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Data Article

Dataset of indoor air parameter measurements relating to indoor air quality and thermal comfort in South African primary school classrooms of various building infrastructure types

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ABSTRACT

In the resource-constrained South African education sector, infrastructure considered temporary or a backup in other countries is used as permanent classrooms, primarily but not exclusively in lower-income areas. Children's cognitive performance and comfort are directly impacted by indoor air quality. Temperature, relative humidity, particulate matter and CO_2 levels, substantial determinants of air quality and thermal comfort, have not been investigated across different classroom building and infrastructure types. We measure these parameters with 11-min intervals in 24 classrooms at schools in Stellenbosch, South Africa. These classrooms consist of a range of different infrastructure types. Container classrooms with and without insulation, mobile (prefabricated) classrooms, and brick classrooms of different configurations are included. Measurements are concurrently sampled over ten months (249 days, still ongoing) across multiple seasons with relevant metadata, including ambient weather conditions, school days and times, and electricity availability in the (South) African context, which impacts air

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conditioning usage. This dataset provides valuable insights into true learning conditions in South African classrooms.

Specifications Table

Subject	Electrical and Electronic Engineering
Specific subject area	A data-in-brief article presenting concurrent indoor air environment measurements in South African classrooms of different building infrastructure types and categories.
Data format	Raw .xlsx file including sheets for codebook, metadata, other information, and data in csv format.
Type of data	Table including measurement data (with metadata and flags)
Data collection	Measurements in 24 classrooms in two South African primary schools using custom sensing devices measuring CO_2 (COZIR-LP-5000), T, RH (DHT22), $PM_{1.0}$, $PM_{2.5}$, PM_{10} (PMS5003). Power meter data is used to see whether power was on at sample time. Weather data from the NEMS dataset (High resolution, for machine learning) for Stellenbosch Central was used for weather conditions. School days and hours are recorded. LoRaWAN-based communication is utilised for live and continuous data capture.
Data source location	All schools where data collection took place are in Stellenbosch, Western Cape, South Africa (33.9372° S, 18.8596° E).
Data accessibility	Mendeley Repository Repository name: Indoor air quality measurements in South African primary school classrooms of various building infrastructure types. [1] Data identification number: 10.17632/tys2gscdv7.6 Direct URL to data: https://data.mendeley.com/datasets/tys2gscdv7/6 At the time of publication, data collection was ongoing. The Mendeley repository may be updated accordingly, and readers are encouraged to download the latest version of the dataset. The information in this paper relates to Version 6 of the repository.

1. Value of the Data

- Indoor air quality and thermal comfort parameters including CO_2 and temperature significantly impact concentration, comfort, performance, and motivation. Other parameters including particulate matter have potential undesirable health impacts. Children are even more susceptible to poor indoor air or thermal conditions than adults. Given the substantial amount of time spent in classrooms while learning, and the cognitive nature of typical school activities, obtaining information on these conditions and investigating the learning environment becomes critical.
- South African schools utilise classrooms of various infrastructure types. Classroom infrastructure, typically considered as merely for temporary use or 'backup' classrooms elsewhere, is used permanently in both high-income and low-income schools. The learning environments resulting from the different building infrastructures must be investigated and quantified. This dataset allows for the assessment of the potential impact on schoolchildren's learning abilities, and how classroom infrastructure potentially disadvantages schoolchildren who receive schooling in these classrooms.
- For the first time, this dataset concurrently measures indoor air environment parameters in classrooms of different types, across various seasons. Weather parameters, electrical availability, school days, lecture times and break times, and other metadata and relevant information, including room dimensions and materials, are also captured. The vast number of concurrent measurements, given that classrooms are in similar orientations and are exposed to the same ambient conditions, makes this data invaluable for direct com-

parisons and analyses of indoor air quality and thermal conditions in different classroom types.

- The captured weather information, room dimensions and materials, in combination with indoor measurements, provide the opportunity to inspect the influence of ambient conditions on resulting indoor environmental conditions. The insulative effect of the wood panels on the container classrooms, and how it affects the impact of different ambient conditions on the indoor environment, can be assessed and modelled. This holds potential for the development of a thermal model or other thermal analyses, relating different infrastructure parameters to the measurements, occupancy data and weather parameters.
- The flagging of data according to school days, school hours, and break times allows for distinguishing and comparisons between school days and non-school days. The impact of occupancy, human activity and emitted body heat on indoor conditions can be investigated. Additionally, free-running conditions, when occupants do not influence or alter the indoor air environment, can be investigated for direct infrastructure comparisons and the resulting indoor conditions. This data will be invaluable when utilised in the development of thermal models.
- Capturing electrical availability and load shedding allows for assessing the impact of load shedding and the lack of air conditioning on the resulting indoor air environment for different classroom types. This data can also be utilised to model the potential impact of load shedding on pupils and their academic performance. Displaying the significant effect that power outages may have on immediate indoor conditions may highlight the severity of indoor conditions in schools where air conditioning systems are unavailable.

2. Background

Mobile/prefabricated and container classrooms are used extensively as permanent classrooms in South African schools. No existing work quantifies the potentially unfavourable indoor air conditions, despite the undesirable impact of poor environmental conditions being greater on children than their adult counterparts [2–4]. It becomes critical to evaluate the indoor air environment in classrooms and its potential effects. Despite it being generally acknowledged that prefab classrooms should serve as a short-term solution, schools are still equipped with them. Additionally, some schools also use container classrooms (converted shipping containers) as permanent classrooms due to their cost-effectiveness. These mobile/prefab and container classrooms are not exclusively located in low-income schools but are prevalent in nearly all South African public schools, including high-income schools. The high prevalence of temporary classrooms in South African schools makes it critical to understand the indoor air learning environment in these classrooms.

3. Data Description

The dataset consists of a .xlsx file, “dataset and codebook.xlsx”, which consists of four sheets. The sheet named “codebook” contains the index, value, and description of each field in the dataset, and the sheet named “dataset” contains the current 372 084 data points and all measurements and flags associated with it. Captured parameters and flags include the measurement vector, information on ambient conditions, infrastructure type and category, room identifiers, hardware identifiers, school identifiers, pupil ages, electrical availability at the sample time, and occupancy at the time of sample using school hours and break times. Table 1 provides an overview of the field names, values, and descriptions of the data fields. This information is also available in the “codebooks” sheet in the .xlsx file.

The sheet named “metadata” contains relevant metadata including classroom dimensions and building materials for each room in the dataset. This includes an illustration to identify which

Table 1
Adaption of codebook and description of parameters in the dataset, as of 7 November 2023, Version 6.

Parameter	Description
Date	Date [yyyy-mm-dd]
Time	Time (GMT+2) [HH:MM:SS]
Classroom Type	Container, No Insulation Container, With Insulation Mobile/Prefab Brick, First Floor Brick, Second Floor Brick, Single Story
Classroom Category	Temporary (Container and prefab classrooms) Permanent (Brick building classrooms)
Room Number	Classroom number of that type
Device Code	Sensing device code (hardware identification number)
School No	1 – School 1 2 – School 2 ... - ... *N* – School *N*
Grade	Grade of learners in classroom (0 to 7). 0 refers to pre-primary
Measured T	Measured indoor temperature [°C]
Measured RH	Measured indoor relative humidity [%]
Measured CO_2	Measured indoor carbon dioxide [ppm]
Measured $PM_{1.0}$	Measured indoor $PM_{1.0}$ [µg/m^3]
Measured $PM_{2.5}$	Measured indoor $PM_{2.5}$ [µg/m^3]
Measured PM_{10}	Measured indoor PM_{10} [µg/m^3]
School Day	Y – School day N – Weekend, public holiday, or school holiday (no school)
School Hours	Y – During school hours on a school day N – Not during school hours
Break Time	Y – During break time on a school day N – Lesson time/after hours on a school day, or non-school day
Power On	On – Power on Off – Power off/Load shedding
Outdoor Temperature	Outdoor/ambient temperature [°C]

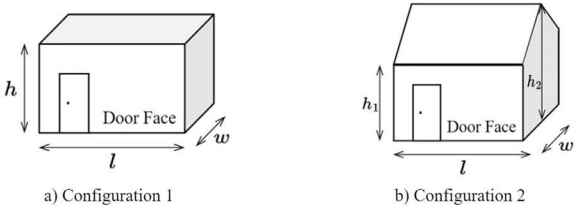

Fig. 1. Different classroom configurations and definitions of dimensions in relation to the door face.

parameters constitute the width, height, and length, relative to the wall face with the door. Table 2 and the corresponding Fig. 1 provides an adapted extract from this sheet.

The sheet named “other information” contains additional relevant information including lecture times, school hours and break times for each school.

Table 2
Adaption of metadata, classroom dimensions and materials. Corresponds to dataset Version 6.

Classroom Type	School	Room Numbers	Classroom Configuration	w [m]	l [m]	h [m]	Ceiling	Wall	Floor
Container, No Insulation	1	1, 2	Fig. 1a	7.125	11.825	2.685	Sheets	Sheets	Non-slip epoxy
Container, With Insulation	1	1	Fig. 1a	7.125	11.825	2.685	Sheets	Sheets	Non-slip epoxy
Mobile/Prefab	2	1	Fig. 1a	8.435	7.242	2.650	Sheets	Sheets	Laminated wood
		2	Fig. 1b	7.165	7.665	h1: 2.480 h2: 3.135	Sheets	Sheets	Vinyl
Brick, First Floor	1	1, 6	Fig. 1a	6.840	6.930	3.060	Concrete, painted	Brick	Linoleum
		2	Fig. 1a	6.865	9.110	3.065	Concrete, painted	Brick	Linoleum
	2	3, 4, 5	Fig. 1a	6.828	6.882	2.941	Concrete, painted	Brick	Wood
Brick, Second Floor	1	1, 2, 3, 4, 8	Fig. 1a	6.850	6.935	3.160	Drywall, painted	Brick	Vinyl
	2	5, 6, 7	Fig. 1a	6.930	7.055	3.040	Suspended ceiling	Brick	Wood
Brick, Single Story	1	1, 2, 3, 4, 5	Fig. 1a	6.865	8.163	3.075	Drywall, painted	Brick	Linoleum

Fig. 2. Aerial view of the schools where data collection takes place. Photos adapted from [6,7].

4. Experimental Design, Materials and Methods

Data collection commences at two quintile-5 (high affluence) primary schools in Stellenbosch, Western Cape, South Africa (33.9372° S, 18.8596° E). All classrooms have a similar and comparable number of pupils (27 to 32). The greatest line-of-sight distance between any two classrooms is 2.74 km, and ambient conditions in all classrooms can therefore be assumed to be the same, using the data obtained from the NEMS dataset (High-resolution, for machine learning) for Stellenbosch Central [5]. All classroom dimensions are captured using a laser distance measurer, and building materials are recorded. The schools are in the same load-shedding zone (electricity is switched off periodically, typically for 2 to 5 h at a time, to reduce strain on the South African electrical grid). In the context of this research, load shedding affects the use of air conditioning and other mechanical HVAC systems. Therefore, electricity (air conditioning) is off simultaneously for all classrooms in the dataset. All classrooms have access to working air conditioning or HVAC systems/mechanisms. Fig. 2 depicts the satellite view of the two schools and the geographic location of the various classroom types, showing that all classrooms have similar orientations.

The classroom types and their infrastructure description and sample sizes are shown in Table 3 and Fig. 3 shows images of the different classroom types.

Table 3
Classroom type description (Number of rooms as on 7 November 2023, dataset Version 6).

Name and Description	Number of Rooms	Category	Image
Container, No Insulation. Shipping containers converted to be used as school classrooms, without insulation	2	Temporary	Fig 3a
Container, With Insulation. Shipping containers which were converted to be used as school classrooms, with decorative wood panels on the front and back. Wood panels were installed for decorative purposes but leave a resulting insulating effect on indoor conditions.	1	Temporary	Fig 3b
Mobile/Prefab. Prefabricated classrooms which were designed and manufactured by dedicated companies, intended as classrooms. Insulated with polyurethane foam and coated with Aluzinc painted steel.	2	Temporary	Fig 3e
Brick, First Floor. First-floor classroom in a two-story brick building.	6	Permanent	Fig 3c
Brick, Second Floor. Second-floor classroom in a two-story brick building.	8	Permanent	Fig 3c
Brick, Single Story. Classroom in a single-story brick building.	5	Permanent	Fig 3d

Fig. 3. Images of classroom types. Image credit: R.E. van der Walt, 2023.

Table 4
Sensing module specifications.

Parameter	Sensor Module	Resolution	Accuracy	Unit
T	DHT22	0.1 °C	± 0.5 °C	°C
RH	DHT22	0.1 %	±1 %	%
CO_2	COZIR-LP-5000	1 ppm	±30 ppm (±3 %)	ppm
$PM_{1.0}$, $PM_{2.5}$, PM_{10}	PMS5003	1 µg/m^3	98 %	µg/m^3

A sensing device to measure T, RH, CO_2, $PM_{1.0}$, $PM_{2.5}$ and PM_{10} was developed, manufactured, and installed. Table 4 summarises the integrated sensing modules used in the sensing device and their most relevant specifications.

The sensing modules in Table 4 were used to create an integrated sensing device, depicted in Fig. 4a. Sensors were programmed with their classroom number and type to transmit 12-byte LoRaWAN packets at 11-minute intervals, per the LoRa Alliance Fair Use Policy. This policy dictates that any end device (sensing device) may not exceed 30 s of airtime in 24 h [8]. By transmitting 12-byte packets every 11 min, with the configured radio parameters, the LoRaWAN network usage is well within compliance with these limitations.

a) Sensing Device. b) Installation

Fig. 4. Sensing device and typical classroom setup.

Table 5
Number of sensing devices for each classroom type, as of 7 November 2023, dataset Version 6.

Classroom Type	Number of Sensing Devices
Container, No Insulation	8
Container, With Insulation	4
Mobile/Prefab	8
Brick, First Floor	7
Brick, Second Floor	8
Brick, Single Story	8

This measurement resolution is comparable to that of related studies of indoor air in classrooms by Jovanovic et al., 2014 (10 min) [9] and Lovec et al., 2020 (15 min) [10]. The 11-minute sampling rate is also of higher resolution than other related publications, including Bunyasi et al., 2022, (40 min) [11], Essah et al., 2016 and Gibberd et al., 2013 (60 min) [12,13]. Several classrooms of interest have multiple sensors placed in each room, increasing the effective sampling resolution of classroom measurements. This is primarily done in classroom types for which there are not many different rooms available, predominantly the container and mobile/prefab classrooms, which have four sensing devices per room. Given the vast number of classrooms for the classroom types, each logging interval consists of multiple captured measurements for each classroom type. Table 5 shows the number of logging devices for each classroom type.

The LoRaWAN gateway allowed for continuous and remote data collection without requiring site visits. This minimised disturbances to school activity.

The sensing module was placed in an enclosure with large openings, allowing for sufficient airflow and ventilation and ensuring accurate measurements. All sensor modules were installed facing the outside of the device and were located next to an opening in the enclosure.

To ensure uninterrupted measurements during load shedding, sensors were powered with a power bank as battery backup. Sensing devices were placed above ground level and away from walls. Fig. 4b depicts the typical classroom setup.

4.1. Weather data

Weather and climatic data with hourly resolution from the NEMS-dataset [5] were obtained from a Stellenbosch weather station. Captured parameters include temperature (2 m elevation corrected), relative humidity (2 m), precipitation amount, sunshine duration (minutes), solar radiation, pressure (mean sea level), wind speed (10 m) and wind gusts. This data is not included in the published dataset but the rights to it can be purchased from MeteoBlu [5].

4.2. School days and school hours

Data collection commenced in two South African public schools which both follow the Western Cape school calendar [14]. School hours and break times were obtained directly from the

Table 6
Lesson and break times for each school. Lessons last 30 min and break times are 20 min.

Description	School 1	School 2
School day commences	07:45	07:45
Lesson times	07:50–09:50	07:50–10:20
Break time	09:50–10:10	10:20–10:40
Lesson times	10:10–12:10	10:40–12:40
Break time	12:10–12:30	12:40–13:00
Lesson times	12:30–14:00	13:00–14:00
School day concludes	14:00	14:00

schools. Measurements are flagged and sorted according to these dates and times. All lecture periods for both schools last 30 min, with the first lesson commencing at 07:50 on school days and the final lesson concluding at 14:00. Pupils do not move among classrooms between lessons and remain in the classroom for all lessons during the day. Classrooms are therefore occupied by the same pupils for the full school day duration, apart from break times. The flag 'Break Time' in the dataset indicates measurements taken during break times. Table 6 shows the lesson and break times for each school.

4.3. Load shedding and power outages

Considering the ongoing South African energy crisis and load shedding, capturing data on electrical availability becomes relevant because it affects the use of air conditioning or mechanical HVAC systems. We, therefore, flag measurements taken while the power is off (and therefore air conditioning measures are not usable), and the potential resulting impact on the indoor air environment. Power meter data captures electrical availability with a 30-minute resolution to obtain this information. All schools participating in this study are in the same electrical 'zone' and experience load shedding at the same time.

4.4. Dataset composition

Data collection commenced in February 2023, near the end of the South African summer season. Therefore, at the time of this publication, most measurements and data points are taken in the winter season. Fig. 5 shows the number of measurements taken per month, and the composition of measurements for each month concerning classroom type and category.

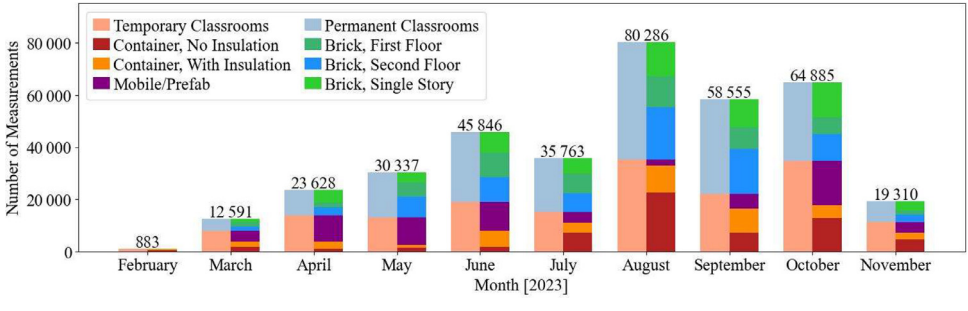

Fig. 5. Dataset monthly composition and growth as of 7 November 2023, dataset Version 6.

At first glance at the monthly dataset growth from Fig. 5, the increase in monthly sample volume may make it appear that the earlier months of data collection did not fully capture the indoor conditions. However, this increase in volume is merely because of the larger number of sensing device in use and near-full-resolution data capture (measurements per hour) has been captured in the earlier months as well.

Table 7 shows the resulting dataset and its composition by filter and classification.

Table 7
Dataset composition by different classifications and flags as on 7 November 2023, dataset Version 6.

Filter	Classification	Data days	Data points	Weight [%]
Class Category	Temporary Classrooms	249	173 182	46.5
	Permanent Classrooms	239	198 902	53.5
Class Type	Container, No Insulation	240	60 873	16.4
	Container, With Insulation	211	43 179	11.6
	Mobile/Prefab	232	69 130	18.6
	Brick, First Floor	230	79 646	21.4
	Brick, Second Floor	231	54 234	14.6
	Brick, Single Story	221	65 022	17.5
School Day	School Days	141	230 177	61.9
	Non-School Days	108	141 907	38.1
School Hours	School Hours	140	55 351	14.9
	Not School Hours	249	316 733	85.1
Electrical Availability	Power On	248	313 337	84.6
	Power Off (Load Shedding)	215	57 243	15.4
Total:			**372 084**	

Table 8 shows the number of samples containing measurement data for each measured parameter.

Table 8
Dataset composition by measurement parameter as on 7 November 2023, dataset Version 6.

Parameter	Data points	Data days
CO_2	338 195	240
T	372 079	249
RH	372 082	249
$PM_{1.0}$	354 202	249
$PM_{2.5}$	354 202	249
PM_{10}	354 202	249

Limitations

Occasionally, devices or the gateway were plugged out by students or school staff, leading to some gaps in measurement data from that specific device, classroom, or school. In these situations, effort was made to remediate it as soon as possible. However, as a result, not all classrooms or devices have continuous data. The vast number of devices and classrooms does, however, make up for this.

Not all devices are equipped with all sensing modules. Although most sensing devices are equipped with CO_2, PM and T/RH sensor modules, some data points do not have measurement data for all parameters. Refer to Table 6 for the number of data points for each filter, flag, or parameter. Initial CO_2 measurements were captured with a different CO_2 sensor, which was found to be inaccurate, and these measurements have been removed from the dataset. Earlier measurements, therefore, have fewer CO_2 measurements.

Ethics Statement

The authors confirm that the ethical requirements for publishing data in Data in Brief have been read and understood and further confirm that the data collected does not involve human subjects, animal experiments, nor data collected from social media platforms.

Data Availability

Indoor air quality measurements in South African primary school classrooms of various building infrastructure types (Original data) (Mendeley Data)

CRediT Author Statement

Rita Elise van der Walt: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft; **Sara Susanna Grobbelaar:** Conceptualization, Formal analysis, Investigation, Methodology, Writing – review & editing, Supervision; **Marthinus Johannes Booysen:** Conceptualization, Formal analysis, Investigation, Methodology, Writing – review & editing, Supervision, Funding acquisition, Project administration.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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