IMPROVING TANZANIAN CLASSROOMS: TRIALLING ENVIRONMENTAL SENSORS IN TANZANIAN SCHOOLS – FIRST PILOT

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Funded by the UK Foreign, Commonwealth and Development Office, the Improving Learning Through Classroom Experience (ILCE) programme focuses on investigating whether modifica of the built environment (temperature, light intensity, and acoustics) can positively impact the classroom experience to improve learning.

This blog post is about the first pilot, where we tested the sensors in preparation for the upcoming fieldwork. Dr Shelina Walli, Chief Executive Officer of Aga Khan Education Services in Tanzania, and her team facilitated OpenDevEd (ODE) in conducting this pilot study at Aga Khan Mzizima Secondary School in the city of Dar es Salaam for one day.

The aim was to test all the devices to be used in the study, so the presence of students was not required.

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FIRST PILOT (23 JUNE)

The purpose of the first pilot was to:

- Conduct an initial test of the commercially available equipment
- Test the environmental sensor built by OpenDevEd
- Compare measurements and analyse the accuracy of devices
- Determine the most appropriate logging period for data for the sensors for maximum battery life and storage capacity.

COMMERCIALLY AVAILABLE SENSORS

The sensors used measured the following indoor environmental quality (IEQ) parameters:

- **Temperature and humidity:**
  - **Onset HOBO MX1101** with accuracy ±0.21°C from 0° to 50°C for temperature measurement and ±2% for humidity. The sensor can collect data independently of a computer system, as it operates on battery power and allows data retrieval through a

mobile app. It has an extended battery life of over 3 months. Cost: £220.

- **Lascar EasyLog EL-SIE-2** with accuracy ± 0.2°C from -18^0 to 55°C for temperature and ± 1.5% from 0-100% for humidity. The sensor can collect data independently of a computer system since it operates on battery power, and data retrieval can be accomplished through a specified manufacturer weblink (easylog.local). It has an extended battery life of over 3 months. Cost: £70.

- **Lighting:**
  - **ATP DT-8809A Lux sensor** data logger with accuracy of ±3% of reading ±0.5% full scale, below 10,000 Lux. Includes a silicon photo diode sensor and spectral response filter. This sensor can be powered by either batteries or electricity. It doesn't have the capability for independent data logging, but it does feature independent memory, capable of storing data up to 99 times without the need for a computer system. Continuous, long-term data logging is only possible when the sensor is connected to a computer system. Data retrieval can be done through its installed computer application. Cost: £137.
- **Noise:**
  - **ATP ET-958 Sound level meter** with accuracy of ±1.4dB (94dB @ 1 Khz). Allows measurement ranges of 30 to 80dB 50 to 100dB, 80 to 130dB, 30 to 130dB (Auto range). This sensor operates exclusively when connected to a computer system. It can

be powered by batteries or electricity. Data retrieval can be done through its installed computer application. Cost: £182.

- **Indoor air quality (IAQ) parameters**
  - Temtop M2000 2nd generation with;
  - – CO_2 accuracy: ±50 ppm + 5% reading.
  - – PM2.5 accuracy: ±10 μg/m^3(0-100 μg/m^3), ±10%(>100 μg/m^3)
  - – PM10 accuracy: ±15 μg/m^3(0-100 μg/m^3), ±15%(>100 μg/m^3)- Formaldehyde accuracy: ±0.03 mg/m^3(0-0.3 mg/m^3), ±10%(>0.3 mg/m^3)
  - The sensor operates independently and is powered by a rechargeable battery with a limited lifespan of under 7 hours when fully charged. For extended use, it must be continuously connected to an electricity source. Data retrieval can be easily done on a computer without requiring any installed applications. Cost: £170.

ASSESSMENT OF THE COMMERCIAL SENSORS

We investigated commercially available sensors extensively and in great detail. The sensors listed above are the best we could find.

Sensors for temperature and humidity are readily available at a reasonable price, with good battery life and the capability to make autonomous measurements for several months.

However, when it comes to sensors for measuring other environmental properties, either the price is high or the sensors have poor battery life (which means they will have limited autonomy). Furthermore, there are no commercially available sensors that can measure the key elements of light and sound autonomously over a period of time.

ENVIRONMENTAL SENSORS BUILT BY OPENDEVED (ODE)

Inspired by available maker-type devices, such as the Pimoroni environmental range, we set about developing a ‘sensor box’ that could measure not only temperature and humidity, but also light and sound. We hoped to draw on cost-effective materials and manufacturing, ideally with a flexible approach that could be repurposed for different uses and in different settings/countries.

The first version of our ’sensor box’ uses a Raspberry Pi Pico, with a customised power circuit and a range of sensors allowing measurement of the following environmental parameters:

- Temperature/humidity using an AHT20 sensor
- Temperature using an MCP9808 sensor
- Luminance in Lux using LTR-559 sensor.

The sensor was also fitted with an I2S MEMS (Micro-Electro-Mechanical Systems) microphone to measure noise; this was unsuccessful due to software issues, and the next version of our sensor used a PDM (Pulse-Density Modulation) microphone instead (to be discussed in a future blogpost). The sensor is powered by two AA batteries, with an expected lifetime of up to several months, depending on frequency of measurements. In the first version of our software, the measurement interval can be set arbitrarily, typically 5, 10, or 15 minutes. The data collected is stored on a memory card and can be easily extracted.

Even though the first version allows the measurement of a fairly limited number of parameters, our design allows us to add additional sensors quite easily, including for sound, but also CO_2, volatile organic compounds (VOCs), and particulate matter (PM). Moreover, the sensor has provision for wireless data transmission, enabling real-time (or near-real-time) logging. These additions will be described in a future blog post. Further technical details and links are provided below, and will also be published in a report at a later date.

OBSERVATIONS FROM THE FIRST VISIT

After leaving all the devices running for a period of approximately 4 hours without students, the team observed that:

- Temperature and humidity show very similar results across all the devices, with a difference of 0.2 to 0.5 °C and 1%, respectively.
- Temperature and humidity do not vary significantly during the day, only by about 2–4 °C. This allows us to consider that an interval of 15 to 30 minutes will be sufficient to gather representative temperature/data for the study.
- Luminance readings between the ATP DT-8809A Lux sensor and the ODE sensor are not comparable because the latter does not include a photodiode sensor. The photodiode sensor makes the commercially available sensor more sensitive to light.
- For optimal luminance and sound readings with an ODE sensor, we will consider using three or more sensors located in strategic locations in the classroom.
- Air quality shows good levels in all its parameters, with measurements of CO_2 serving as a surrogate for ventilation adequacy, as well as measurements of PM2.5, PM10, and formaldehyde to represent volatile organic compounds (VOCs).

ABOUT OUR SENSOR

Links and further information are listed below for readers interested in the technological details of our sensors.

- The datalogger design was led by Bernhard Bablock; it was based on some of his prior designs. Details about the sensor (hardware and software) are available here: https://github.com/bablokb/pcb-pico-datalogger.
- The datalogger connects to a 'sensor board', mounted with a range of (mainly) I2C sensors: https://github.com/OpenDevEd/sensor-stripboard-v1
- To keep costs down, we used a commercially available ABS box, but replaced the lid with a 3D-printed lid, that allowed mounting. The 3D print files are available here: https://github.com/OpenDevEd/case-for-pico-datalogger-rev1.00

WHAT'S NEXT?

Next time, we will report on the outcome of the second school's visit, which focused on testing comfort with students. This means we will be measuring temperature, humidity, acoustics, lighting, and air quality with students in situ. We will also conduct the walk through survey, which explores classroom conditions.