Clearing the Air with Low-Cost & Conversational Air Quality Monitoring

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Indoor Air Quality (IAQ) affects health, comfort and cognition, yet existing monitors can confuse or overwhelm users. This paper presents a low-cost, conversational IAQ device that offers clear prompts alongside data, adapting its advice using local sensor readings and external air quality API's. Designed with input from classroom deployments, the prototype aims to help balance good IAQ and thermal comfort whilst considering stakeholder requirements through accessible, open-source and sustainable design.

I. Introduction / Background

Poor indoor air quality (IAQ) negative affects focus, comfort and long-term health. CO_2 levels above 1,000ppm (part per million; measuring gas concentration per million parts of air) can impair cognitive performance [1], while exposure to PM2.5 (particulate matter <2.5 microns in diameter) is associated with respiratory and cardiovascular risks [2]. Yet in many schools and homes IAQ remains an invisible, under-monitored and poorly understood threat.

Existing solutions sit at two extremes: commercial monitors like Awair or AirThings offer sleek dashboards but are expensive and proprietary [3], while open-source, citizen science, projects such as Sensor.Community or PurpleAir provide data but with little guidance [4]. From our own deployments in classrooms across the North-West of England teachers repeatedly expressed confusion over what the numbers mean or what actions to take. As one explained: "We've got the monitors, but they're just behind the board… no one really knows what they're for" [5].

This paper introduces a prototype IAQ monitor that is low-cost, contextual and conversational. Rather than flashing red lights or showing raw numbers, this device aims to offer actionable prompts such as "CO_2 is creeping up – consider opening a window". It connect to local APIs to avoid counterproductive advice, such as warning against opening windows when external temperatures are low, as this could lead to increased heating usage and cost.

This prototype is designed to empower rather than overwhelm using a dialogue based interface to aid human behaviour in managing indoor spaces.

II. Related Work

A number of citizen science and open-source initiatives have emerged to address growing concerns around air quality. Projects like PurpleAir [6] and Sensor.Community [7] enable global data sharing by encouraging uses to build and deploy their own PM2.5 monitors. While these platforms promote environmental awareness, their main focus is on outdoor conditions, whereas we spend up to 80% of our time indoors [8]. These sensors would offer little contextual support in improve IAQ.

In the UK during the pandemic period, the government distributed thousands of CO_2 monitors to highlight lack of ventilation in indoor spaces in a bid to reduce the spread of COVID-19. However our findings found that these devices were offered with little explanation and in many cases were underutilised or misunderstood: "They just told us to put it in the room and look for green, amber, red… that was it". More recently the SAMHE project (Schools' Air quality Monitoring for Health and Education) has combined sensors with curriculum material to support IAQ literacy in schools [9]. Our prototype aims to do this at a lower cost, whilst also being applicable to use outside of the classroom.

Within the field of human-computer interaction (HCI) research has emphasised the need for ambient, contextual feedback to bridge the gap between data and actions [10]. Existing monitors, whether high-end or DIY, may not integrate these principles. Most either expect technical literacy or reduce complex environments to a traffic light with little adaptation to context or user agency.

From the above we can observe the shift in priority from insulation (keeping warm air in to improve comfort, at the cost of "fresh" air) and ventilation (increasing air flow to reduce the spread of COVID-19). This shift is not static, and with recent rises in energy costs due to political factors we find these priorities shifting again. Approximately 80% of UK energy usage is spent on heating and hot water [11], with bills rising over 50% in the last decade alone [12] – this is further compounded to the UK's commitment to Net-Zero and reducing carbon emissions.

There is a need for dynamic management of indoor spaces, which forms the foundation of my PhD – balancing IAQ, energy usage and stakeholder requirements.

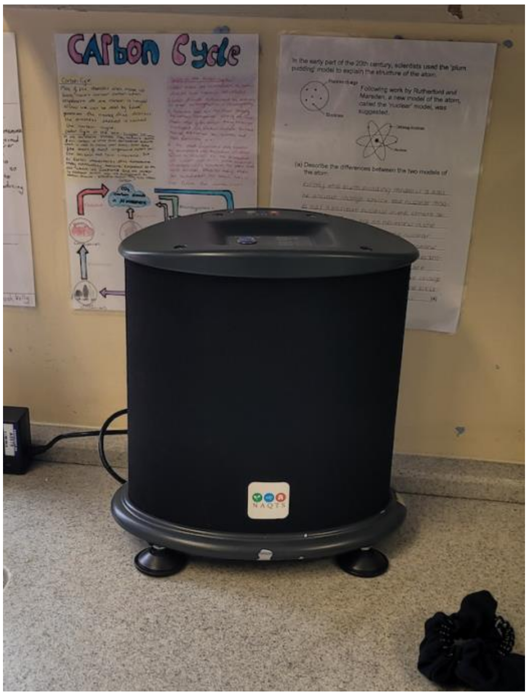

Fig. 1. NAQTS V2000 Deployment

This balance can be expressed as a trilemma, which is the focus of our first paper entitled “The Indoor Air Quality Trilemma: Improving Air Quality, Using Less Energy and Meeting Stakeholder Requirements”. As part of the data collection for this process we used three National Air Quality Testing Services (NAQTS) [13] supplied V2000 air quality monitors in a Science Lab in a high school in Preston, England. It’s from this PhD that many of the quotes and design choices from this prototype have arrived.

This prototype aims to build on these efforts by proposing a monitor that is not just accurate or open, but conversation and supportive. It will also be affordable to build and operate - giving occupants the means to respond, not just observe.

III. Prototyping

Our goal is to develop a feature-rich yet affordable air quality monitor that supports both real-time indoor sensing and context-aware feedback, including smart ventilation suggestions based on external air quality conditions.

To achieve this our prototype would make use of low-power, low-cost hardware, detailed below:

TABLE I. HARDWARE

Component	***Usage***	***Price***
LilyGo T-5 2.13” E-Paper Display [14]	Processing unit and screen	£15.00
Nova SDS011 Sensor [15]	Optical sensor for PM2.5	£8.50
Sensiron SCD30 Sensor [16]	CO_2, Temperature and humidity sensor	£50.00
TP4056 + Battery [17]	Rechargeable battery + charging module	£4.50
PCB, Connectors, Case (3d Printed)	Wiring, connectors and shell	£5.00

Fig. 2. Table of Components

The above components are represented in the below fritzing diagram.

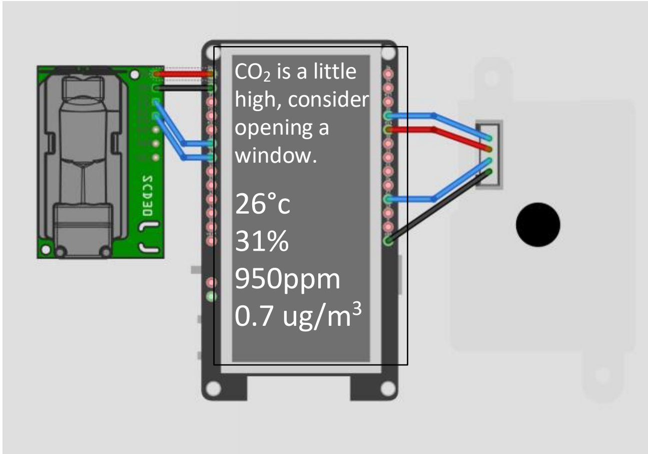

Fig. 3. Wiring Diagram

All sensor readings are processed locally and displayed in a conversational format (“Feeling stuffy? Try a short break or opening a window”). In addition, the device fetches external air quality data via public APIs (e.g. OpenWeatherMap, Sensor.Community, or DEFRA feeds), allowing it to suppress suggestions to ventilate if external PM2.5 levels exceed indoor levels. This context-awareness improves both trust and usability in polluted environments.

Data is logged to an onboard SD card and made available via a local WiFi web interface. The full system is built for under £85 per unit in small batches, using commonly available components and no proprietary cloud infrastructure. All firmware and hardware designs will be open-sourced to support reproducibility, classroom adaptation, and long-term repair.

IV. Responsible innovation

This project is grounded in the principle that air quality sensing should be understandable, actionable, and accessible—not just to technical users, but to everyday people in homes and classrooms. In our deployments, we saw how often teachers felt excluded from using air quality tools: “It’s there flashing, but no one really tells us what to do with it”. Our conversational approach responds to this by prioritising clarity, agency, and behavioural nudging over raw data or red lights.

From a societal perspective, the project adds value by offering an affordable, transparent alternative to commercial devices—particularly important in under-resourced schools and households where poor ventilation and high occupancy coincide with limited technical support. The device is open-source, modifiable, and designed to support educational engagement and community science.

We also take environmental sustainability seriously. The system is designed to operate with:

- Ultra-low power consumption through e-ink displays and sleep cycling
- Modular sensors that can be swapped rather than scrapped

- Local data storage and API access, avoiding cloud reliance and reducing embodied energy

Materials will be sourced from readily available components, and enclosures will support 3D-printed or repurposed housings to extend life and reduce waste. Long-term, we aim for the system to support repairability and adaptation, enabling schools and communities to respond to changing environmental conditions without buying into closed ecosystems.

By centring usability, openness, and longevity, we aim not just to measure air quality—but to meaningfully support healthier, more equitable, and sustainable indoor environments.

V. Author bio(s) / experiences

I'm Iman Hussain, a graduate researcher working with National Air Quality Testing Services through the Centre for Global Eco-Innovation at Lancaster University. My PhD explores how advanced sensing technologies can be used to balance indoor air quality, energy efficiency, and the needs of building occupants—especially in school environments. I aim to create healthier indoor spaces while reducing the carbon footprint of the built environment.

My recent research, published at CHI EA 2023, investigates this "indoor air quality trilemma" through a mixed-methods pilot study in a UK school classroom. We explored how energy usage, stakeholder practices, and air quality interact—and what this means for future human-centered design in sustainable buildings. You can read the paper here: https://doi.org/10.1145/3544549.3585898

My PhD is continuing with a further 2 papers to be published this year, aiming to complete in late 2025.

Previously, I worked with IBM, CapGemini, and Highways England, where I focused on applying technology to support sustainable and green solutions.

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I would also like to personally acknowledge my PhD supervisors Adrian Friday and Doug Booker for their continued support towards my PhD.

VII. Refernces

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