Project: Using a low-cost sensor platform to explore the indoor environment in New Zealand schools

Using commercial equipment to test the air quality in every New Zealand classroom would be prohibitively expensive. This project developed a low-cost sensor platform with remote logging and data transmission and tested it in 11 schools. The platform worked well, opening opportunities for affordable indoor air quality monitoring in New Zealand schools.

Children spend a lot of time at school, and a good classroom environment is essential for their health and cognitive performance. Nearly all New Zealand classrooms (90%) depend on manual ventilation through opening windows, yet surveys indicate that windows are often closed. This can result in temperature extremes and high levels of carbon dioxide - both found in this project.

Investigating the indoor air quality (IAQ) in large numbers of classrooms can be expensive. A commercial monitoring station costs around NZ$4,000 for temperature, relative humidity (RH), carbon dioxide (CO_2) and carbon monoxide (CO) monitoring, with a particulate matter (PM) monitor adding around NZ$10,000.

A low-cost platform, SKOMOBO (SKOol MOnitoring BOx), was developed and a passive infrared sensor added to confirm room occupancy. The platform was enclosed with 3 mm clear acrylic (Figure 1). Data was transmitted through a wifi adapter (wifi hotspot) (Figure 2).

SKOMOBO component costs were estimated at NZ$400 per unit, not including labour or development. This is approximately 15% of the cost of commercial equipment. Remote logging and data transmission reduce fieldwork costs, and there is less disturbance to building occupants as no visits are required for data downloading.

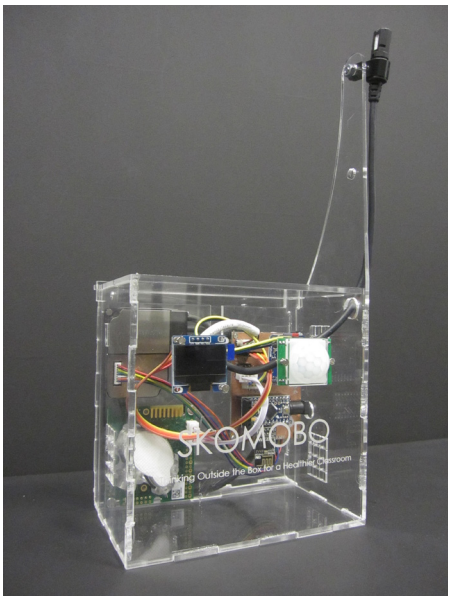

Figure 1. A clear SKOMOBO platform in the acrylic enclosure.

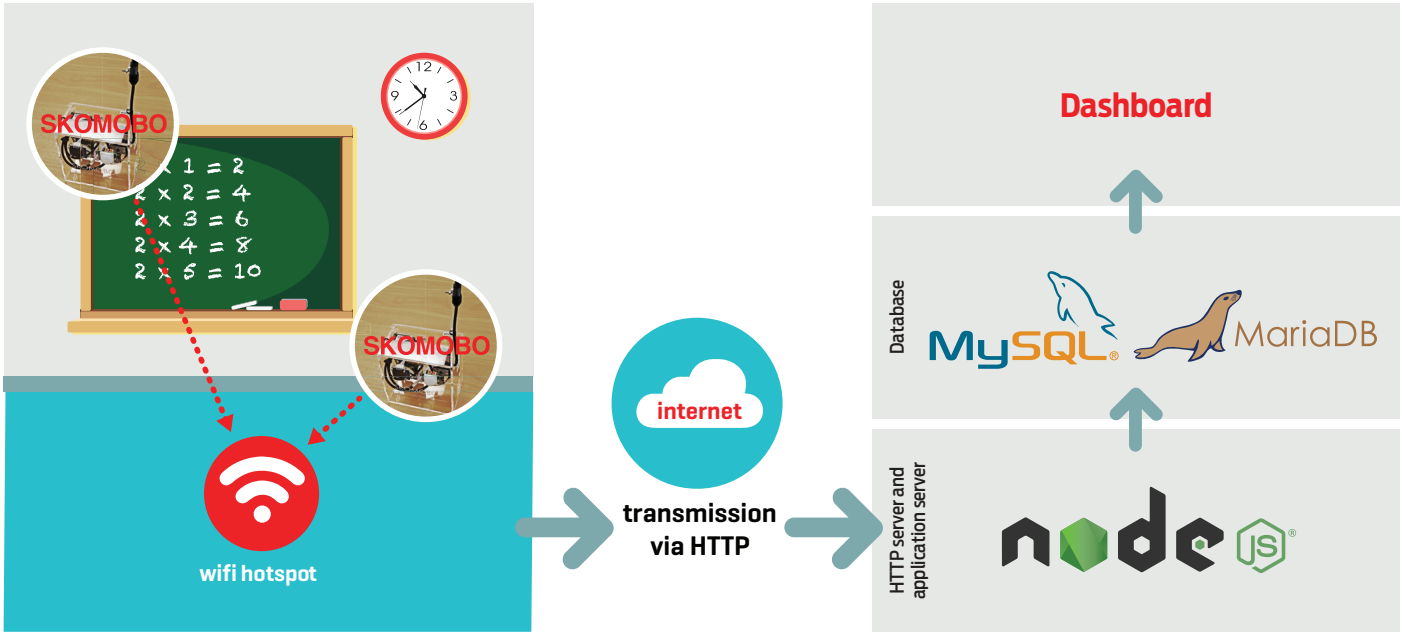

Figure 2. SKOMOBO system overview in the classroom.

Six SKOMOBO platforms were tested against commercial equipment. The results showed good agreement for temperature, RH and the CO_2 sensors. The SKOMOBO platform particulates sensor estimated 90% of the commercial measurements.

SKOMOBO PLATFORM DEPLOYMENT IN SCHOOLS

A test deployment was made in a primary school close to Massey University's Auckland campus. Three classrooms were monitored in winter/spring 2017, and SKOMOBO worked well. It was then rolled out to Hawke's Bay (two schools), Christchurch (four schools) and Dunedin (four schools) over four seasons from October 2017 to October 2018.

TEMPERATURE AND RELATIVE HUMIDITY

The World Health Organization (WHO) recommends a temperature of 18-24°C during school hours. The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) recommends relative humidity at 40-60%. Humidity over 60% allows longer survival of airborne pathogens.

Children were exposed to a mostly comfortable average level of temperature and RH across all four seasons.

However, uncomfortable environments were recorded in some schools:

- In one Hawke's Bay classroom, students were exposed to temperatures below 16°C for one third of the winter week.
- In two Christchurch schools during summer, students were exposed to temperatures above 24°C for most of the week and above 28°C for around 20% of the time in one school (equivalent to 1 day a week).
- In two Dunedin schools during summer, students were exposed to temperatures above 24°C for a third of the week.
- In two Dunedin schools during spring, students were exposed to low temperatures. In one classroom, temperatures were below 18°C for 15% of the time and below 16°C for 9% of the time.
- In autumn and winter, a few Hawke's Bay classrooms saw RH well above 60% and some above 70%.
- RH of 60-70% for a whole winter week was recorded in one Christchurch classroom.
- In Christchurch and Dunedin, a few classrooms were both warm (above 24°C for a third to half of the week) and damp (RH over 60%) in summer - not pleasant for a learning environment.
- Some of the Dunedin classrooms suffered the reverse in spring, with low temperature and low humidity.

CO_2

NZS 4303:1990 *Ventilation for acceptable indoor air quality* recommends a CO_2 level below 1,000 parts per million (ppm). In 2017 guidelines for new school buildings, the Ministry of Education requires that the average concentration of CO_2 in classrooms should not exceed 1,500 ppm when measured at seated head height (1200 mm) during the continuous period between the start and finish of teaching on any day. Less than a third of average measurements in Hawke's Bay were below (or around) 1,000 ppm, with 44% for Christchurch and 53% for Dunedin. In Hawke's Bay and Christchurch, a very small number of classrooms returned high CO_2 levels. One Hawke's Bay classroom had an average summer level around 2,000 ppm, and a Christchurch classroom recorded 2,800 ppm in summer and 3,800 ppm in autumn. These figures indicate that windows were not opened. In Dunedin, no students were exposed to CO_2 above 2,000 ppm. Results show a lower average CO_2 level in summer in all four Dunedin schools, indicating that windows were being opened.

PARTICULATE MATTER

Particulates are tiny pieces of matter. $PM_{2.5}$ (fine) particulates are less than 2.5 micrometres in diameter. PM_{10} (coarse) particulates are 10 micrometres or less in diameter - one-tenth the thickness of a human hair. High levels of PM_{10} can irritate the eyes and throat, but finer $PM_{2.5}$ particles may pose a greater risk because they can penetrate the deepest parts of the lung. WHO specifies that the annual mean concentration of $PM_{2.5}$ and PM_{10} should not exceed 10 µg/m³ and 20 µg/m³. The 24-hour concentrations of $PM_{2.5}$ and PM_{10} should not exceed 25 µg/m³ and 50 µg/m³.

In general, low levels of particulates were estimated in the classrooms in the three regions, with the notable exception of one Dunedin classroom. In winter, it experienced a $PM_{2.5}$ level above 25 µg/m³ for 9.7% of the school hours while other classrooms only exceeded this for 1.2% of school hours. The same classroom also experienced a PM_{10} level above 50 µg/m³ for 3.8% of school hours, while other classrooms experienced this for only 0.2% of school hours.

A QUESTIONNAIRE ON VENTILATION PRACTICES IN SCHOOLS

A questionnaire about ventilation was completed by 33 teachers from nine schools as part of the project (Table 1). Key findings were that:

- 58% agreed that their classrooms could be smelly (especially after the weekend)
- 79% agreed that when the doors and windows are open, they allow enough fresh air in to the classroom to make it feel comfortable
- 58% said windows and doors are easy to open and close, and 76% said that opening windows did not pose a risk to safety
- only 15% said they open windows each time they teach a class - the key reasons for not opening windows were noise and wind.

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M. Boulic, Y. Wang, R. Phipps, C. Chitty, C. Cunningham, A. Moses, R. Weyers, J. Julian Jang-Jaccard, G. Olivares, A. Shekar, I. Longley, L. Tookey, A. Ponder-Sutton, & D. Waters.

More information

Research Now: Indoor air quality #1 *An overview of indoor air contaminants in New Zealand houses*

Research Now: Indoor air quality #2 *An overview of indoor air contaminants in New Zealand schools*

Research Now: Indoor air quality #3 *The impact of ventilation in New Zealand houses*

Research Now: Indoor air quality #4 *Project: Indoor air quality in New Zealand homes and garages*

Research Now: Indoor air quality #6 *Project: Indoor air pollution at a New Zealand urban primary school*

Table 1. Ventilation practices.

N#	QUESTION	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE	DID NOT ANSWER
1	It could be **smelly in my classroom** (especially after the weekend).	15%	43% total: 58%	15%	18%	9%	0%
2	When the windows and doors are open, they allow **enough fresh air** in to make the classroom feel comfortable.	18%	61% total: 79%	9%	12%	0%	0%
3	I **open the windows** each time I teach a class.	6%	9% total: 15%	30%	37%	15% total: 52%	3%
4	During the teaching hours, the **noise** from outside enters the classroom and deters me from opening windows.	12%	30% total: 42%	37%	12%	9%	0%
5	The windows and doors are **easy enough to open** and close in terms of hardware mechanisms, e.g. handles, fasteners, locks.	31%	27% total: 58%	3%	21%	3% total: 24%	15%
6	When the windows are open, they pose a **risk to the safety** of the children either internally or externally.	0%	15%	9%	58%	18% total: 76%	0%
7	Windows can be opened even on **windy days**.	3%	21%	21%	51%	3% total: 54%	0%
8	It is **easy to break into** classrooms through doors and windows.	3%	30% total: 33%	24%	34%	3% total: 37%	6%