature is greater than 100 and less than 200, the file hundred.wav is called. In the file hundred.wav the numbers 100 to 199 will be stored as a voice message. The output will be displayed to the user as a voice command. Delay will be 1000 millisecond.

```
tmrpcm.play("degree.wav");delay(1000);
tmrpcm.play("celcius.wav");delay(1000);
```

While saying the temperature, the terms degree and Celsius have to be sounded along with it. The above two statements play the term degree and Celsius once the temperature is read by the system.

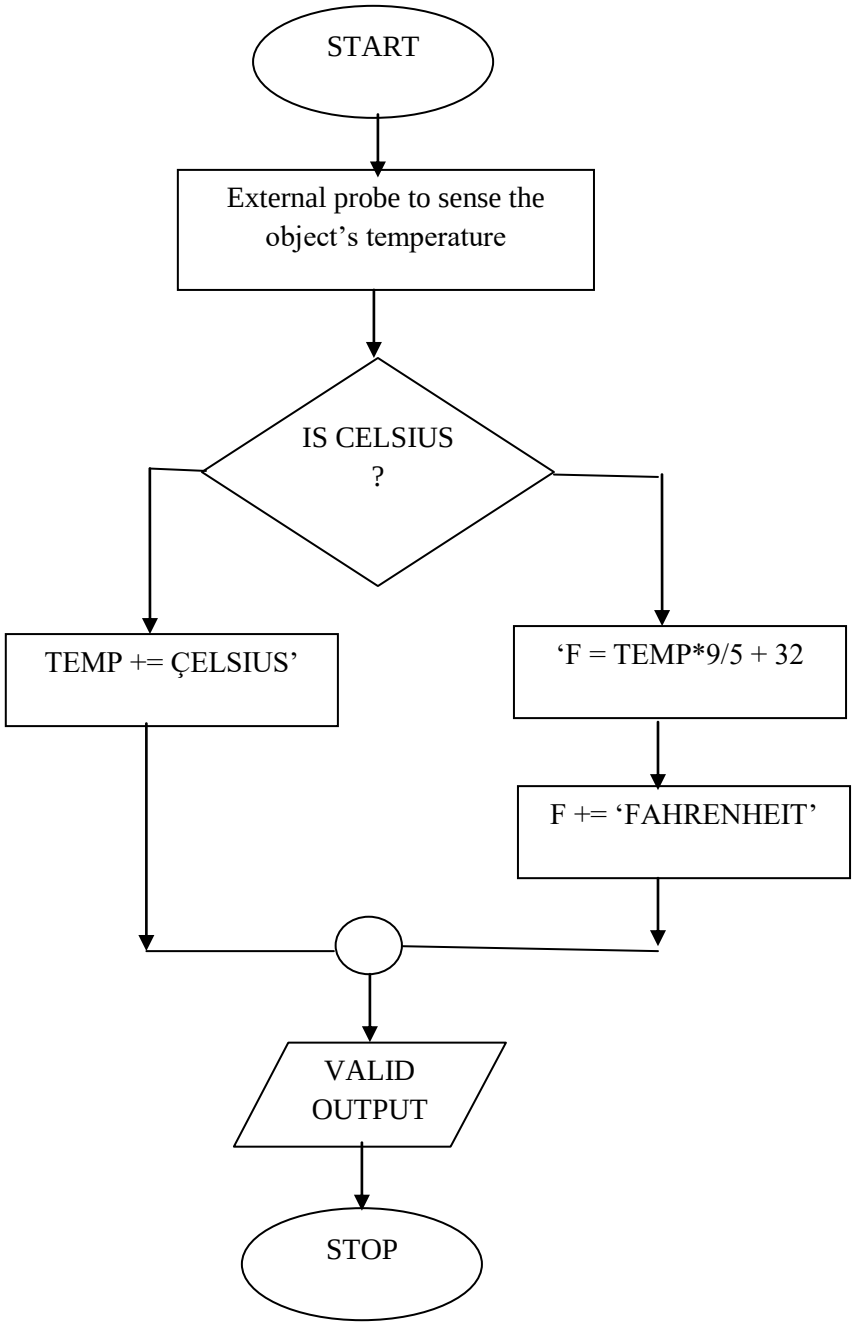

Fig 3.8 (a) Flow Chart for Temperature Sensor

The external probe of temperature sensor senses the temperature of a given object or a human. The sensed information is sending it to Arduino Mega 2560. Initially, the temperature is measured in terms of Celsius. The device asked the user that the user wants to know the measured temperature in Celsius or Fahrenheit. Operations are performed to convert the temperature into Fahrenheit. The user gets a voice output of the measured temperature. Figure 3.8 (a) shows the flowchart of

temperature sensor and figure 3. 8 (b) describes the circuit diagram of temperature sensor connected with Arduino Mega 2560.

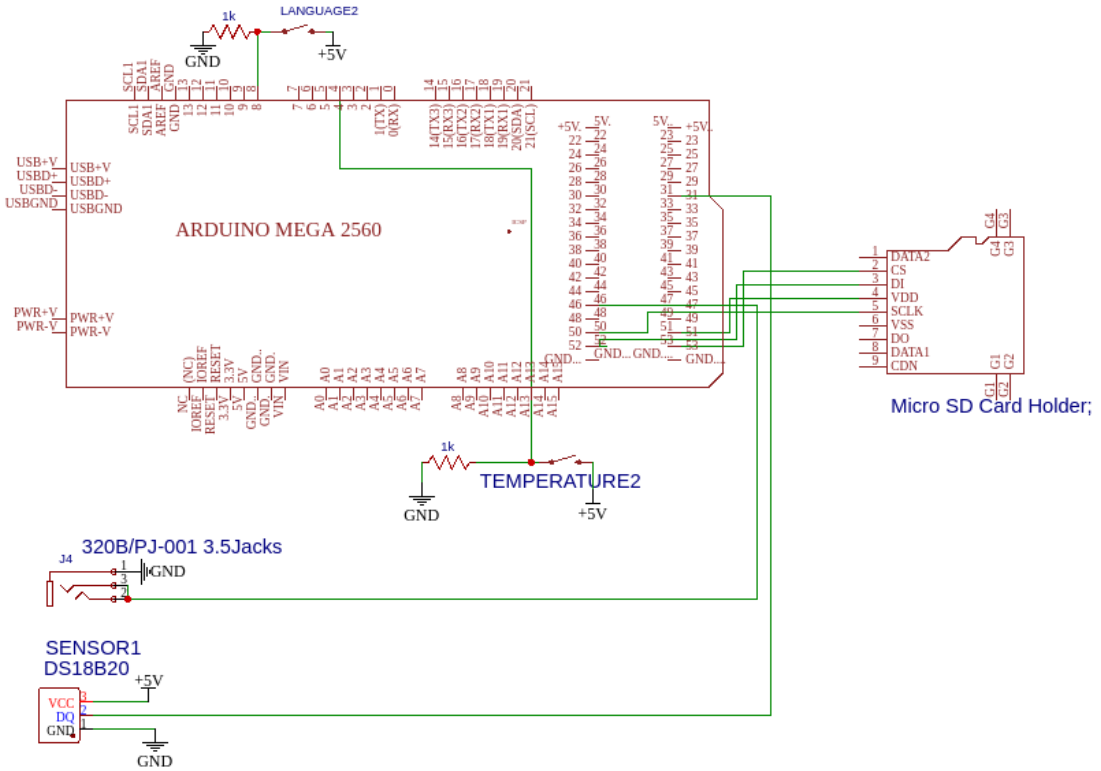

Fig 3.8 (b) Circuit Diagram for Temperature Sensor with Arduino

3.2.10 Pilot Study

Pilot study was conducted when the device was ready for use. For this purpose, 30 Teachers for the students with visual Impairment were oriented of the functionality of the device mostly individually or a maximum of three teachers in a group. The SLTD has been assessed with the help of special teachers. After demonstration with experiments, a questionnaire eliciting responses for the three major components are i) Features of the device, ii) Usability of the Device and the iii)Accessibility of the device. The component features, represents the size of the device portability Language option, volume range and safety of the device and exportable by hands. Under component 'usability', accuracy in measuring weight, accuracy in detecting colour changes ,accuracy in measuring temperature, water sensitivity of the device, uses for self experimentation and allowing volt, Ammeter circuit connection. The Accessibility features include: Display real time data, reading out real time data, and language access (Tamil & English).

The tool has been administered to 30 teachers individually along with the device. The feedback received from the teaches contributed in refining the device by reducing the sharp edges of device, appropriate volume range, and portability of the device. Keeping in view of teachers' feedback, the device has been modified. The result reveals that the tool was highly reliable and the score of Cronbach Alpha is 0.88.

3.3 Stage II: Study the Effectiveness of the Science Lab Talking Device

To study the Effectiveness of the SLTD, samples from the population of persons who are visually impaired have been selected. A description of the study process is given below.

3.3.1 Site Selected

The study was conducted in Secondary Schools in Coimbatore and Madurai district of Tamil Nadu. The students with visual impairments from Grade VI to X were selected.

3.3.2 Selection of the Sample

The sample consisted of 60 students with visual impairment with 24 Boys and 36 Girls. A stratified random sampling technique was adopted to select the sample. In the selection of the sample, Inclusion and Exclusion criteria were kept in mind. Inclusion includes students with visual impairment studying Special and Inclusive schools from Grade VI to X studying in urban schools as specified in the District Educational Office. The exclusion criteria include students with visual impairment with associated disability, students studying in Private schools, visual acuity more than 6/18, those students whose parents were not willing to permit their ward to participate in the study. Keeping these factors, the researcher adopted random sampling. The total number of the sample selected was 78 and out of this, 60 students with visual impairment were finally selected.

Table 3.2 Sample Description

S. No	Type of School	Group				Gender								Total	
		Group I		Group II		Group I				Group II					
						Boys		Girl		Boys		Girls			
		No	%	No	%	No	%	No	%	No	%	No	%	No	%
1	Inclusive Schools	24	40	16	27	8	13	16	27	10	17	6	10	40	67
2	Special School	6	10	14	23	3	5	3	5	3	5	11	18	20	33
Total		30	100	30	100	11	37	19	43	13	43	17	57	**60**	**100**

The above table presents that there were equal number of sample, 30 each in Group I and Group II with 40 students from Inclusive Schools and 20 from Special school. As regards Gender, there were 36 girls and 24 boys. Stratified Random sampling procedure was adopted to select the sample.

3.3.3 Design of the Study

The design adopted in the study is Quasi experimental design. It is a single group design. Here Pre observations/ test and Post observations/ test were made besides Treatment. The layout of the design is:

$$O_1 \times O_2$$

Here O_1 is Pre observation and O_2 is Post observation and ×is the Treatment in the Experimental study.

The students with visual impairment population is very limited. Hence this research adopted quasi experimental design without control group. Here in this quasi experimental research the independent variable is manipulated, participants are not randomly assigned to conditions or orders of conditions.

3.3.4 Variables

Table 3.3 Variables

Variables	Level
Independent Variable	
Designing of 3 / 4 Science Experiments	i) Temperature Measurement ii) Acid & Base Detection iii) Electricity Measurement
Gender	i. Male ii. Female
Dependent Variable	
Science Concepts	Level of Acquisition of Concepts i. Temperature Concept ii. Acid & Base Concept iii. Electricity Concept
Rating of the Device	i. Teachers Opinion on ii. Features iii. Usability iv. Accessibility
Performance of Experiment	i. Assessment in Listing each Material ii. Assessment of Identifying each item and voice out iii. Assessment on Setting the Apparatus iv. Assessment on Performing the procedure of the Experiment and getting the result.

The study mainly intended to examine the use of SLTD to teach science concepts and experiments. Hence the primary independent variable of the study was the manipulations of SLTD using four experiments in science and making students understand science concepts for teaching students with visual impairments. Thus the primary independent variable is SLTD.

The primary objective of the study was to evaluate whether the SLTD would enable students to understand the science concepts & experiments.

The outcome variables were measured on the basis of Features of the device, Usability of the device, Accessibility of the device using the questionnaire.

The study also measured the efficacy of SLTD using other variables such as the Level of Acquisition of science concepts and independently performing the experiments. Since these experiments were designed exclusively for students with visual impairment. Variables control was done in terms of subject selection in terms of prior learning and uniform distribution of teaching, learning environment, and evaluation method.

The first control on sample selection was meticulously chosen by applying strict inclusive exclusive criteria such as visual acuity of more than 6/18, Urban and Inclusive, and special schools.

The experiment was very particular in controlling the environment in which the subjects were taught the science concepts & experiments by herself with the assistance of the concerned science teachers from the beginning thus prior learning or learning through other methods was restricted or controlled.

In terms of the evaluation method, the experimenter tries to control the effect of learning by applying a customized evaluation method for these students who have been a part of the experiment and thereby could generalize the results obtained only to this learning method.

3.3.5 Construction of the Tool

i. Personal Data Bank

To collect general information regarding Gender, Type of School Programme and Grade, Personal data bank was developed. The tool is given in ***Annexure I***

ii. Assessment of Level of Acquisition of Science Concept before and after Introduction of Science Lab Talking Device

The test was aimed to measure the acquisition of the Physical Science Concepts. Multiple choice questions were selected from the curriculum for three concepts viz.

Temperature, Acid & Base and Electricity. There were three choices for each question which had very minimal differences between choices.

For Group I students (Grade VI to VIII) ,15 Multiple Choice Questions and for Group II, (Grade IX & X), 30 Multiple Choice Questions were given. This test was administered as pretest and posttests.

Scoring: For each correct response, One score and Zero score for incorrect response. The tool is appended in ***Annexure II & III.***

iii. Assessment of Performance in Experiments

The test was aimed to measure the Performance of students in the following Experiments.

a. ***Experiment for Group I***

1. Temperature Measurement Experiment
2. Acid & Base Experiment
3. Light Detection -Electricity Experiment

b. Experiment for Group II

1. Temperature Measurement Experiment
2. Acid & Base Experiment
3. Electric Current - Ammeter Experiment
4. Electric Force - Voltage Experiment

c. Measurement criteria

The measurement criteria for both Group I& Group II include:

1. Stating the items/Materials required (aware of the required items/ Materials for the experiment)
2. Identification of Material by exploration except Acid & Bases
3. Setting the Apparatus
4. Performing the Experiment

d. Scoring procedure:

Total Score for each experiment for Group I& Group II is 25 & 30 respectively. The score was done on task basis and the level of difficulty of the task. The tool and the scoring procedure is appended in ***Annexure IV to X.***

iv. Measuring Internal Consistency of Tool

A rating scale describing the device in terms of appropriate feature, usability and accessibility of the device was developed to get the rating of device from the Teachers of students with visual impairments and students with visual impairment themselves.

For students' rating 15 questions and for Teachers' Rating, apart from 15 questions 10 more additional questions were included. A four point rating was given as 4-Strongly Agree, 3-Agree, 2-Disagree, 1-Strongly Disagree. The tool and the scoring procedure is appended in ***Annexure XI to XII.***

Tools were developed with the help of literature survey and expert opinion. Necessary modification was made after administering the tools in the Pilot Study.

3.3.6 Implementation of the Intervention

The intervention was given to Students with visual impairments in four major areas

1. Orientation to Basic Science Concepts
2. Introduction of Existing Science Lab Materials/Instruction & the Adaptation made in Materials/Instruction
3. Instruction for Using the Device for Various Experiments
4. Procedure for Introducing to Science Experiment using SLTD

1. Orientation to Basic Science Concepts

Prior to the actual study intervention was given to students for acquisition of basic concepts related to Temperature, Acids & Bases, and Electricity. The intervention to acquire basic concepts include the following :

a. Concept of Heat

1. Source of Heat
2. Heat
3. Hot and Cold Objects
4. Temperature
5. Heat and Temperature
6. Expansion in Solids
7. Thermos Flask (Vacuum Flask)

b. Concept of Acid and Bases

1. Acids
2. Bases
3. Tests for Acids and Bases
4. Salts

c. Concept of Electricity

1. Sources of Electricity
2. Cell
3. Electric Circuits
4. Conductors and Insulators
5. Battery
6. Electric Current

2. Introduction and Orientation on Existing Science Lab Materials& the Adaptation made in Materials and Instruction

The most common materials used in the Science laboratories were introduced to the students with visual impairments. The purpose of each materials and the procedure to how to use it was taught to the Students with visual impairments. Thus safety precautions, skills, and tools were the considered.

Table 3.4 Existing Vs Adapted Material/Instruction

Existing Material /Instruction	Adapted Material /Instruction
Glass Funnels and Bottles	i. Labelled in Braille and Large Print. ii. Placed in stands or clamps so they cannot be unintentionally knocked over.
Beakers with Print Label	Beakers of different sizes labeled with Braille & Large Print. Ex. 25 ml, 50 ml
Conical Flask	Conical Flasks of different sizes where labeled in Braille & Large Print.
Lab Stands	i. Lab Stands No adaptation ii. Adapted Instruction : Keep it near while doing Heat Experiments
Test Tubes	Labeled in Braille and Large Print
Bunsen Burner	Bunsen Burner: Painted with contrasting non-flammable paint in the inlet and outlet for Low Vision students.
Wire Gauze	Wire Gauze: No adaptation
Tripod stand	Tripod stand: No adaptation
Match Sticks for Handling Flames	Lighter to lit
Stop Watch - visual	Talking Stop watch
Litmus paper	Litmus paper: No adaptation
Phenolphthalein Paper	Phenolphthalein Paper: No adaptation
Battery	(+) ,(-) terminal is marked in tactile
Wires for circuit	No adaptation
Light sources such as flashlights, bulbs, and LEDs	No adaptation
Syringe	Tactual markings on the plunger to indicate liquid is contained in the device. Tactual markings are notches with Braille numbers as labels.
Handling Flames - Safely Handle	Instructional Adaptation Bunsen burner - i. check the gas line very carefully if it is attached securely ii. Resting a finger lower on the barrel if necessary, and then turn on the gas.

Existing Material /Instruction	Adapted Material /Instruction
	iii. The student to listen to the sound of the gas igniting. Aware of the sound of the burning, in case the flame goes out
Handling Chemicals	i. Name of the chemical is labelled in Braille & Low Vision. ii. Get the correct chemical by reading the label. iii. Use funnel or syringe to pour chemicals iv. Replace it in the same place after the experiment
Thermometer	Temperature Sensor of SLTD
Colour detection	Colour Sensor of SLTD
Ammeter	Ammeter Sensor in SLTD
Volt meter	Volt meter sensor of SLTD
Light Detection	Light sensor of SLTD

3. Instruction for Using the Device for Various Experiments

The Science Lab Talking Device was introduced to students with Visual Impairment. The students were allowed to explore the device with their hands and each part of the device was introduced with its features.

Basic Step involved in operating the SLTD device

1. Check the head phone connection of the device and place the head phone in both the ears
2. Connecting the power cable of device with the power supply and turn on the switch of the power supply
3. Select the Language Key (Tamil /English). Consider the selected language is English
4. Device voice out "Ready"

Fig: 3.9 Investigator Introducing Sensor Device to VI Student

Steps involved in detection of color in color sensor

1. Place blue litmus paper on the colour sensor probe
2. Operate the colour sensor key push button
3. Device detects the colour of the litmus and voice out as “Blue”
4. Repeat the process with different colours of litmus papers.
5. The same steps can be done using Tamil voice selection

Steps involved in measurement of temperature in temperature sensor

1. Place Temperature sensor probe inside the substance ex. Boiling water, ice cube etc.
2. Operate the temperature sensor key push button
3. Device measure the temperature and voice out as “100 degree” or “0 degree”.
4. Repeat the process with different surface/substance.
5. The same steps can be done using Tamil voice selection

Steps involved in detection of light

1. Place light sensor probe near the light source E.g Bulb
2. Operate the light sensor key Push button
3. Device detects the light and voice out as ”light is on or off”
4. Repeat the process with different lighting condition.

Steps involved in measurement of current in ammeter sensor

1. Connect the circuit with + and - terminals of the inbuilt ammeter sensor
2. Operate the ammeter sensor key Push button
3. Device measure the current and voice out as “5 Amp” or “10 Amp”.
4. Repeat the process with different power circuits.
5. The same steps can be done using Tamil voice selection

Steps involved in measurement of voltage in voltmeter sensor

6. Connect the circuit with + and - terminals of the inbuilt volte meter sensor
7. Operate the volte meter sensor key Push button
8. Device measure the voltage and voice out as “6volt” or “12volt”.
9. Repeat the process with power circuits.
10. The same steps can be done using Tamil voice selection

The below use case diagram explains the Input and Output of the device**.**

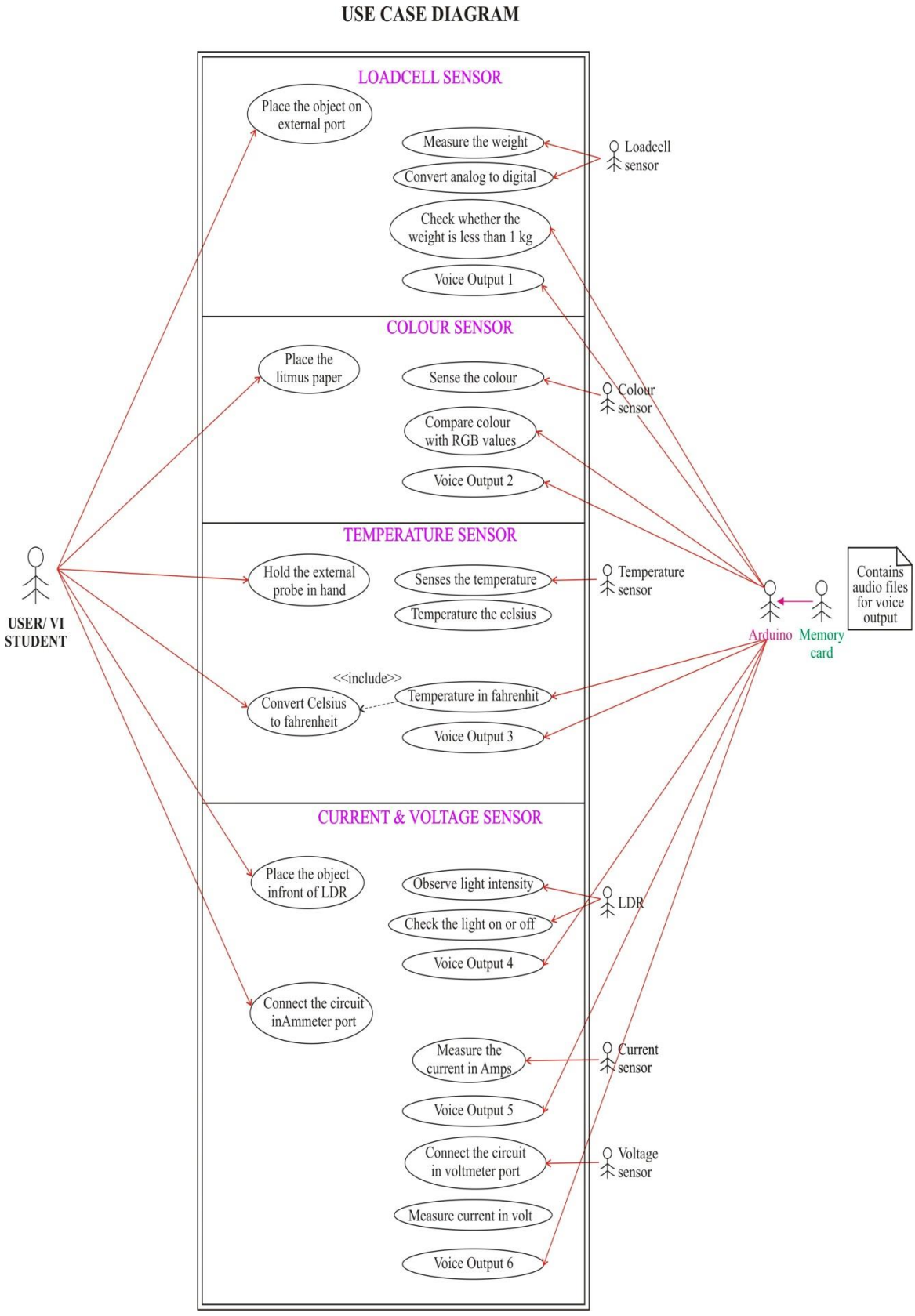

Fig: 3.10 Use Case Diagram of SLTD Device

4. Procedure for Introducing to Science Experiment using SLTD

Students with visual impairments were exposed to various laboratory activities and experiment using SLTD. During intervention Phase time duration of six months was spent to teach lab experiments and activities Students exposed to various activities are described below

a) Experiment/Activity related to Temperature Measurement

1. Temperature of Boiling Water
2. Comparing Temperature of Hot/Cold/Room Temperature Water
3. Temperature of Ice Cube
4. Comparing Time Taken for boiling 1ltr/5ltr water
5. Comparing the Temperature of 1 cup of boiling water/1 Spoon of Boiling Water
6. Comparing the Temperature of 1 cup of Hot Water/ 1 Spoon of Hot Water
7. Temperature of human(Hand/Neck)
8. Heat Conduction Activity
9. Latent Heat of Ice Cube Activity
10. Melting Point of Wax Experiment

b) Experiment related to Detecting Acid and Base

1. Finding out the nature of the solution using litmus paper (Lemon juice, Vinegar, Calcium Hydroxide, Bathing Soap Solution and Orange Juice)
2. Finding out the nature of solution using litmus paper (Hydrochloric acid, sulphuric acid, Nitric acid, Sodium Hydroxide and Potassium hydroxide)
3. Finding out the nature of the solution using Phenolphthalein Paper

c) Experiment/Activity related to Electricity Experiment

1. Source of Electricity - Lemon with Zinc & Copper Electrodes
2. Source of Electricity - A bulb connected with Electric cell
3. Conductor& Insulator - Bulb Glows or not (Pin, Match Stick, Pen, Metal Rod, Wooden Rod, Spoon, Rubber)
4. What happens when an electric current is passed through water
5. Comparison the physical properties of metal and non metal
6. Simple Electric Circuit

7. Series Circuit
8. Parallel Circuit
9. Measuring the Electric current- Ammeter
10. Measurement of Electric Potential - Volt meter
11. Do Iconic compound conduct electricity or not?
12. Do Components made of different materials offer different electrical resistance?

Each activity was introduced to students in four major components

i. Listing the materials required for the activity/Experiment
ii. Identification of Materials
iii. Setting the Apparatus
iv. Performing the Experiment using Science Lab Talking Device.

An example for the Procedure of introducing the student to an experiment is given below:

Name of the Experiment: Temperature of Boiling Water

Initially the student was asked to list & identify the items/materials required for measuring the temperature of boiling water

i) Listing &Identification of the Materials Needed for the Experiment

1. Bunsen Burner
2. Tripod stand
3. Wire Gauze
4. Beaker
5. Water
6. Science Voice Talking Device
7. Record Note/Braille Note Taker

ii) Setting the apparatus & Performing the Experiment

In this particular experiment, the students were expected to set the apparatus with procedure & performing the experiment. The order of the procedure described below:

1. Set the Bunsen Burner
2. Place Tripod Stand on Bunsen Burner
3. Place the Wire Gauze on the Tripod stand
4. Place the Beaker with water on the Tripod Stand
5. Place the Head Phone of the Science Lab Talking Device on both the Ears
6. Connect the power supply with the device
7. Select the Language Option -Tamil/English
8. Connect the Science Lab Talking Device with the Power Supply
9. Place the Temperature Sensor Probe in the Beaker of water
10. Lit the Bunsen Burner and Heat the Water with lighter
11. Watch for The water to Boil - Listen to the sound of boiling water
12. At the time of Boling, Press the Temperature Sensor Push Button and get the Temperature Measurement (100C)with the audio Voice output

The investigator initially selected three experiment for Group I and four Experiments for Group II as pretesting their performance and during the intervention the same experiment were given to assess the performance and the scores taken as intermittent score and after intervention, the same experiments were given to assess their performance and the scores were considered as posttest score.

3.3.7 Assessment of Students performing Experiments using SLTD

3.3.7.1 Experiment 1: Melting Point of Wax Experiment

Step 1: Listing the items required for the Experiment

Student was asked to list the items/materials required for performing the experiment

For listing of each item ½ mark was given. Students had to tell the following items: Beaker, Burner, Tripod Stand, Boling Tube, Wire Gauze, Stand and Clamp, Candle Wax, Bowl of Sand, Talking Stop Watch and Science Lab Talking Device. For those 10 items, total score given is 5.

Step 2: Identification of the Items

The students were asked to identify the listed items. For identification of each item ½ mark was given. Total mark of 5 was given for identification.

Step 3: Set the Apparatus

The students were asked to set the apparatus. For each task mark was allotted according to the difficulty level. Observation was made minutely to assess the performance of students. For setting the apparatus total mark allotted was 8.

Fig: 3.11 VI Student performing Melting point of Wax Experiment

i. Does the Student set the Burner?
ii. Does the Student Set the Tripod Stand?
iii. Does the Student Place the wire Gauze on the Tripod stand?
iv. Does the student place beaker with water on the Stand?
v. Does the Student fix boiling tube with stand and clamp?
vi. Does the Student put the candle wax in to the boiling tube?
vii. Does the student place the thermometer /temperature sensor into the boiling tube?

Step 4: Performing the Experiment

The students were asked to complete the experiment by performing it and finding the results independently. The following steps need to be performed by the students to complete the experiment. For each task, mark was allotted according to the difficulty level. Total mark allotted for procedure was 12 and the Total mark for Melting Point of Wax experiment is 30

i. Does the student note the beginning reading of the temperature using SLTD?
ii. Does the student on the burner & Melt the wax in warm water bath?
iii. Does the student note the temperature when wax melted entirely?
iv. Does the student remove the boiling tube from bath and pour the candle into the bowl of sand?
v. Does the student record the temperature for each 30 sec using SLTD Stop watch/ Talking Stop watch?
vi. Does the student find out the same time for constant temperature at which liquid and solid are present?

3.3.7.2 Experiment 2: Detecting Acid or Base

Step 1: Listing the Items required for the Experiment

For listing of each item ½ mark was given. Total marks of 4 given for listing. Students have to tell/name the following items

i. Test Tubes(4 nos)
ii. Blue Litmus Paper
iii. Red Litmus Paper
iv. Phenolphthalein indicator
v. Sample Liquid - Hydrochloric
vi. Sample Liquid Sodium Hydroxide
vii. Liquid Filler &/ Test Tube Holder
viii. Record Note &SLTD

Fig: 3.12 VI Student Performing Acid & Base Experiment

Step 2: Identification of the items

The students were asked to identify the listed items. For identification of each item ½ mark was given. Total mark of 4 was given for identification

Step 3: Set the Apparatus

The students were asked to set the apparatus. For each task, mark was allotted according to the difficulty level. Observation was made minutely to assess the performance of students. For setting the apparatus total marks allotted was 7.

i. Does the student take 2 ml sample liquid- Hydrochloric in liquid filler and pour in Test tube 1?
ii. Does the student place the test tube 1 in Test tube holder?
iii. Does the student take 2 ml sample liquid- Sodium Hydroxide in liquid filler and pour in Test tube 2?
iv. Does the student place the test tube 2 in Test tube holder?
v. Does the student ready with Litmus papers?
vi. Does the student ready with Phenolphthalein indicator?
vii. Does the student ready with Record & Set up SLTD?

Step 4: Performing the Experiment

The students were asked to complete the experiment by performing it and finding the results independently. The following steps need to be performed by the students to complete the experiment. For each task mark was allotted according to the difficulty level. Total mark allotted for procedure was 15.Total marks for Acid & Base detection experiment is 30.

i. Does the student take Blue Litmus -Check for Colour of the litmus paper with Senor Device
ii. Does the student take the test tube 1 and Dip the Blue litmus in it
iii. Does the student check for any colour Changes in Blue litmus with Sensor Device (Red colour)
iv. Does the student record the reading in note book
v. Does the student take Red litmus (Check for litmus colour with Sensor device)
vi. Does the student dip in to the liquid in Test tube 1
vii. Does the student check for any colour Changes in Blue litmus with Sensor Device (No changes)
viii. Does the student record the reading in note book
ix. Does the student take Phenolphthalein indicator & check for colour with Sensor Device
x. Does the student dip in sample liquid in test tube1
xi. Does the student check for any Colour Changes in Phenolphthalein indicator (No changes- Colourless)
xii. Does the student record the reading in note book
xiii. Does the student take Blue Litmus -Check for Colour of the litmus paper with Sensor Device
xiv. Does the student take the test tube 2 and Dip the Blue litmus in it
xv. Does the student check for any colour Changes in Blue litmus with Sensor Device (No changes)
xvi. Does the student record the reading in note book
xvii. Does the student take Red litmus (Check for litmus colour with Sensor device
xviii. Does the student dip in to the liquid in Test tube 2

xix. Does the student check for any colour Changes in Blue litmus with Sensor Device (Red will Change into Blue Colour)
xx. Does the student record the reading in note book
xxi. Does the student take Phenolphthalein indicator & check for colour with Sensor Device
xxii. Does the student dip in sample liquid in test tube 2
xxiii. Does the student check for any Colour Changes in Phenolphthalein indicator (Change to pink colour)
xxiv. Does the student record the reading in note book

3.3.7.3 Experiment 3: Measuring Current Ammeter Experiment

Step 1: Listing the Items required for the Experiment

For listing of each item ½ mark was given. Total mark of 4 was given for listing. Students have to tell/identify the following items

i. Wires 4
ii. Battery 1
iii. Bulb 1
iv. Switch
v. Ammeter with SLTD
vi. Record Note

Step 2: Identification of the Items

The students were asked to identify the listed items. For identification of each item ½ mark was given. Total mark of 4 was given for identification.

Step 3: Set the Apparatus

The students were asked to set the apparatus. For each task mark was allotted according to the difficulty level. Observation was made minutely to assess the performance of students. For setting the apparatus total mark allotted was 5.

i. Does the student place the Bulb at down centre of the circuit?
ii. Does the student place the switch left to the bulb?
iii. Does the student place the battery at top centre of the circuit?

iv. Does the student place the inbuilt Ammeter connection in SLTD at right side of the circuit?
v. Does the student connect the SLTD with power supply?

Step 4: Performing the Experiment

The students were asked to complete the experiment by performing it and finding the results independently. The following steps need to be performed by the students to complete the experiment. For each task mark was allotted according to the difficulty level. Total mark allotted for procedure was 15.

i. Take wire 1 and connect (-) terminal of the bulb
ii. Connect the other end of the wire 1 with (-) terminal of Ammeter port in SLTD
iii. Take wire 2 and connect in (+) terminal of the bulb
iv. Connect the other end of the wire 2 with switch
v. Take wire 3 and connect the other port of the switch
vi. Connect the other end of the wire 3 with (-) terminal of the battery
vii. Connect wire 4 in (+) terminal of the battery
viii. On the switch
ix. Operate the SLTD Ammeter Sensor with push button
x. Listen to the Measurement of current Ex. 6 Amp

3.3.7.4 Experiment 4: Measuring Electric Potential Volt meter Experiment

Step 1: Listing the Items required for the Experiment

For listing of each item ½mark was given. Total marks of 4 given for listing. Students have to tell the following items.

i. Wires 4
ii. Battery 1
iii. Bulb 1
iv. Switch
v. Volt meter with SLTD
vi. Record Note

Fig: 3.13 VI Student Detecting Light using the SLTD Device

Step 2: Identification of the items

The students were asked to identify the listed items. For identification of each item ½ mark was given. Total mark of 4 was given for identification.

Step 3: Set the Apparatus

The students were asked to set the apparatus. For each task mark was allotted according to the difficulty level. Observation was made minutely to assess the performance of students. For setting the apparatus total mark allotted was 7

i. Does the student place the Bulb at down centre of the circuit?
ii. Does the student place the switch left to the bulb?
iii. Does the student place the battery at top centre of the circuit?
iv. Does the student place the inbuilt Ammeter connection in SLTD at right side of the circuit?
v. Does the student connect the SLTD with power supply?

Step 4: Performing the Experiment

The students were asked to complete the experiment by performing it and finding the results independently. The following steps need to be performed by the students to complete the experiment. For each task mark was allotted according to the difficulty level. Total mark allotted for procedure was 15.

i. Does the student take wire 1 and connect (-) terminal of the bulb?
ii. Does the student connect the other end of the wire 1 with (-) terminal of Volt meter port in SLTD?
iii. Does the student take wire 2 and connect in (-) terminal of the bulb?
iv. Does the student connect the other end of the wire 2 with (-) terminal of the Battery?
v. Does the student take wire 3 and connect (+) terminal of the battery?
vi. Does the student connect the other end of the wire 3 with (+) terminal of the bulb?
vii. Does the student connect wire 4 in (+) terminal of the bulb?
viii. Does the student connect the other end of wire 4 with (+) volt meter terminal of SLTD?

ix. Does the student operate the SLTD Volt meter Sensor with push button
x. Does the student listen to the Measurement of volt Ex. 6 Volt?
xi. Does the student note the reading in Braille?

Points to be Borne in mind while introducing the Science Experiments to Students with Visual Impairments

The following standards were set while performing activity/experiment:

i. The existing knowledge of the students is tried to be elaborated before each activity.
ii. Enough time is given to each student to investigate the activity materials by touching.
iii. Student activity guide is distributed to each student before the activity.
iv. The teachers must allow students to do each activity on his own.
v. Student safety is emphasized at every stage and precautions are to be told initially.
vi. Students' active involvement was reinforced to learn concepts better.
vii. Students are taken note about each concept at the end of the activity.
viii. Students are taken to Real laboratory
ix. Set a Work table for Students with visual impairments made of stone to avoid accidents during handling chemicals
x. Set a work corner of the Laboratory for students with visual impairments.
xi. Place all items needs for the experiment left side of the table
xii. Teachers of students with visual impairments incorporate other modes of teaching the visual concepts to the students
xiii. Organization of the Lab and of material is very important for the students those who are blind or students with visual impairment student's understanding. To aid the student's mobility through the room, the furniture should maintain in its configuration. Also, the student needs to have a firm mental picture of where objects are in the laboratory so they are able to locate them independently. Therefore, every object should have a permanent location. For the students those who are blind or students with visual impairment student to accurately follow the material in class it must be presented in an organized manner.

Lesson plans prepared in advance will enable the teachers to ensure a progression in a logical fashion that is easy to follow both orally and in text.

xiv. Using real examples provides concrete reinforcement for students those who are blind and students with visual impairments. Two-dimensional representations and verbal descriptions do not convey as much information as real, three-dimensional objects. It is best to provide these objects whenever possible. To aid in the students understanding of the interactions between objects, demonstrations should relate to the student's daily life or experiences.

xv. The student's peers can be useful resources as well. The can sighted lab partner. The classmates can explain what is happening during a demonstration. The assistance of a sighted peer is sometimes more beneficial than the minimal experience gained by performing the task unaided. This type of relationship is beneficial to both students, as both can still participate equally in the classroom.

xvi. Power cords are dangerous because they provide an unexpected obstacle for the students those who are blind or students with visual impairment. Cords can trip people, upset machines or other devices, and cause objects to move or fall. To avoid these situations, power cords should be kept out of the way.

3.4 Data Collection Procedure

Stage I: Designing & Development of SLTD

This phase took for a period of 13 months.

Stage II: Study the he Effectiveness of Science Lab Talking Device

Phase I

To find out the acquisition of the science concept, a questionnaire was administered and data were collected

To find out the knowledge and performance level of science experiment, the students were asked to demonstrate/perform experiments viz. Temperature Measurement Experiment, Acid & Base Experiment and Electricity Experiment

The duration for the activities in the Phase I was a period of two months. This testings were considered as pretest.

Phase II

The students in Group I and Group II were intervened separately. In this phase, the students were exposed to various activities related to measurement of Temperature, Acid &Base Experiment and Electricity Experiment with the help of the device. This phase has consumed a period of four months. For intervention, four to five students were grouped and also individual instruction was given whenever needed.

Phase III

Posttest was administered using the same tool adopted in pretesting. Posttest was administered by making the students perform the experiment individually. This phase has consumed one month duration. The score collected in this phase was considered as posttest score.

3.5 Data Analysis

For analysing the data, following statistical techniques were used

i. Factor Analysis was used for Teachers Rating on Device Usage
ii. For Comparison of Science Concept of Students with visual impairments '***t***' *test* was used
iii. For Comparison of Temperature Concept, Acid & Base Concept and Electricity Concept of Students with visual impairments t test was used
iv. The Repeated Measures ANOVA was employed to for Performance Score of Temperature Experiment for both Group I & II
v. The Repeated Measures ANOVA was employed for Performance Score of Acid & Base Experiment for both Group I & II
vi. The Repeated Measures ANOVA was employed for Performance Score for Electricity Experiment for both Group I & II
vii. The Repeated Measure ANOVA was employed for analyse of component wise performance as Listing of Material, Identification of Material, Setting the Apparatus and Performing the Procedure during pre, Post & Intermittent.

65,67,69,72,74,76,79,80,82,83,85-92,94,96,97,98,101,102,104-107

66,70,71,73,75,77,78,81,84,93,95,99,100,103