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School Community Project and Integrated STEM Education Practice: Smart Classroom Design

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Abstract: *This study aims to present a best practice example of a school community project carried out in the context of open schooling in which integrated STEM education is reflected. In this context, how the school community project can be carried out and how the integrated STEM education understanding can be reflected were emphasized. The study was conducted in a public school with 6th-grade students aged 12-13. Thirteen of the participant students were male, and six were female. In the process of conducting the study, the Invite, Co-create, Act, Share, and Evaluate (INCREASE) roadmap, which was created within the scope of the Meaningful Open Schooling Connects Schools To Communities (MOST) project and designed for the implementation of school community projects in the context of open schooling, was followed. Student-student and student-stakeholder interactions were managed, the factors to be investigated in the project, how the research would be carried out, and how the evaluation would be carried out were decided collaboratively in the Co-create stage. Students also were supported to produce and discuss ideas based on evidence in the Co-create stage. Students researched collaboratively how an energy-efficient classroom could be designed within the plan they created with stakeholders and made a model by working on actual data. Arduino Uno circuit boards, sensors and software were used while creating the model. Therefore, students worked on software and hardware.*

Keywords: *Open schooling; school community project; integrated STEM education activity; smart classrooms*

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Introduction

Individuals need more knowledge and skills to produce solutions to the problems that arise in an increasingly complex world in the 21st century. There is also a need to develop the necessary tools to produce solutions, critically analyze the information, and make decisions by considering the industry's challenges, technological innovations, and society (Mulero et al., 2022). Therefore, educating qualified individuals and engaging them in critically analyzing and producing solution processes is necessary. However, it is argued that education with curricula focusing on physics, chemistry and biology does not meet the needs of the majority of students who need a broad overview of the main ideas that science offers, how it produces reliable knowledge and the limits of certainty. Moreover, its content and pedagogy are increasingly failing to enable individuals to learn more about science (Osborne & Dilon, 2008).

The international economy has been experiencing rapid technological and global growth resulting in huge demand for labour in science, technology, engineering and mathematics since the early 21st century (Casto & Williams III, 2020). Within the European Union, countries increasingly face labour shortages in science, technology, engineering and mathematics (Triangle & Argutyan, 2022). Therefore, there is a need for educational activities that include innovative perspectives in terms of providing individuals with the qualifications needed regarding knowledge and skills, the quality of the training provided, and meeting the required labour force. In this regard, open schooling and integrated STEM education can be considered two key aspects. In other words, open schooling and integrated STEM education contain the necessary understanding for raising qualified individuals and meeting the needs. Because the understanding that the involvement of stakeholders and citizens in research and development activities increases the degree of co-creation and maximises its impact (European Commission, 2017) and the open schooling approach stand on similar fundamentals. Both reflect the efficiency and strengths of stakeholders and citizens working together and establishing collaboration and integration across fields. Therefore, reflecting these two understandings in the education process creates opportunities to address the requirements mentioned earlier.

Kelley and Knowles (2016) explained integrated STEM education as "the approach to teaching the STEM content of two or more STEM domains bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning" (p. 3). Open schooling also involves the understanding that schools are places that influence community well-being in cooperation with stakeholders, encouraging families to become real stakeholders in school life and activities and allowing experts from businesses and civil society to actively bring real-life projects into the classroom (European Commission, 2015).

Open schools have the below understandings.

- They support collaborations with non-formal and informal education providers, businesses, parents and local communities to ensure relevant and meaningful participation of all social actors in science, to increase understanding of the study of science and the competitiveness of science-based careers, employability and competitiveness.

- They become a tool for community well-being.
- They support partnerships that promote science and technology research findings, expertise, networking, sharing and application, thereby bringing real-life projects into the classroom.
- They focus on effective parental involvement (Sotiriou et al., 2017, pp 15-16).

School community projects offer valuable educational opportunities to carry out activities in open schooling. Because with school community projects, the problems related to the well-being of society are investigated and solved with the cooperation established [www.icse.eu/most/]. In this context, reflecting the integrated STEM understanding to the process of finding solutions to problems in school community projects both supports the process of finding solutions to the problems affecting the well-being of society and offers an innovative understanding to educate the individuals needed in STEM fields.

As a result of the aforementioned requirements and opportunities, this study aims to present a good practice example of a school community project carried out in the context of open schooling where integrated STEM education is reflected. In this context, how the school community project can be carried out and how the integrated STEM understanding can be reflected are emphasized.

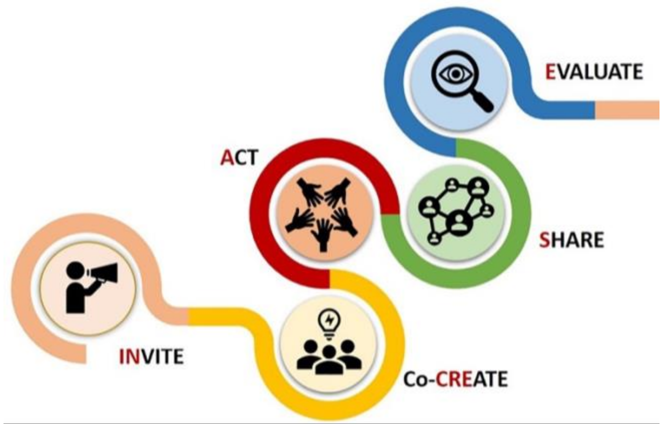
Method

This study was conducted in a public school with 6th-grade students aged 12-13. Thirteen of the participating students were male, and six were female. The students have experience with the Arduino Uno circuit board, sensors, and coding system. However, students do not have prior knowledge and understanding of school community projects. The teacher is familiar with the school community project process, has been involved as a stakeholder in different school community projects, and has experience with Arduino circuit board, sensors and software.

While conducting the study, the Invite, Co-create, Act, Share, and Evaluate (INCREASE) roadmap (see Figure 1), which was created within the scope of the Meaningful Open Schooling Connects Schools to Communities (MOST) project [www.icse.eu/most/] and designed for the implementation of school community projects in the context of open schooling, was followed.

Figure 1

INCREASE Road Map [www.icse.eu/most/]



The study includes eight science and engineering practices (National Research Council, 2013) reflecting the practices of professional scientists and engineers specified in Table 1. The following outcomes are expected to be achieved during the project process.

- To create a model for a safe and energy-efficient classroom in COVID-19.
- To teach the understanding of energy efficiency,
- To shift students' attitudes towards science, technology, and engineering.
- To clarify the relationship between the model and daily life.

Table 1

Relation of the Study to Science and Engineering Practices

Scientific and engineering practices	Stage addressed in the study
Asking questions and defining problems	Opening lesson and Co-create
Analyzing and interpreting data	Act
Constructing explanations and designing solutions	Co-create and Act
Obtaining, evaluating, and communicating information	Act and Share
Planning and carrying out investigations	Co-create and Act
Using mathematics and computational thinking	Act
Engaging in arguments from evidence	Co-create

The activities carried out at each stage, and their relationship with science and engineering practices are described below.

Before starting the stages of the INCREASE roadmap, an opening lesson was organised with the students by the teacher who will lead the activities of the school community project. The students were informed about sustainability and energy management themes in the lesson. In addition, it was emphasised what could be researched in the context of energy management and which topics the students would like to research. As a result of the lesson, a researchable issue was identified. The issue is how an energy-efficient classroom can be designed in the condition of the COVID-19 pandemic. It can be said that the opening lesson was focused on the well-being of society or the identification of a problem that concerns the community. After the opening lesson, the first stage of the INCREASE roadmap, Invite, was started.

Invite Stage

Students and the teacher invited people who may contribute to the school community project. Two experts in computer and instructional technologies, two experts in science education, and three people who are family members of some students accepted the invitation and supported the project process as stakeholders.

Co-create Stage

In the co-create phase, stakeholders and students collaboratively designed the project's research process, focusing on the issue previously determined in the opening lesson. In this process, an online meeting was held since the stakeholders were located in different provinces, the common time problem for stakeholders and students, and the pandemic conditions. The starting point was how to design an energy-efficient classroom considering the COVID-19 pandemic in the meeting. It was decided to use Arduino Uno circuits to investigate classroom illuminance, classroom ventilation and the body temperature of the individuals who joined the lesson.

Effective meeting moderation is essential to reach shared decisions for the research process. The focus of stakeholders and students on a common goal can be met as a result of effective management of the interaction between stakeholders and students. In this process, students asked questions and tried to identify the problem. In addition, students were involved in the discussion process based on evidence in the decisions to be taken, tried to create explanations and contributed to the solution for the problem. Therefore, students both experience science and engineering practices and design the research process together with stakeholders on a subject related to social well-being.

The following decisions were taken during the meeting.

- Establishment of Arduino Uno circuit board system (see appendix 2 for an anecdote on the history of science and engineering for coding)

- For classroom illuminance level,
    - investigation of the ideal illuminance level of the classroom environment
    - determination of the level of the illuminance of different areas in the classroom
    - activating or deactivating the classroom lighting system, depending on the level of illuminance

- For classroom ventilation,
  - determining the amount of CO_2 in the classroom (see appendix 2 for an anecdote on the history of science and engineering for air smog)
  - the system gives a warning for ventilation or opening the windows when the amount of CO_2 in the classroom exceeds critical values

- Determining the body temperatures of the people joining the lesson and warning the system in people with critical body temperature (see appendix 2 for an anecdote on the history of science and engineering for temperature).

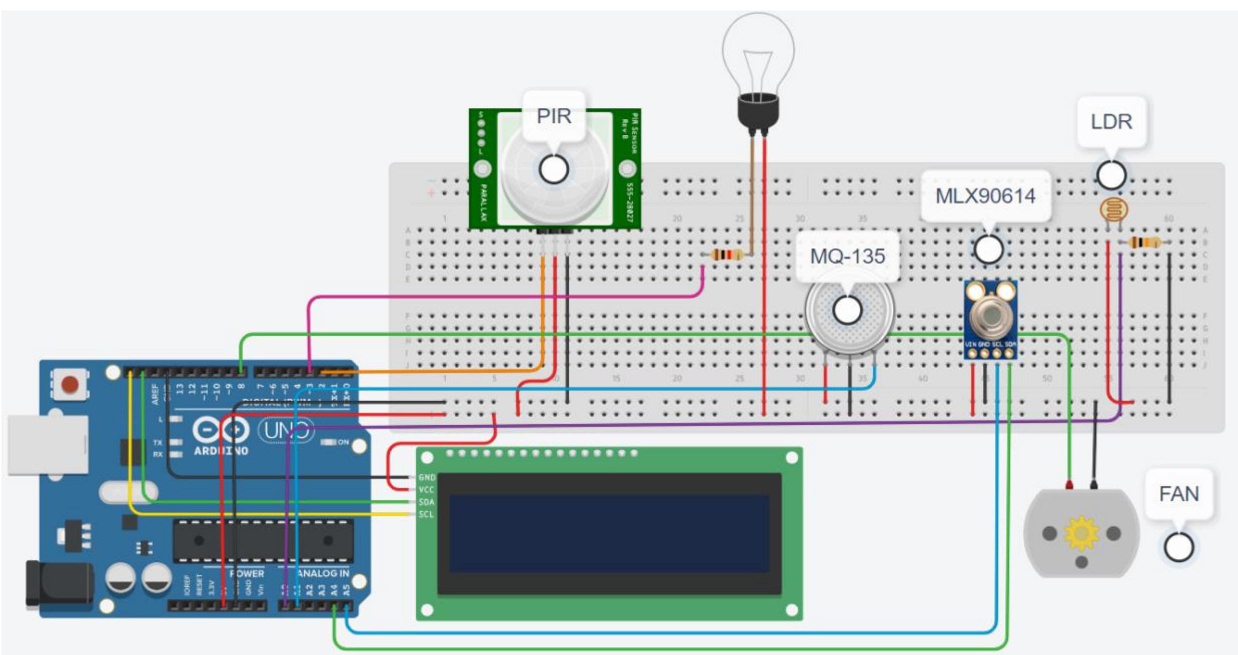
Finally, it was emphasised how the project would be evaluated to determine whether or not the school community project has been successful. Whether the system can be simulated, whether it can measure illuminance level, CO_2 and temperature in the circuit systems to be created and whether it gives appropriate responses have been determined as evaluation situations.

Act Stage

Students conducted the research aligned with the decisions taken during the Co-create stage. They designed solutions on how an Arduino Uno circuit board and sensors can be connected and created their systems using Arduino IDE software. The software provides students with information about whether the system will work without using hardware elements. Figure 2 shows the working circuit produced on the software.

Figure 2

Circuit Designed by Software



The students built the circuit using the following materials.

- Computer
- Arduino Uno
- Arduino USB cable
- Breadboard and jumper cables
- Resistors
- LDR light detection sensor
- PIR Motion Detection Sensor
- Mq-135 Gas sensor
- MLX90614 infrared temperature sensor
- LED display

Students obtained from the literature that the minimum illuminance level of a classroom should be 500 lux (Pelsan, 2022). The illuminance levels were measured from different areas in the classroom. In this way, the necessity of using light devices in various classroom areas was determined. In other words, they reached results for illuminance level by analysing and critically evaluating the information they acquired.

The research on classroom ventilation showed that the amount of CO_2 in the classroom environment should not exceed 1000 ppm (Bulut, 2011). Students used the information in the coding of the Arduino sensor.

Finally, for the body temperatures of the people joining the lesson, the system was designed to warn people with critical body temperature, which was determined as 37^{o}C. In this process, it can be said that students used mathematical and computational thinking from science and engineering practices to create the codes running in the background of the Arduino Uno system. The system developed in the Act stage can be accessed in Video (https://youtu.be/omyZgVkQ9zM)

If the school, teachers, or students have Texas Instrument (TI) tools rather than Arduino Uno boards and components, they can conduct their research according to decisions made through TI tools during the Co-Creation phase. They can build their system using the coding platform that students code with TI graphing calculators to explore math, science, and STEM principles (see examples of circuit design and codes that can be used in alternative system designs for TI in Figure 3 and Appendix 4). The software informs the students whether the system will work without hardware elements. The TI-Innovator™ Breadboard Package is a very convenient toolkit for exploring electronic principles. The Texas Instrument tools that students can use for this study are given below.

Graphic calculators

- TI-Nspire™ CX/CX II or TI-Nspire™ CX CAS/CX II CAS

Accessories

- Multi-sensor data collection with the TI-Nspire™ Lab Cradle

- Adapter EasyLink® USB sensor interface
- TI Connectivity Cable or Unit-to-Unit link cables

Sensors

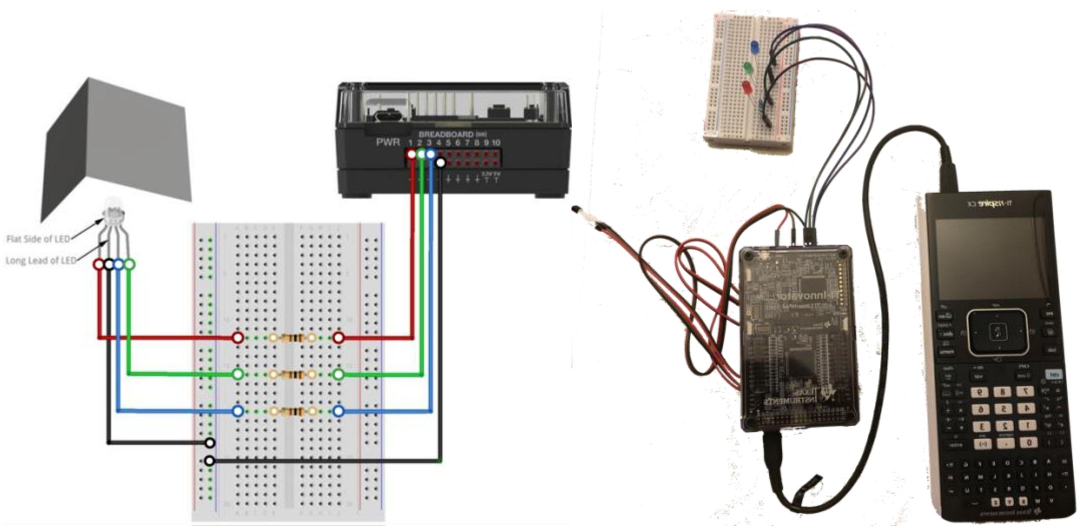
- CBR2 motion sensor
- TI Light Sensor (packaged with the CBL 2)
- Gas Pressure Sensor
- Stainless Steel Temperature Probe or EasyTemp™

Software

- All USB sensors and interfaces mentioned can connect to a TI-Nspire™ CX or TI-Nspire™ CX II graphing calculator or to a computer running TI-Nspire™ CX Premium Teacher Software. Also, TI-Nspire™ Apps for iPad®

Figure 3

Circuit Designed for TI Nspire Technologies



Share Stage

Students shared the experiences gained, tools developed and results achieved with community members. Social media tools were used in the sharing process.

Evaluate Stage

It was evaluated whether the project was successful or not. The questions determined for the evaluation at the Co-create stage were taken into consideration. These questions are given below.

- Can the system be simulated on the software?
- Can the system respond appropriately to the classroom illumination level?
- Can the system respond appropriately to the amount of CO_2 in the classroom?

- Can the system respond appropriately according to the body temperature of the person joining the lesson?

Results

As a result of the school community project, students investigated how an energy-efficient classroom could be designed within the plan they created with stakeholders. Students created a model by working on real data. People thought to be able to contribute to the students' learning helped them, and the education process was carried out in an open schooling approach by going beyond the school walls. Student-student and student-stakeholder interactions were managed, and the factors to be investigated in the project, how the research would be carried out, and how the evaluation would be carried out were decided collaboratively in the Co-create stage. Students were encouraged to generate and discuss ideas based on evidence in the co-create process and to work collaboratively in the Act stage. Students experienced science and engineering practices of asking questions and defining problems, analysing and interpreting data, constructing explanations and designing solutions, obtaining, evaluating, and communicating information, planning and carrying out investigations, and using mathematics and computational thinking at various stages during the project.

Arduino Uno circuit boards, sensors and software were used while creating the model. Students worked on software and hardware together. In addition, simulating whether the circuit board will work on the software contributed to building the model process.

Students worked on a problem with a social dimension from a STEM education perspective. The activities carried out and the result reached in the Share stage were tried to be disseminated. In addition, the evaluation situations planned in the Co-create stage were handled in the Evaluate stage. Both process and result evaluations were carried out using the questions mentioned early.

Discussion

Stakeholders were persuaded to be involved in the Invite stage, and students planned the research and development process together with stakeholders in the Co-create stage of the school community project. This co-creation understanding supported the effective implementation of the school community project and research and development activities in integrated STEM education. From a similar perspective, the European Commission (2017) states that the involvement of stakeholders, citizens, and end-users in research and development activities increases the degree of co-creation and maximises its impact, stimulating a stronger demand for innovative products and services and social change. This way, it is thought that open science and innovation will be maximised. Therefore, it can be said that an innovative perspective is provided to the research and development process with the stakeholders, and a product is produced in this school community project. In addition, as a result of managing the student-student and student-stakeholder interaction in the Co-create stage, it was decided collaboratively how the research process would be carried out and how the evaluation would be made. In this process, it is essential that the person managing the interaction adopts an interactive/dialogic communicative approach (Mortimer & Scott, 2003). It is thought that the efficiency of the creation process will be increased by using effective communication approaches.

Students implemented what they planned in the Co-create phase in the Act phase. In this process, they carried out basic activities using the Arduino Uno circuit board, sensors and software, experiencing many science and engineering practices. They also used collaborative working, problem-solving and algorithmic thinking skills. As a matter of fact, Arduino Uno is a frequently used tool in both software and hardware dimensions in the STEM education process (i.g. Carbone et al., 2022). In parallel with this situation, Alimisis and Kynigos (2009) state that robotics and coding activities contribute to students' engineering design processes, knowledge construction, algorithmic thinking, collaborative working, programming logic, creativity and problem-solving skills.

After completing their activities in the Act stage, the students shared their knowledge and products with the community. In this way, it can be said that the knowledge obtained in the school community project is disseminated to society and the activities aimed at increasing the well-being of society are supported. This aligns with the understanding that open schooling is a tool for social well-being (Sotiriou et al., 2017).

Limitation and Implications

This study is limited to the activities performed with the Arduino Uno circuit board, three sensors, and software. If more different sensors are used, the quality of the designed classroom can be increased. The school community project carried out in the study is considered in the context of open schooling. Therefore, it is a guide for both researchers and teachers for open schooling practices. In addition, the fact that STEM education is integrated into the content of the school community project offers opportunities to carry student acquisitions to higher levels in the process.

Declaration of Interest Statement

All authors state that there is no conflict of interest in this study.

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Appendix 1: Questions that can be used for measurement and evaluation activities

1. What can be investigated in a different school community project similar to the subject of this study, where the theme of sustainability is addressed?
2. Excluding the system used in this study, what are the alternative systems where light, temperature, and carbon dioxide sensors can be used together?
3. Are there any devices in homes where light, temperature or carbon dioxide sensors are integrated? If so, what are these? What are their basic working principles?
4. Identify at least two sensors other than light, temperature and carbon dioxide sensors. How can these sensors be used to solve a daily life problem?
5. How should the Texas Instrument and Arduino codes written within the scope of this study be in C++?

Appendix 2: People From The History Of Science And Engineering

Samuel Pierpont Langley (1834 - 1906)	Samuel Pierpont Langley invented the bolometer, an instrument used to measure far infrared radiation. The bolometer enabled scientists to detect a temperature change of less than 1/100,000 of a degree centigrade (Samuel Langley, 2023).
Maximilien Ringelmann (1861-1931)	Maximilien Ringelmann was a French professor of agricultural engineering and agricultural engineer who impacted the scientific testing and development of agricultural machinery. He developed the Ringelmann scale for measuring air smog. He also discovered the Ringelmann effect in social psychology (Max Ringelmann, 2023)
Ada Lovelace (1815 - 1852)	Ada Lovelace was an English mathematician and author, particularly known for her work on the Analytical Engine, the mechanical general-purpose computer proposed by Charles Babbage. She was the first to realise that the machine had applications beyond pure computation and published the first algorithm intended to be performed by such a machine. As a result, she is often considered the first computer programmer (Ada Lovelace, 2023).

Appendix 3: Codes Generated for The System ([Click] to access the code files)

Codes created in Arduino IDE for temperature, light, and gas sensors

Light

```
#define PIR 2
int ldr;
int bri;
int LDRvalue;
#include <LiquidCrystal_I2C_AvrI2C.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C_AvrI2C lcd(0x27, 16, 2);
float x, y;
float ldrdeger = 0;
int c1 = 0;
void setup() {


 pinMode(A0, INPUT);
 pinMode(3, OUTPUT);
 pinMode(2, INPUT);
 lcd.begin();
}
void loop() {

 ldr = analogRead(A0);
 delay(300);
 bri = map(ldr, 0, 1023, 0, 255);
 x = 5 * ldr / 150.0;
 c1 = (float)x * 100.0;
 lcd.setCursor (0, 0);
 lcd.print("Light Value");
 lcd.setCursor(0, 1);
 lcd.print(c1);
 lcd.print(" LUX ");

 int value_pir = digitalRead(PIR); // read input value

 Serial.println(value_pir);
 {
  if (digitalRead(PIR) == HIGH)
  {

   LDRvalue = map((A0), 0, 1024, 254, 0);
   analogWrite(3, bri);

  }
   if ( (c1 > 500) )
   digitalWrite(3, HIGH);

 }
}
```

CO_2

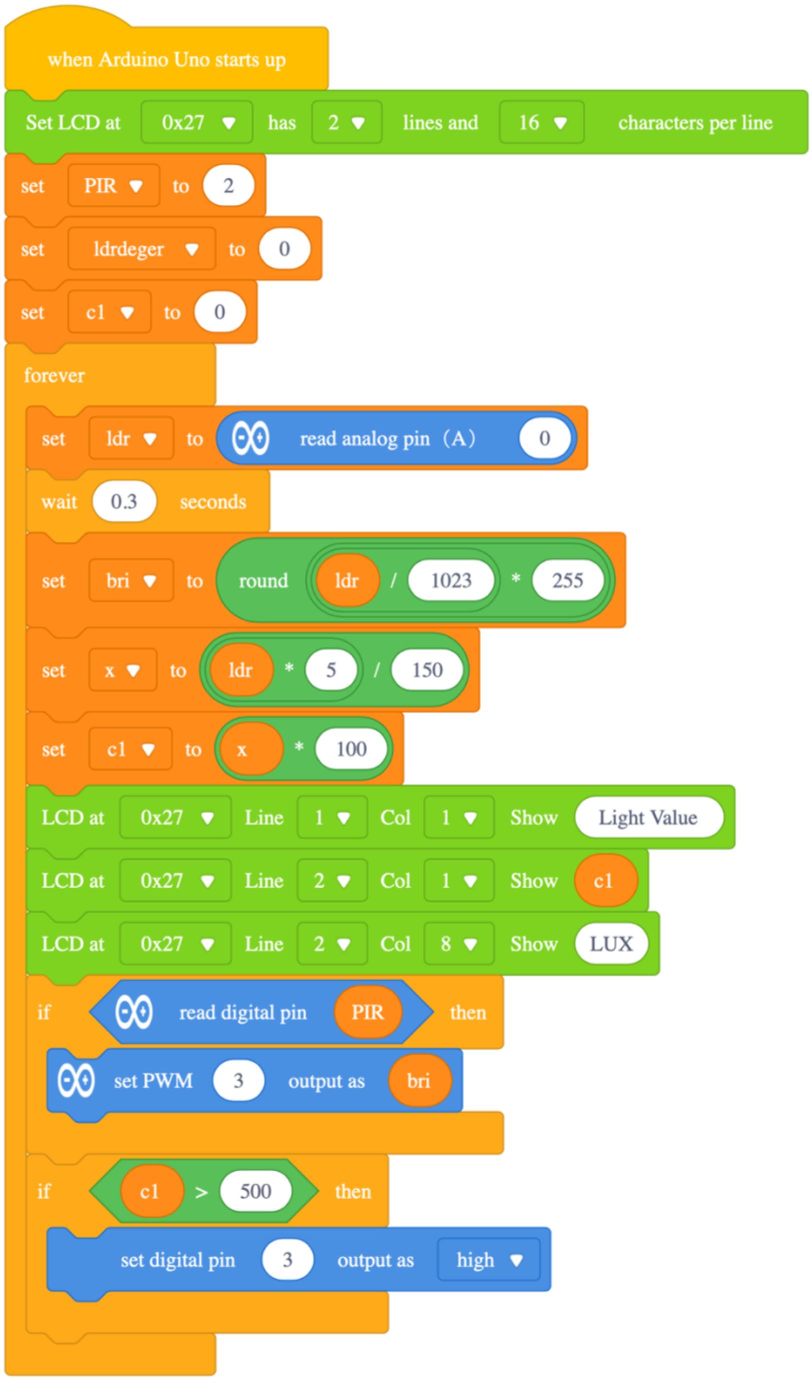
```
#include <LiquidCrystal_I2C_AvrI2C.h>
#include <LiquidCrystal_I2C.h>
const int gasPin = A1;
LiquidCrystal_I2C_AvrI2C lcd(0x27, 16, 2);
float t = 0;
int motor_pin = 8;
void setup()
{
 Serial.begin(9600);
 lcd.begin();
 lcd.backlight();
 pinMode(motor_pin, OUTPUT);
}

void loop()
{
 Serial.println(analogRead(gasPin));
 delay(1000);
 lcd.setCursor(0, 0);
 lcd.print(analogRead(gasPin));
 lcd.setCursor(0, 1);
 t = analogRead(A1);
 Serial.println(t);

 if ((analogRead(gasPin)) <= 130)
 {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("CO2:");
  lcd.print (t + 870);
  lcd.print(" PPM");
  lcd.setCursor(0, 1);
  lcd.print("Clean Air");
  digitalWrite(motor_pin, LOW);
 }
 else if ((analogRead(gasPin)) >= 131)
 {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("CO2:");
  lcd.print (t + 870);
  lcd.print(" PPM");
  lcd.setCursor(0, 1);
  lcd.print("Polluted Air");
  digitalWrite(motor_pin, HIGH);
 }
}
```

Temperature

```
#include <Wire.h>
#include <Adafruit_MLX90614.h>
#include <LiquidCrystal_I2C_AvrI2C.h>
#include <LiquidCrystal_I2C.h>
int light = 3;
Adafruit_MLX90614 mlx = Adafruit_MLX90614();
LiquidCrystal_I2C_AvrI2C lcd(0x27, 16, 2);
void setup() {
 Serial.begin(9600);
 lcd.begin();
 lcd.backlight();
 Serial.println("Adafruit MLX90614 test");
 pinMode(light, OUTPUT);
 mlx.begin();
}

void loop() {
 Serial.print("Ambient = ");
Serial.print(mlx.readAmbientTempC());
 Serial.print("*C\ tObject = ");
Serial.print(mlx.readObjectTempC());
Serial.println("*C");
 Serial.print("Ambient = ");
Serial.print(mlx.readAmbientTempF());
 Serial.print("*F\ tObject = ");
Serial.print(mlx.readObjectTempF());
Serial.println("*F");
 lcd.setCursor(0, 0);
 lcd.print("Body Temperature");
 lcd.setCursor(0, 1);
 lcd.print(mlx.readObjectTempC());
 lcd.print("*C");
 Serial.println();
 delay(2000);

 if ((mlx.readObjectTempC()) >= 37)

 {
  digitalWrite(light, HIGH);

 }

 else {
  digitalWrite(light, LOW);
 }
}
```

Block codes for the gas sensor in mBlok (Click to access the code file)

Block codes for the light sensor in mBlok ([Click]() to access the code file)



Block codes for the temperature sensor in mBlok ([Click](#) to access the code file)

Appendix 4: TI Codes That Can Be Used in Alternative System Designs (Click to access the code file)

1-TI Nspire technologies Pyhton) Lights

```
# Hub Project
#================================
from ti_hub import *
from math import *
from time import sleep
from ti_plotlib import text_at,cls
from ti_system import get_key
#================================
color.rgb( • , • , • )
```

2- TI Nspire technologies Pyhton) Lights Coulors

```
# Hub Project
#================================
from ti_hub import *
from math import *
from time import sleep
from ti_plotlib import text_at,cls
from ti_system import get_key
#================================
cls()
text_at(13,"Press [esc] to end","center")
brightness.range(0,255)
while get_key() != "esc":
  b=brightness.measurement()

  color.rgb(b,255-b,0)
  text_at(7,"brightness = " +str(),"left")
  cls()
```