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Development of Indoor Air Quality Measuring Device and Application to Support Campus in Post-Covid-19 Pandemic Class Preparation

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ABSTRACT
The Covid-19 pandemic has left our campus classrooms empty for a long time. The main concern of this research is to ensure the cleanliness of the classroom, not only for the materials and the room, but also for the air in it. Clean and safe indoor air is determined by several factors, one of which is air ventilation. Standard classrooms usually need to have plenty of ventilation to ensure airflow, but in general, in most large cities, the case is not that simple. Some schools have a narrow area, some are in dense rural areas or in industrial areas, some use air conditioning but lack maintenance, etc. This research focuses on the development of indoor air quality measuring device that can be used to check the air quality of classrooms and transmit the results to parents and other related parties. The device is made using a wi-fi integrated microcontroller module which is equipped with sensors measuring air conditions. It is also connected to the application on the android phone, and the data is stored on the web. It is also embedded with geolocation tagging to indicate the exact location of activity. The stored data can be used as basic data to make predictions about air quality conditions in a particular place in the future.

INTRODUCTION

It has been more than 2 years since the Covid-19 outbreak in Wuhan, China. The pandemic has changed many things in the world, including education system. Schools and universities are racing with the pandemic to create new and comfortable environments for their curricula, leading to the abandonment of classrooms and other facilities, while students are forced to study from home, resulting in new types of learning methods and procedures. Although online learning is considered as a sophisticated new way of learning and in line with technological developments, classroom facilities are still needed, especially for practical studies and discussions between students and teachers. Places such as classrooms, laboratories, cafeterias, and workshops in schools can never be abandoned. Now that the pandemic has been contained, and everyone go back to school, the need of those facilities is immediate (Sharifi and Khavarian-Garmsir, 2020; Elkhwesky *et al.*, 2022).

No matter how great online learning is, not all parents are ready to handle their children in this kind of learning process. This is not only true for K-12 students who currently need more attention to their learning progress compared to the period before the pandemic, but also for college students. This is a new challenge for parents, because they are more involved in the learning process of their children, and are 'forced' to prepare infrastructure, such as: smartphones, computers with online conferencing capabilities, internet connections, printers, etc. Things that were once considered secondary needs in the pre-pandemic period, have now turned into primary needs. But going back to school is also not a wise choice, even after the pandemic. There are things that need to be prepared, both for the school and parents/students. New habits, skills, knowledge, and new understanding on socializing are some of

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them. Facilities and infrastructure, cleanliness, the ability of schools to formulate new rules and regulations can affect the formation of new habits of students (Saha, Guha and Roy, 2012; Khan, Kolarik and Weitzmann, 2020).

The World Health Organization (WHO) seems to have thought about this and prepared some guidelines for countries to prepare for the reopening of schools after the pandemic (World Health Organization, 2020). The checklist has been distributed and is expected to be used as a basic guideline before it is developed and adapted to country-specific needs and specifications. Several other organizations such as the Center for Global Development and ASHRAE have also issued similar references (Annie Hoang, 2021) (ASHRAE, 2020) to help countries prepare.

Schools and campuses along with the government, have a very important role in convincing parents to let their children go back to school. They need to be more proactive in providing information, especially about school or campus conditions. The cleanliness of the classroom as well as the quality of the air in it is one of the first pieces of information that they should share with parents and students. Indoor air quality (IAQ) has become a major concern for the public since the pandemic (Habibi, 2016; Akanmu, Nunayon and Eboson, 2021; Holubar, 2021).

IAQ is also an issue that requires some concerns since it might trouble human body in general. The emergence of IAQ is generally generated by several factors, i.e.: inadequate air ventilation (52%), the existence of sources of contamination in the room (16%), contamination from outside (10%), microbes (5%), building materials (4%), and other (13%) (Vidyautami, Huboyo and Hadiwidodo, 2015). Insufficient IAQ can create actual short term health consequences such as eyes, nose, and throat irritations which can establish a major significance on people with poor health statuses, such as asthma and allergies. Poor IAQ can also cause headaches and fatigue. In the long-term period, poor IAQ is associated with respiratory disease, heart disease, and cancer.

Indoor air could be polluted by a variety of contaminants including chemical pollutants, moulds, dust, volatile organic compounds (VOCs), pet dander, and odours. Inadequate ventilation exacerbates this problem, increasing indoor pollutant levels by not bringing in enough outside air to dilute the pollutants. A portable indoor air quality device is required to mark classroom conditions. It must be able to determine at least four aspects of air cleanliness, namely CO_2 level, CO level, temperature and humidity level, and dust level in the air. The device needs to be connected to the mobile application for the results to be accessible to all relevant parties. One more thing that is important is that the device must be relatively easy to manufacture, with easily available pieces, also the production cost must be relatively cheap (Mandayo *et al.*, 2015; Morawska *et al.*, 2018; Chojer *et al.*, 2020; Sharma *et al.*, 2021; Sa *et al.*, 2022).

The MQ-135 and MQ-7 sensors seem to be the favourite equipment in the manufacture of air quality monitoring tools because they are designed to detect CO and CO_2 concentrations in the air. They are best used to measure indoor air quality, as in studies (Perera and Jayasinghe, 2012) (Waworundeng and Lengkong, 2018) and (Sugiarso *et al.*, 2019). Long Short-Term Memory (LSTM) is used as a method and machine learning as data processing for research (Sai, Ramasubbareddy and Luhach, 2019). Several microcontrollers are used for this kind of device, such as Arduino, Node-MCU, and Raspberry Pi.

To expand the range of the sensor, (Rosmiati *et al.*, 2019) a device with a Raspberry Pi sensor and an MQ LoRa series sensor module was made as a data receiver. Can be used with GPS and aerial sensors and can reach 1.7 km in longitude and 400 meters in latitude. Another thing that can be implemented on the device is geo-tagging. Geo-tags provide latitude, longitude, distance, and several other features to support many IoT-based devices, including these air quality monitoring devices.

The device will be equipped by 2 sensors: MQ-135 and MQ-7 which are implemented into the Node-MCU ESP32 module. We also use IoT which connects and displays sensor results on the android platform and stores the data on the Cloud platform. Community involvement is one of the concerns in making this device. The idea is to get as many people as possible using the device and share the results in an android app. This will result in at least two benefits, one, that everyone, even those without a device, can still access the information, and two, the stored data can be used as the basis for making future predictions.

The urgency of this research is: a) There are fundamental problems related to classrooms and other infrastructures, especially those dealing with indoor air quality when opening schools/campuses for hybrid/offline teaching and learning activities, and b) Application requirements with the application of automated information technology for classrooms and other infrastructures, especially those dealing with indoor air quality when opening schools/campuses for hybrid/offline teaching and learning activities.

There are some research concerning this matter such as that was done using DSM501a and MQ-135 sensors (Nur Arminarahmah, Muhammad Rasyidan and Zaenuddin, 2017), MQ-7 and HC-05 wireless technology (Faroqi *et al.*, 2016), gas, temperature, and humidity sensor (Sebayang, 2017), MQ-135 sensor, LED and buzzer (Waworundeng, 2017), and the one that just only uses MQ-135 sensor (Zikri and Khair, 2018).

In the studies above, air quality was measured using an Arduino-based device and sensors. Some use gas sensors (MQ-07), air sensor (MQ-135), and HC-05 wireless technology. The weaknesses of the studies above are that: 1) the tools tend to be bulky and less convenient to carry around; 2) almost all studies use LCD, which means that it only displays real-time data; 3) only one study made connectivity with the internet; and 4) does not involve many people so that data communication only takes place in one direction.

The advantages and novelty of the MEDIA-QLASS device that we made is a prototype indoor air detector that: 1) Portable (easy to carry around), 2) Compact, 3) Wearable, 4) Applicable, 5) Accessible (easy to access), and Connectible (to smart phones and websites). The device will monitor IAQ using sensors: MQ-135 and MQ-7. The results of which are directly sent to a linked smartphone and will be kept in cloud and should also be retrieved via the website. The stored data can then be used as the main data for an air quality prediction system at that location.

METHODS

The research begins by identifying the current system analysis and continues with the making of the proposed system analysis. The current system is taken from the pre-covid era and is focused on how schools and campuses carry out their room cleaning procedures. The proposed system focuses on the post-covid time soon. The system can be seen in the following figure.

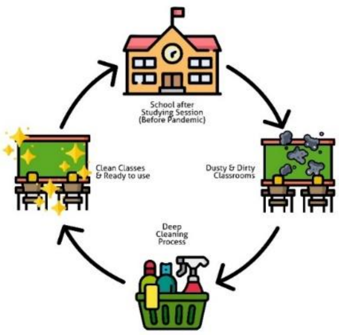

Figure 1. Current System Analysis

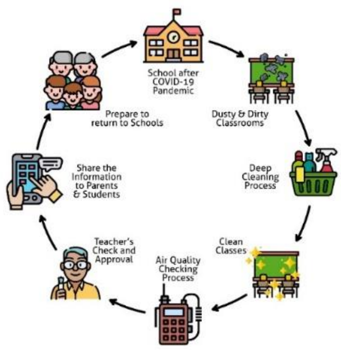

Figure 2. Proposed System Analysis

The study framework was created to explain the flow of making this device. The flow includes the process of data collection, design, assembly, web and application creation, connection process, and device testing. A clearer flow can be seen below:

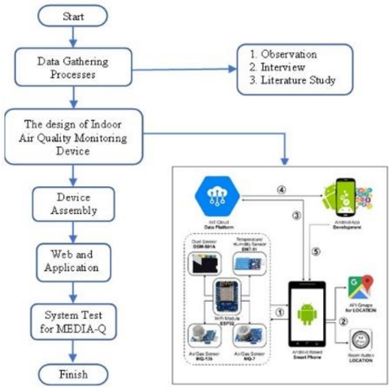

Figure 3. Research flow

As stated earlier, there are two steps taken in making this system, i.e., hardware design and software design. Block diagrams are created to see the design from the best perspective. The Node-MCU ESP32 is used as the base circuit and functions as a processing unit while providing a Wi-Fi connection. The sensors used here are MQ-135 to measure CO_2 concentration in indoor air, and MQ-7 to measure CO.

Software design is done using Arduino software which is embedded in the ESP32 unit. The Android application is compiled using the MIT Inventor software which is then connected to the main unit software. This programming code line software is created using the Arduino IDE version 1.8.1 application with a Java language base that is adapted to support the overall performance of the device.

The device will then be connected to an Android-based smartphone and a website. The device is paired with the app on the smartphone via the ESP32 Wi-Fi module. The app reads the location (using Google APIs) and determines the floor location (height). Sensor modules MQ-135 plus MQ-7 are also linked to the ESP32 which checks IAQ. The data obtained will be transferred back to the smartphone, then sent to the internet. From the internet (website) that has been provided, other users can access data, databases, or forecasts in real-time. Furthermore, figure 4 below illustrates the process.

Figure 4. Device Process Illustration

RESULTS

The results of designing tools and applications for building an Android-based indoor air quality measuring device using the geolocation tagging method using ESP32 and applying Java language.

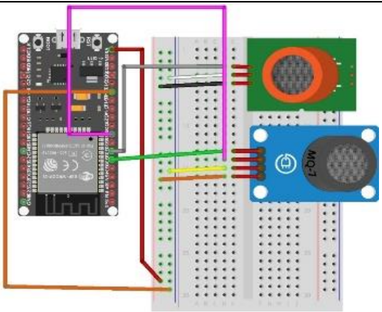

Figure 5. Device Prototype

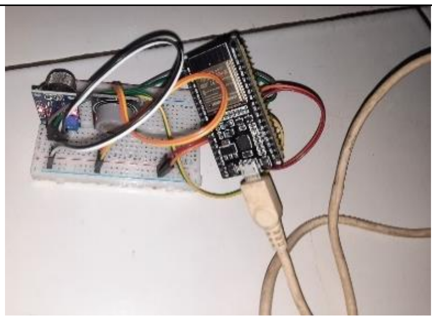

Figure 6. Device Structure

After designing the device, then continued by checking whether the sensor can read data accurately or not. The data displayed by the MQ-135 and MQ-7 sensors can be seen on the serial monitor on the Arduino IDE. The following are the results of the experiment to get data from the sensor:

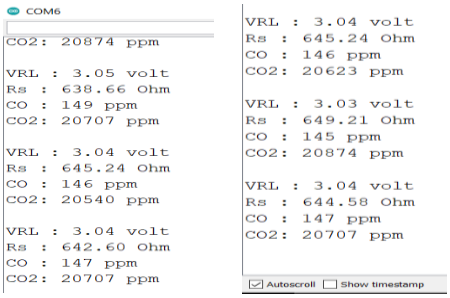

Figure 7. Sensors Results

Figure 7 shows data in the form of VRL, Rs, Co and Co_2. The VRL can be interpreted as an output voltage sensor with load resistance on the sensor circuit, Rs itself is a Resistance Sensor, while for Co and Co_2 is the level of Co and Co_2 in a room.

The data obtained is not only displayed in the Serial Monitor on the Arduino IDE but is sent to the real-time database from the firebase. The function of the database itself is to accommodate Co and Co_2 data which will later be accessed by software on smartphones. The following is an image of the real-time database view:

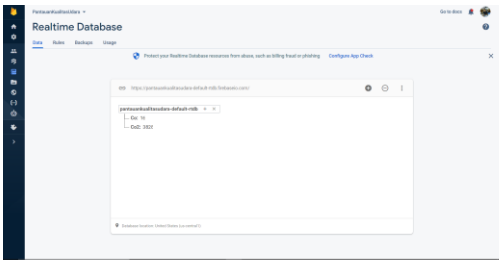

Figure 8. Firebase Realtime Database

Based on the explanation above, from the design phase of the device, the results of the data obtained and also the data and display on the real-time database can be translated into a design algorithm. The function of the design algorithm here is to describe and explain how this device works, so that the reader can understand clearly. The results of the application and data can be seen in the following figures and tables:

Figure 9. Main Page

Figure 10. Report Page

Figure 11. Data Page

Figure 12. View Page

The main page is the first page that appears when the application is run, on this page there is writing in the form of the name of this application and 2 menus, i.e., the air quality report menu to view the current user's air quality while also report it and air quality view to see the entire list of quality air user application throughout the area.

On the Air Quality Report page there is information in the form of CO_2 and CO levels, status of CO_2 and CO levels, level position in a building, address, latitude, and longitude. For latitude and longitude, the user can press the location button to get the current latitude and longitude data, then there is a report button to send data to the application database.

The List of Air Quality Data for Various Places page is a list of databases containing information about the air content, position, and address of the sender so that the public can see the information. Also, if one of the information is pressed, it will go to the maps where the address is located.

The Location Point View page is a Google Maps page where there is a pointer to where the air quality has been previously reported. In this feature, there is already a directional button in the lower right corner and a g-maps button that can be opened in the g-maps application if the users want to know detailed information of the location. The result data will explain the results that has tested at the ITPLN Building. The data will be described in tabular form as follows:

TABLE 1. Result Data

id	Co_2	Co	Co_2 Stat.	Co Stat.	Latitude	Longitude	Location	Date and Time
20	1089	21	Medium	Safe	-6.1844564	106.7075474	Green Lake City	2022-06-17 19:59:31
22	2997	14	Medium	Safe	-6.1729546	106.7266653	Pondok Randu No. 44	2022-06-17 20:00:05
23	13114	19	Medium	Safe	-6.1684031	106.7266509	Menara PLN 5th floor	2022-06-18 10:58:36
24	9843	26	Medium	Safe	-6.1684031	106.7266509	Menara PLN 5th floor	2022-06-18 11:00:42
25	11366	26	Medium	Safe	-6.1684031	106.7266509	Menara PLN 5th floor	2022-06-18 11:01:50
26	1931	13	Medium	Safe	-6.1683652	106.7266172	Menara PLN 5th floor	2022-06-18 11:07:30
27	1318	11	Medium	Safe	-6.1683261	106.7265021	Duri Cengkareng No.3	2022-06-18 11:10:32

28	2251	12	Medium	Safe	-6.168336	106.7265602	Menara PLN 5th floor	2022-06-18 11:15:03
29	4312	16	Medium	Safe	-6.168336	106.7265602	Menara PLN 5th floor	2022-06-18 11:15:45
30	4154	16	Medium	Safe	-6.168336	106.7265602	Menara PLN 5th floor	2022-06-18 11:16:13

Some protocols and algorithms have been used to determine the location and its map, as explain below. First, we need to make a request permission on android to access the internet. Here in order for the application to access the internet, permission is needed from Android to be able to use the internet features in the application. below is an example of android permission to use the internet.

```
<uses-permission android:name="android.permission.INTERNET" />
```

Second, request permission on android to use the location feature. In this section as with the internet, the application requires permission from the android system to be able to access the location feature.

```
<uses-permission android:name="android.permission.ACCESS_FINE_LOCATION" />
<uses-permission android:name="android.permission.INTERNET" />
<uses-permission android:name="android.permission.ACCESS_COARSE_LOCATION" />
```

Third, get the latitude on the smartphone. Here before getting the complete address which will be used as a reference location, you must get Latitude.

```
private void getLocation() {
    if (ActivityCompat.checkSelfPermission(
            context: MainActivity2.this, Manifest.permission.ACCESS_FINE_LOCATION) != PackageManager.PERMISSION_GRANTED && ActivityCompat.checkSelfPermission(
            context: MainActivity2.this, Manifest.permission.ACCESS_COARSE_LOCATION) != PackageManager.PERMISSION_GRANTED){
        ActivityCompat.requestPermissions( activity: MainActivity2.this, new String[]{Manifest.permission.ACCESS_FINE_LOCATION}, REQUEST_LOCATION);
    } else {
        Location locationGPS = locationManager.getLastKnownLocation(LocationManager.NETWORK_PROVIDER);
        if (locationGPS != null){
            double lat = locationGPS.getLatitude();
            double longi = locationGPS.getLongitude();
```

Fourth, Get Longitude on the smartphone. Here is the same as latitude, to get the address required to get the longitude first. Then fifth, upload the results of latitude and longitude to gps. After getting the latitude and longitude, to get the address, you are required to send the latitude and longitude to GPS, so that later you can get the complete address.

```
private String getCompleteAddressString(double lat, double longi) {
    String stradd = "";
    Geocoder geocoder = new Geocoder( context: this, Locale.getDefault());
```

Sixth, get the full address based on the longitude and latitude uploaded to the previous GPS. After uploading to GPS, the complete address is obtained. Based on the complete address, latitude and longitude it can be directed directly to the Google Maps API to mark the location with a pin.

```
try {
    List<Address> addresses = geocoder.getFromLocation(lat, longi, maxResults: 1);
    if (addresses != null){
        Address returnaddress = addresses.get(0);
        StringBuilder strReturnAddress = new StringBuilder("");

        for (int i=0; i <= returnaddress.getMaxAddressLineIndex(); i++){
            strReturnAddress.append(returnaddress.getAddressLine(i)).append("\n");
        }
        stradd = strReturnAddress.toString();
    }else {
    }
} catch (Exception e){
    e.printStackTrace();
```

Then, to create a pin on the Google Maps API, the latitude, longitude, and full address are sent to the G-Maps API Activity. After being sent to the it, the Geolocation Tagging method can be fully operated.

```java
@Override
public void onMapReady(GoogleMap googleMap) {

    Intent terima = getIntent();
    xId = terima.getIntExtra( name: "xId",  defaultValue: -1);
    xLatitude = terima.getStringExtra( name: "xLatitude");
    xLongitude = terima.getStringExtra( name: "xLongitude");
    xAlamat = terima.getStringExtra( name: "xAlamat");



    double Latitude = Double.parseDouble(xLatitude);
    double Longitude = Double.parseDouble(xLongitude);

    mMap = googleMap;

    // Add a marker in Sydney and move the camera
    LatLng lokasi = new LatLng( Latitude, Longitude );
    mMap.addMarker(new MarkerOptions().position(lokasi).title("Lokasi : "+xAlamat));
    mMap.moveCamera(CameraUpdateFactory.newLatLngZoom(lokasi, zoom: 13));
}
```

The testing phase aims to check the results of the implementation phase whether they are in accordance with the results of the needs analysis and the results of system design or not. In the testing phase, 3 testing methods were carried out, namely accuracy testing, validation testing, and compatibility testing. The test results from the geolocation tagging as many as 10 trials and from all 10 trials the accuracy obtained reached 100%, which means that all can be detected properly, and the location is appropriately tagged. Validation testing is done by running all existing functions on the system. The results of this test indicate that all existing functionality in the system obtains valid results. So, it can be concluded that the system built has been running according to its function both under normal conditions and alternative conditions. Compatibility testing is done by running the system on a different version of the Android operating system. The results of the compatibility test state that the system can run on different Android versions, i.e., 7.1 and 8.0. The existing functionalities can run well on them, and the display layout on those versions are similar and clearly visible.

CONCLUSION

From the research done, it can be concluded that: 1) The making of the geolocation tagging method starts from determining latitude and longitude. These information helps the residents measure the distance between their location to the incident's location, 2) The device is equipped with MQ-7 and MQ-135 sensors to get the amount of CO_2 and CO levels in the air. After the data obtained from the two sensors, then the data obtained will be calibrated with calculations from each sensor. After the calibration is complete, the results of the CO and CO_2 levels in the form of PPM are obtained, and 3) the results of the accuracy, validation and compatibility tests show that of the 10 trials carried out, the tool can provide accurate results with all functions in the tool and system running well on android systems starting from version 7.1.

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