UKFIET 2023
Order of presentation

1. **Ravina Pattni (15 mins):** Linkages between temperature and learning outcomes – initial findings and anticipatory action

2. **Xuzel Villavicencio and Oluyemi Toyinbo (15 mins):** Observations from the classroom in Tanzania and low cost retrofit interventions

3. **Jamie Proctor and Catriona Forbes (15 mins):** Practical considerations (and experience) – climate smart / learning and friendly builds (Malawi and Sierra Leone)

4. **Questions (30 mins)**

5. **Conclusions / Next Steps**

https://doi.org/10.53832/opendeved.1025

Improving learning through classroom experience in Tanzania

Preliminary findings

September 2023

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Contents

1 Study background

Motivations and objectives

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Motivation for the study in Tanzania

Limited evidence on classroom conditions and outcomes in developing countries

Evidence on temperature from temperate climates

Wargocki et al.'s (2019) meta-analysis of 18 studies indicated an average 20% performance increase in children's psychological tests and school tasks with temperature reduction from 30°C to 20°C.

Evidence on light from the US

Mott et al. (2012) found that in the US, higher-level ‘focus’ lighting improved oral reading fluency more than did ‘normal’ lighting.

Evidence on noise from developing countries

A review of studies by Klatte et al. (2013) find that excess noise can affect cognitive performance in children, especially those with language or attention disorders.

Evidence context

- Environmental classroom factors are both under-researched in a Sub-Saharan African context and overlooked in education programming
- There is only limited evidence on sound and air quality from Nigeria and South Africa, respectively

Research objectives

Generate proof-of-concept for classroom conditions in the Tanzanian context

Evidence on linkages

Using geospatial data and publicly available test score data to generate evidence on the potential links between classroom conditions and learning outcomes.

School infrastructure

Draw insights on how temperature, light and sound conditions link with school-level infrastructure (e.g. the size and layout of classrooms, availability of windows, the building materials etc.) and administrative data

Enhance conditions

Articulate concrete recommendations on how modifications to the classroom environment can enhance learning outcomes

2 Exploring temperature linkages

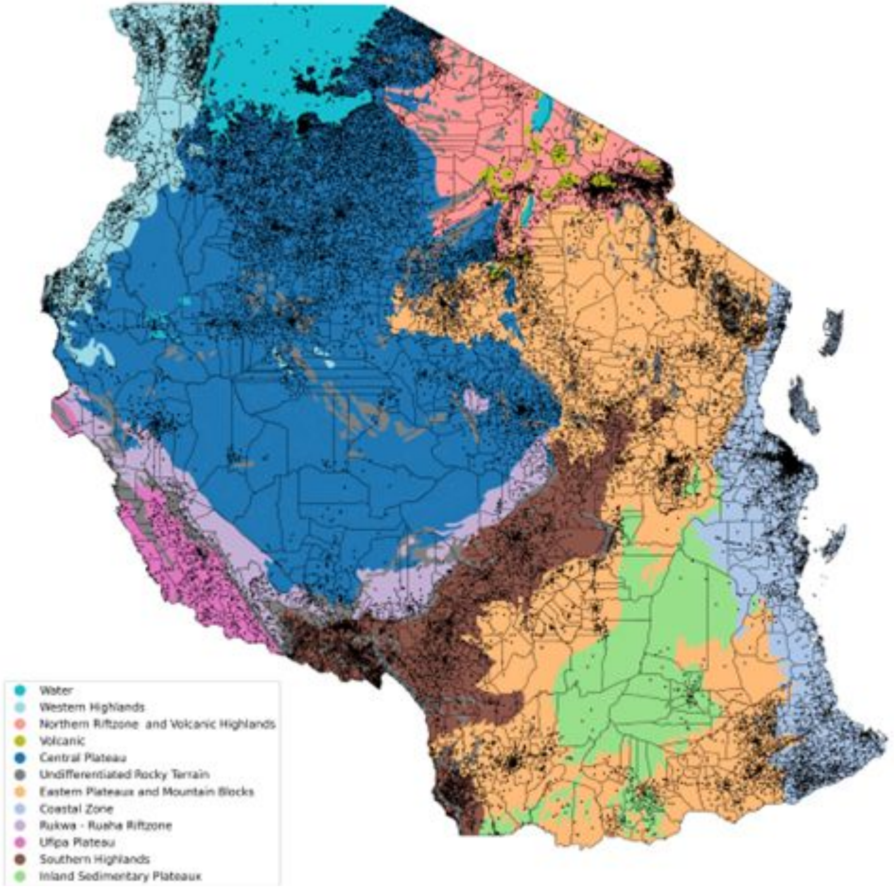
Geospatial and test score data

Primary schools in Tanzania

Location of primary schools in Tanzania mapped using agroclimatic zones

Primary schools in Tanzania by agroclimatic zones

Each color on the map highlights a different agroclimatic zone



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Mapping of school data

- Divide Tanzania into 12 agroclimatic zones obtained from the World Agroforestry Center data
- Use the publicly available primary school GPS data for each primary school in Tanzania
- **The major agricultural zones for schools are the Central Plateau, the Eastern Plateau and Mountain Blocks, and the Coastal Zone.**

Definition of extreme heat and time periods

Tested three definitions across three different school years

A. Defining extreme heat[1]

- **Maximum temperature** during the year
- The accumulated **number of days** that are hotter than **28.7º C**[2]
- The accumulated **number of days** that were hotter than **3 standard deviation to historical mean** (from 1950 to 2018)

B. Defining the time periods used for analysis

- The **whole school year from 2019-2021**
- In the **term** before exam
- On the **exam day**

We excluded weekends and school holidays to match the heat exposure to the time in school

[1] ERA5 satellite data provides precipitation data measured in depth in meters with approximately 9 km2 (0.1° X 0.1°lat and long) granularity for each hour
[2]Park, R. J., Behrer, A. P., & Goodman, J. (2021). Learning is inhibited by heat exposure, both internationally and within the United States. Nature human behaviour, 5(1), 19-27.

These definitions ensure a variety of robustness checks for the analysis

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Analysis method

Use of multilevel regression models to evaluate the relationship between temperature and school percentage PSLE marks

1. **Simple OLS regression**
   Use of simple OLS regression as the base model with and without control variables. The outcome of interest in the standardized percentage Primary School Leaving Examination score.

2. **Agro-climatic zone fixed effects model**
   Control the factors that are “fixed” within the agro-climatic zones that are not observable in our data.

3. **School-fixed effects model**
   Looks at correlation between changes in temperatures *within the same school over time*, and changes in the PLSE marks over time. Any time-invariant school characteristics, will be netted out (or substantially reduced).

Regression results

We specific several models, to control for external factors.

Correlation between school point temperatures and percentage PLSE scores

	OLS	OLS with control	Agro-climatic FE	School FE
Average temperature in school year	**0.0777*****	**0.223*****	**0.286*****	**-1.116*****
	(0.021)	(0.020)	(0.029)	**(0.089)**
Average temperature in exam term	0.030	**0.291*****	**0.308*****	**-1.216*****
	(0.018)	(0.017)	(0.025)	(0.111)
Average temperature on exam day	**-0.175*****	**0.057****	**0.109*****	**-0.379*****
	(0.019)	(0.018)	(0.021)	(0.046)

Dependent variable exam percentage (0-100); models reported are 2019-2021; data pooled with year fixed effects (2020 is the reference year).
All models apart from Base OLS use controls for PTR, relative wealth, school type and its distance to a city

As there are likely to be many unobserved factors which will confound the results when looking at differences across schools, the school-fixed effect is our preferred specification

Discussion of the regression results (1)

Effects are small overall given the ‘slow burn’ of change.

- The results in the school fixed effects model are statistically significant for all three definitions of average temperature.

- **But the impact is relatively small**. In standardized terms, our results indicate that an increase of 1°C in average temperature during the entire school year is associated with a difference of 1.1 percentage point (2.5 exam points out of 250) in the school average PSLE score.

Shutterstock

Discussion of regression results (2)

Substantial variation across agro-climatic zones

Average temperature per school year by agro-climatic zone

Zones	Beta	P-value	Average temperature	No. of schools
Central Plateau	0.69	0.00	26.08	5,713
Coastal Zone	-3.58	0.00	28.32	1,978
Eastern Plateaux and Mountain Blocks	-1.42	0.00	25.97	3,705
Inland Sedimentary Plateaux	-7.23	0.00	27.63	177
Northern Riftzone and Volcanic Highlands	-0.17	0.69	23.36	1,644
Rukwa - Ruaha Riftzone	2.13	0.02	26.79	363
Southern Highlands	-0.77	0.04	22.19	2,061
Ufipa Plateau	4.87	0.00	23.02	339
Undifferentiated Rocky Terrain	1.15	0.00	24.93	939
Volcanic	-0.77	0.70	22.63	76
Water	-1.27	0.57	24.19	158
Western Highlands	-2.03	0.00	24.79	1,414

Key points

- Regression for each agro-climatic zone separately to understand the variation
- **Find a positive correlation in schools in the central plateau** which has the largest number of schools
- **Need for further investigation** to understand the reason for this variation driving the positive relationship

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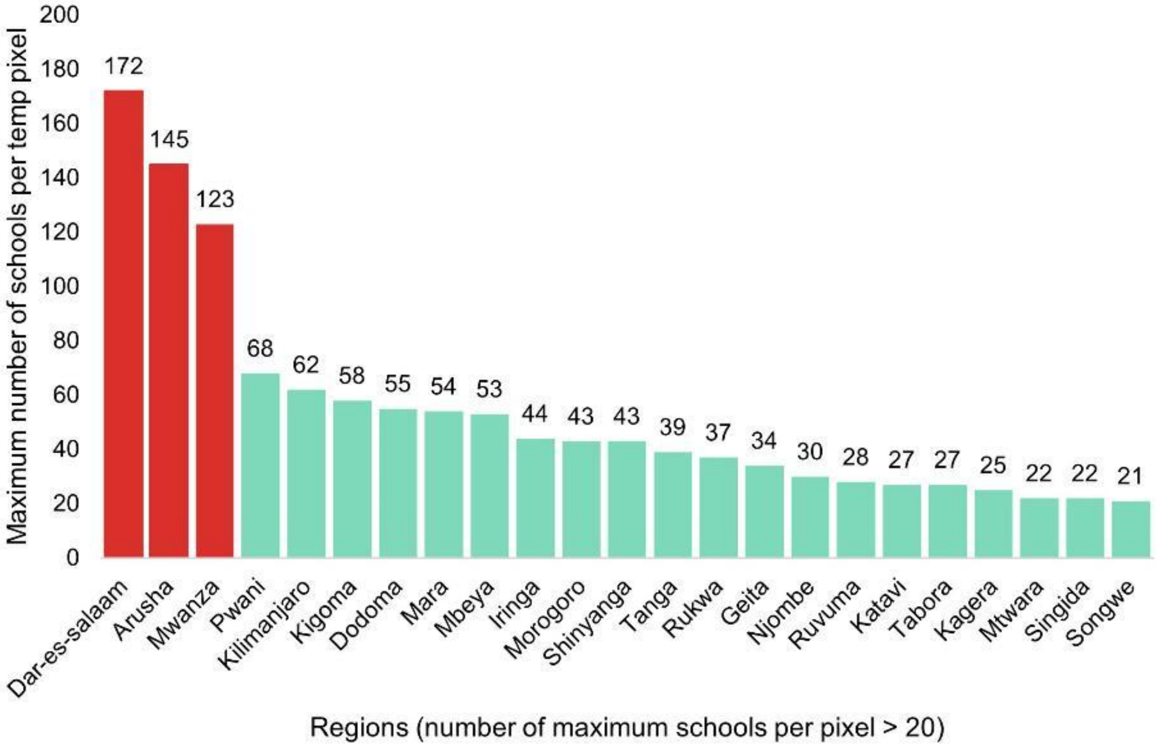
Discussion of regression results (3)

The temperature measurement from satellite data is shared across many schools

- **The number of schools in each measurement ‘pixel’ varies by region for the satellite temperature measurement**. These large outliers mean one measure has to cover up to 172 schools – which will affect the ability to model the relationship (estimates of the coefficients and the statistical significance).

- This is largely observed in cities and developed regions of Tanzania like Dar es Salaam, Arusha and Mwanza. **These outliers make a case for the need of primary data collection for more precise estimates of temperature at the school-level.**

Maximum number of schools per temperature reading, by region



Only showing regions that have more than 20 schools per temperature pixel

3 Primary data collection

Gaining contextual understanding

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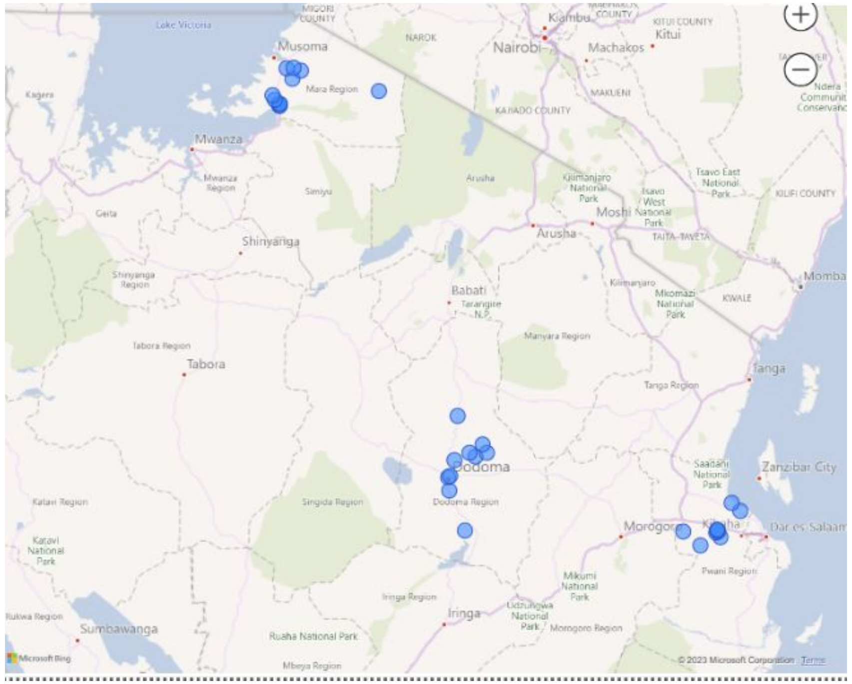
Collecting primary data in 48 schools

Sample stratified at the district level with clustering at the school-level

A. Purposive sampling of regions

- We selected three regions within Tanzania that experience different agro-climatic conditions throughout the year
- The three regions are Pwani (coastal and humid), Dodoma (dry, low rainfall), and Mara (wet, cooler)



B. Purposive sampling of two districts within each region

- Due to budget constraints we had to pick districts that were not too far apart in distance yet relatively different in terms of their socioeconomic development
- Our team of experts that are aware of the Tanzanian context, purposively sampled two districts with each region

C. Random sampling of schools within districts

- Eight primary schools were randomly sampled within each district

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Data collection tools

Using remote temperature sensors, headteacher and classroom observation surveys

Measuring indoor temperature

Trialing remote sensors in a low-resource setting to capture temperature data every 30 minutes from one classroom in each school. A proof-of-concept for scalability based on trialing experience

Headteacher survey

A 40-minute survey with the school headteacher to collected administrative data and headteacher's perception of classroom conditions affecting learning

Classroom observation survey

Collection of observational data on school-level infrastructure, including information on roofing/building materials, the classroom layout, the number of window, shade, source of noise/light etc

Where we are now?

We have completed the first round of primary data collection

Classroom conditions across the regions

The roofs, windows and walls of the classrooms

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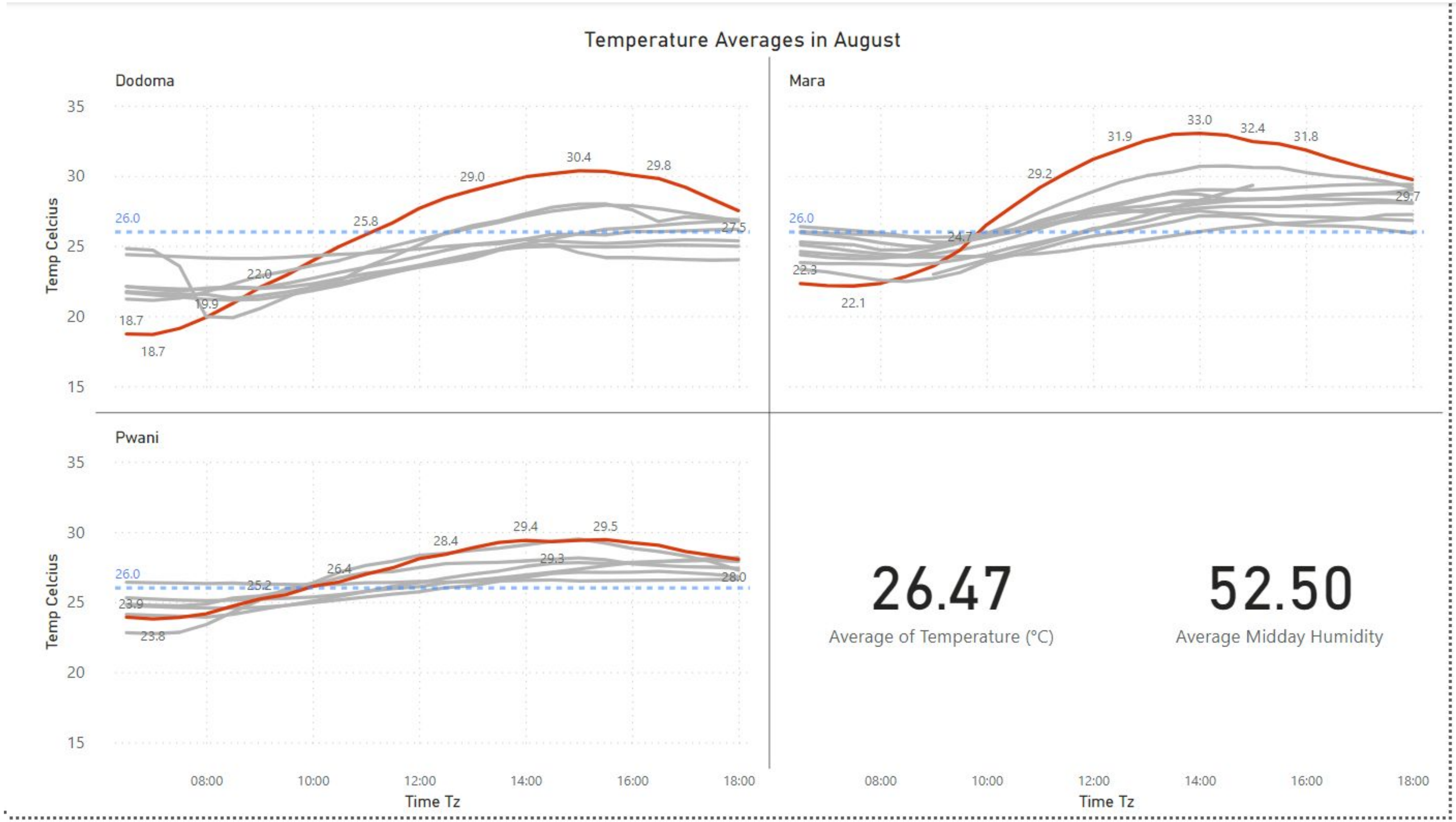
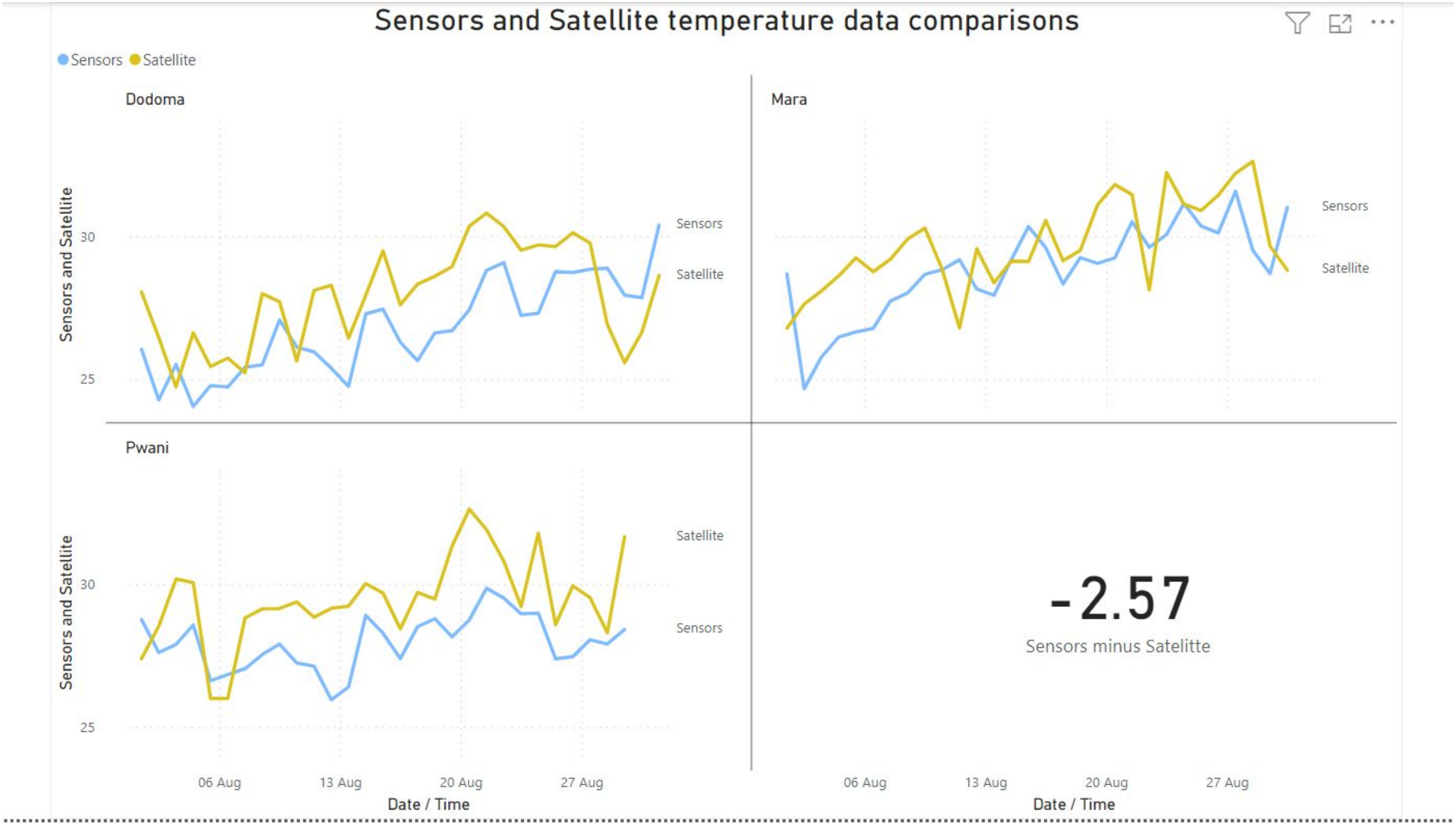
Key observations

- Majority of the roofs are corrugated iron sheets and did not have ceiling boards
- Most classrooms do not have access to electricity. Their source of light is natural light from windows/doors
- Classrooms in Pwani were constructed using cement blocks while the use of burnt and unburnt bricks was more common in Mara and Dodoma

Classroom temperatures are high for one of the coldest months



The indoor temps from schools are below the measured satellite temperature



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4 What is next?

More modeling and analysis

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Combine the secondary and primary data

Contextualize the secondary data with the primary data for modeling

We will continue to collect temperature data and add sensors to collect light and sound

We will merge the secondary and primary datasets to model indoor and outdoor environment for further analysis to develop concrete recommendations

This is one part of a wider series of work on climate, environment and education

Reducing vulnerability – flooding in Sierra Leone

Working with IRC to develop an anticipatory action for education model

Developed a set of responses that can be rolled out ahead of/at the beginning of an extreme weather event

Anticipatory Action model can be applied to drought and extreme heat

Working with The World Bank to create a school Flood Vulnerability Index

We modelled flooding hazard using GIS satellite data and school geo-location data

We developed a be-spoke Flood Vulnerability Index using Annual School Census data

Future climate agenda

Crop Failure and its impacts on schools

Community action planning to develop climate resilience

Anticipatory Action implementation for drought and extreme heat

Integrating gender, climate change, and vulnerability

Combining data mapping and community-based research.

Cross-cutting elements

Working with the government of Sierra Leone to develop climate-smart education infrastructure planning policy guidelines.

Across all projects linking current climate and extreme weather to climate models to support adaptation to mitigate future vulnerabilities.

Thank you!

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Improving Learning through Classroom Experience

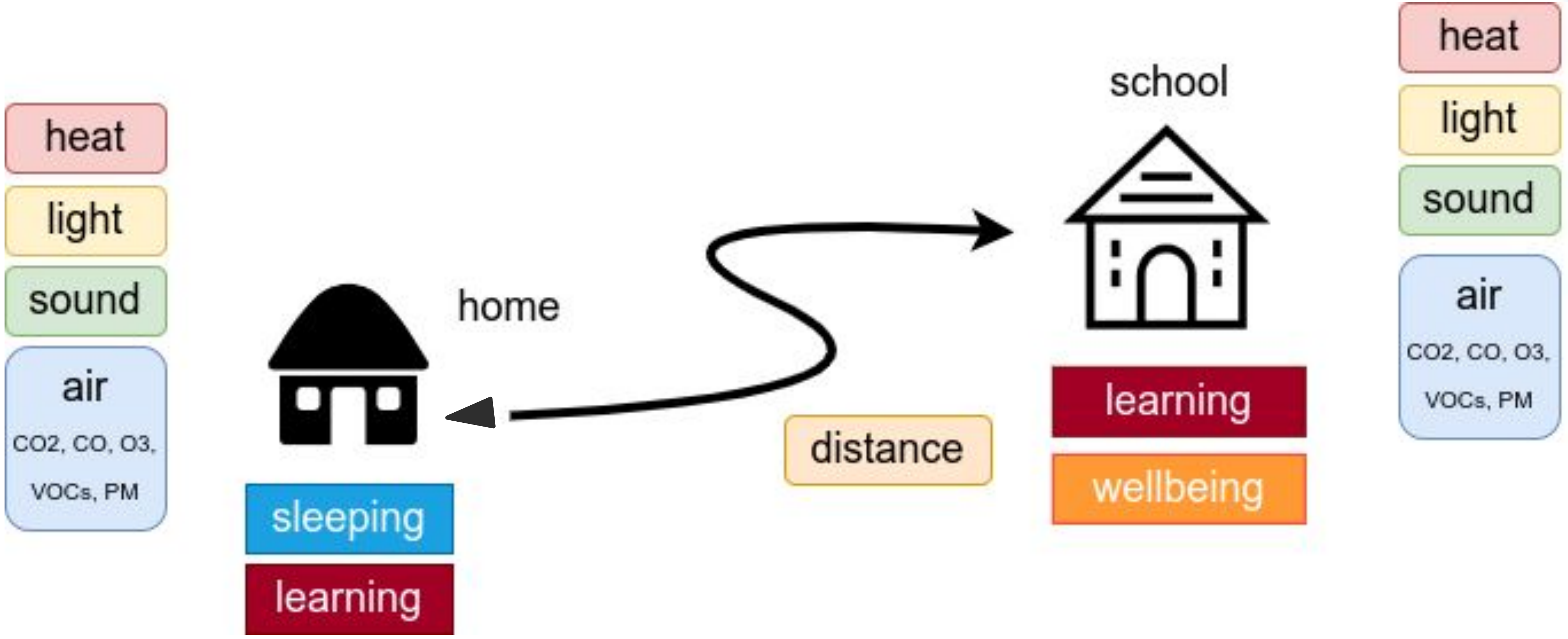
UKFIET 2023

Open Development and Education

https://opendeved.net

Climate-friendly schools

Our focus - what can be done to improve comfort for students?



What literature says about indoors spaces and classrooms?

Thermal comfort

Recommended values:

21–24 °C summer
24–26 °C winter

(The South African Labour Guide)

Recommended values should be considered through the lense of ***adaptive comfort****, which* addresses the need for a more flexible definition of the numerical parameters affecting thermal comfort and includes human psychology alongside physical characteristics of the indoor environment.

Humidity comfort

Recommended values:

30% to 60%

(ASHRAE)

What a person deems appropriate might also vary greatly amongst individuals.

Acoustic comfort

Recommended values:

35 dbA

*background noise in an unoccupied space

(World Health Organization)

Visual comfort

Recommended values:

300 lux

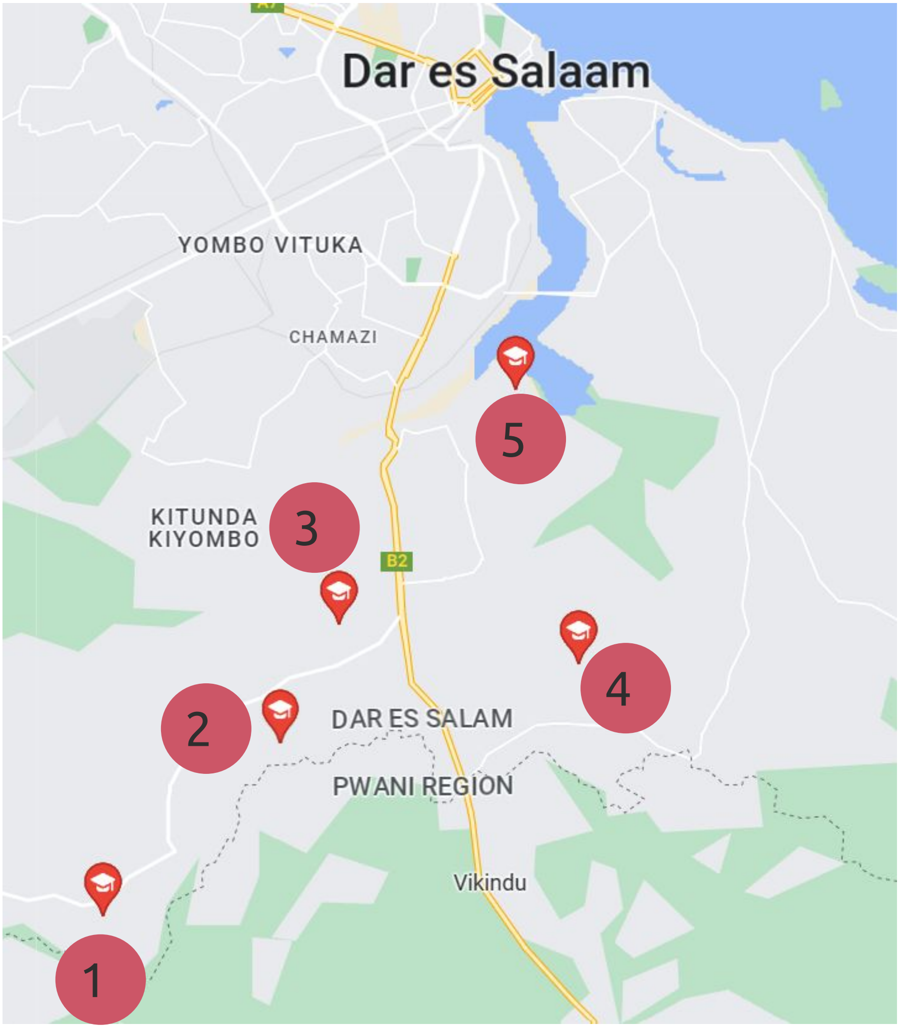
(ISO & CIE) International Commission on Illumination.

Evidence also suggests that illuminance **between 100 and 3000 lux** will likely result in a significant decrease in the amount of electricity used for lighting

How are we going to do that?

Data collection	Analysis	Implementation	Evaluation
1. Comfort survey	Analyse data collected		
2. Walkthrough survey	Explore retrofits suitable for each classroom	Implement retrofits in selected classrooms	Assess impact of retrofits on students through environmental data collection and surveys
3. School building scan	Modelling retrofits		
4. Environmental data	Determine suitable retrofits for each classroom		

Schools selected for initial trials



Temeke district, Dar es Salaam
5 government schools, 3 classrooms in each school

1. Mbande secondary school
2. Charambe secondary school
3. Nzasa secondary school
4. Toangoma secondary school
5. Kijichi secondary school

Other parts of the programme work in Shule Bora schools.

Engagement and comfort survey with students

A poster (in Swahili) was placed in each school answering the main questions about the study.

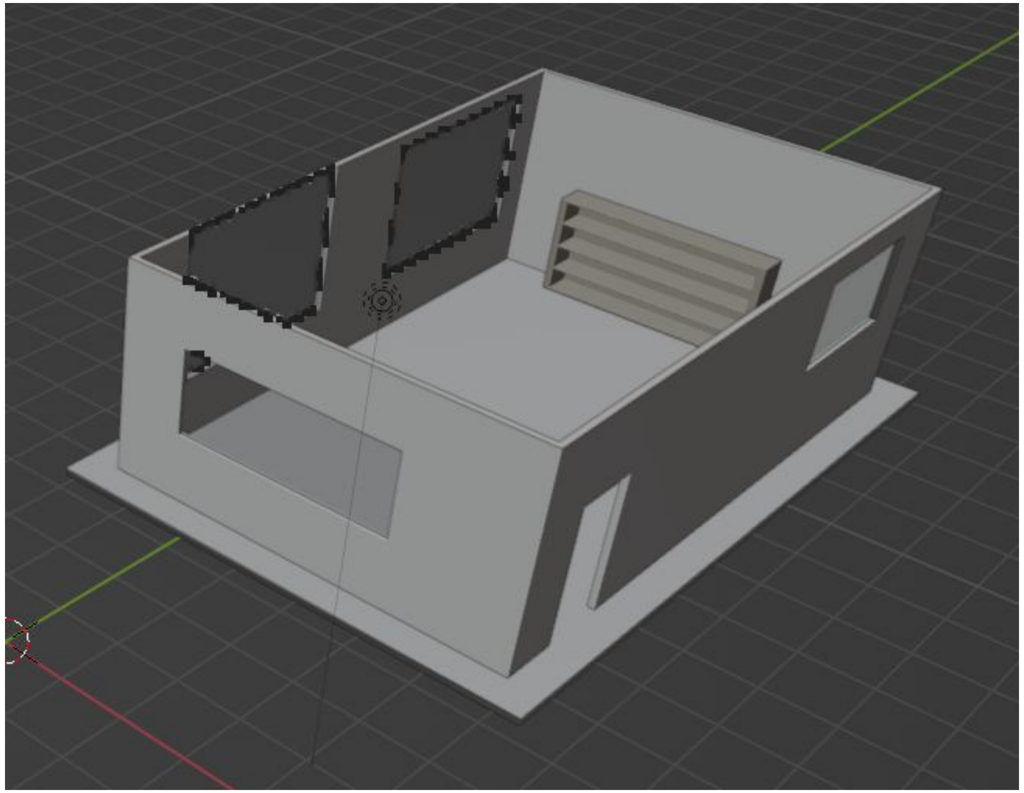
Workshops were conducted in each classroom to engage the school community with the importance of addressing the climate change challenges in the education field.

Students answered comfort surveys offered in Swahili. Their answers will allow us to know how students feel in the current conditions and what environmental conditions they feel are impacting negatively on their comfort.

Walkthrough survey

A walkthrough survey was conducted to gather data on the particular characteristics of each classroom. Details on the **infrastructure** and **maintenance work** was possible thanks to the collaboration of the head teachers.

Building scan



Using a LIDAR scanner, it was possible to obtain detailed models of the classrooms. This allows us to **run simulations** for testing possible retrofits.

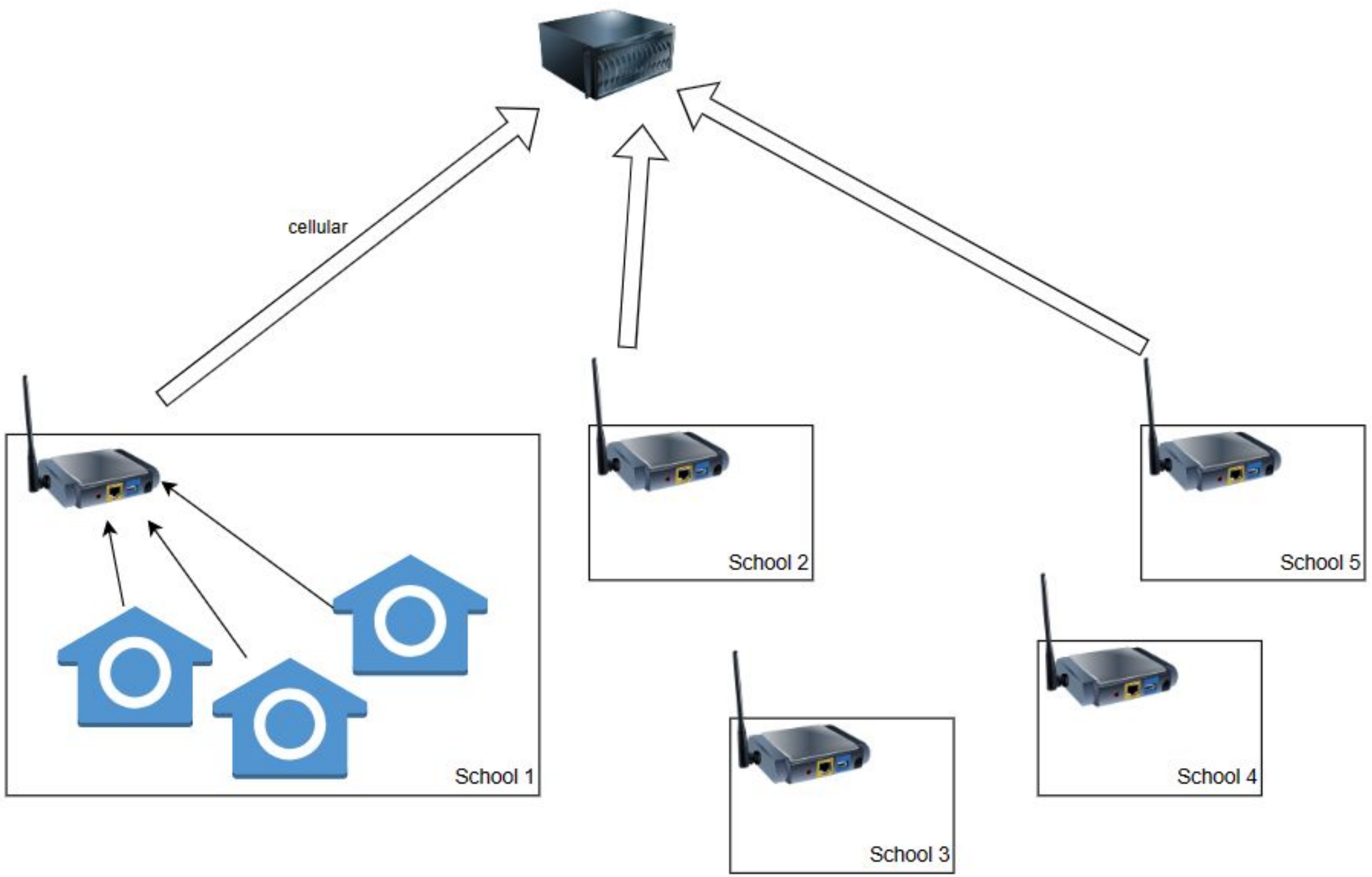
Environmental data

Commercially available handheld meters for measuring temperature, humidity, illuminance, acoustic, and air quality.

First version of OpenDevEd built-in sensor measuring **temperature**, **humidity**, and **illuminance**.

Placing OpenDevEd built-in sensor in front of the classroom, at a height out of reach of students

Environmental data



The second iteration of OpenDevEd built-in sensor will measure not only temperature, humidity, illuminance, and noise, but also **air quality** (CO_2, VOC)

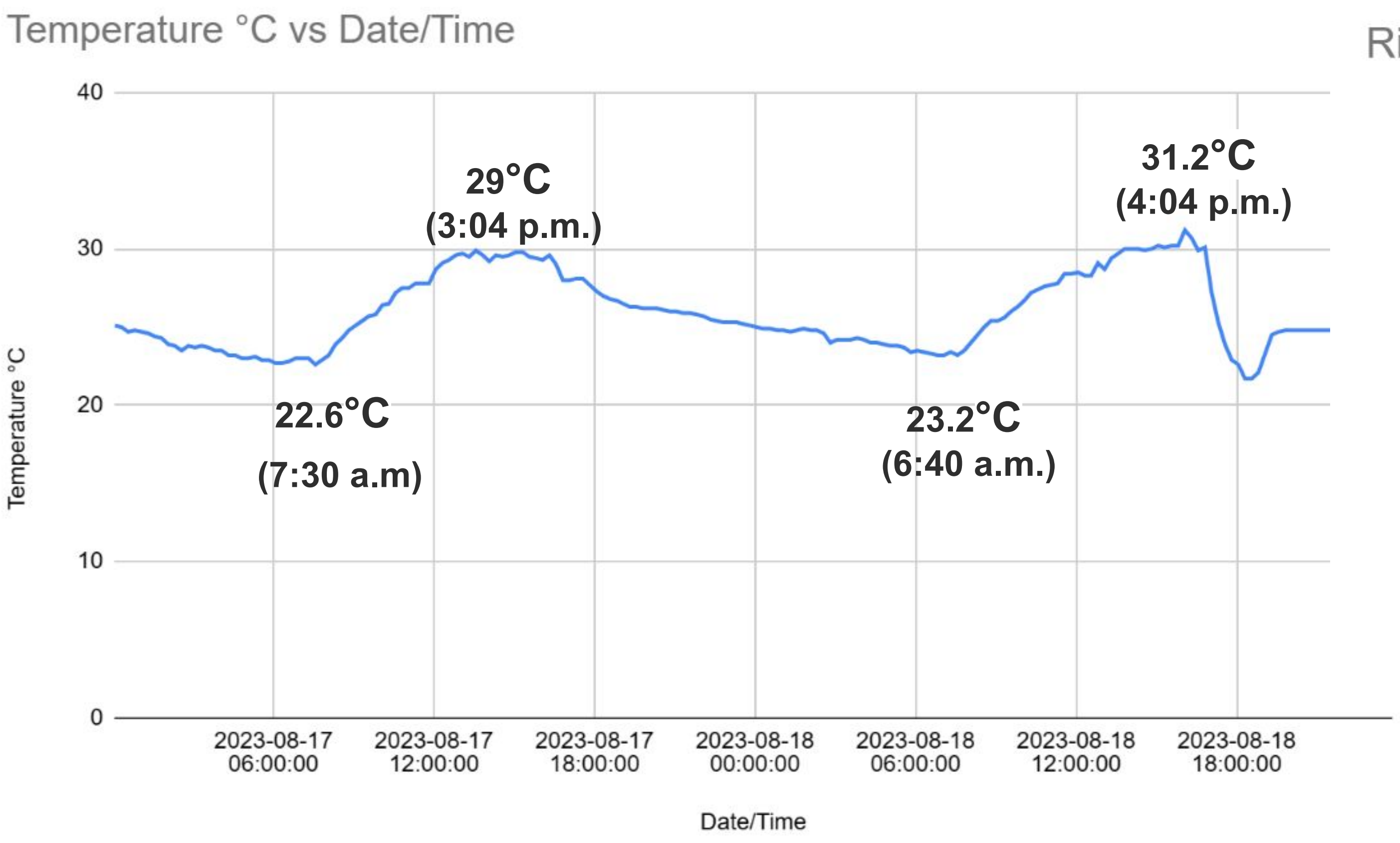
Sensors send data to a base station, placed in each school

Data would be accessed from everywhere and could be analysed in **real time**

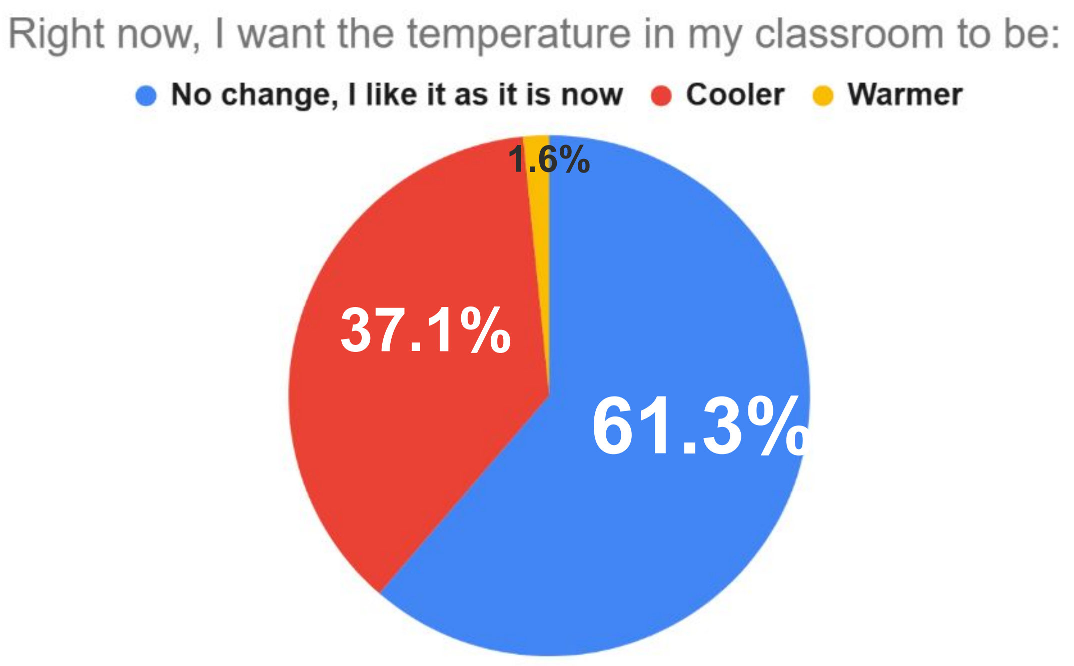
Preliminary insights (summary)

District	Temeke, Dar es Salaam
School	Mbande Secondary school
Classroom A	62 students
Type of school	Government school
Date of data collection	17 and 18 August 2023
Climate of the area	Tropical wet and dry or savanna climate
Temeke's yearly temperature	27.09°C

Preliminary insights (temperature)

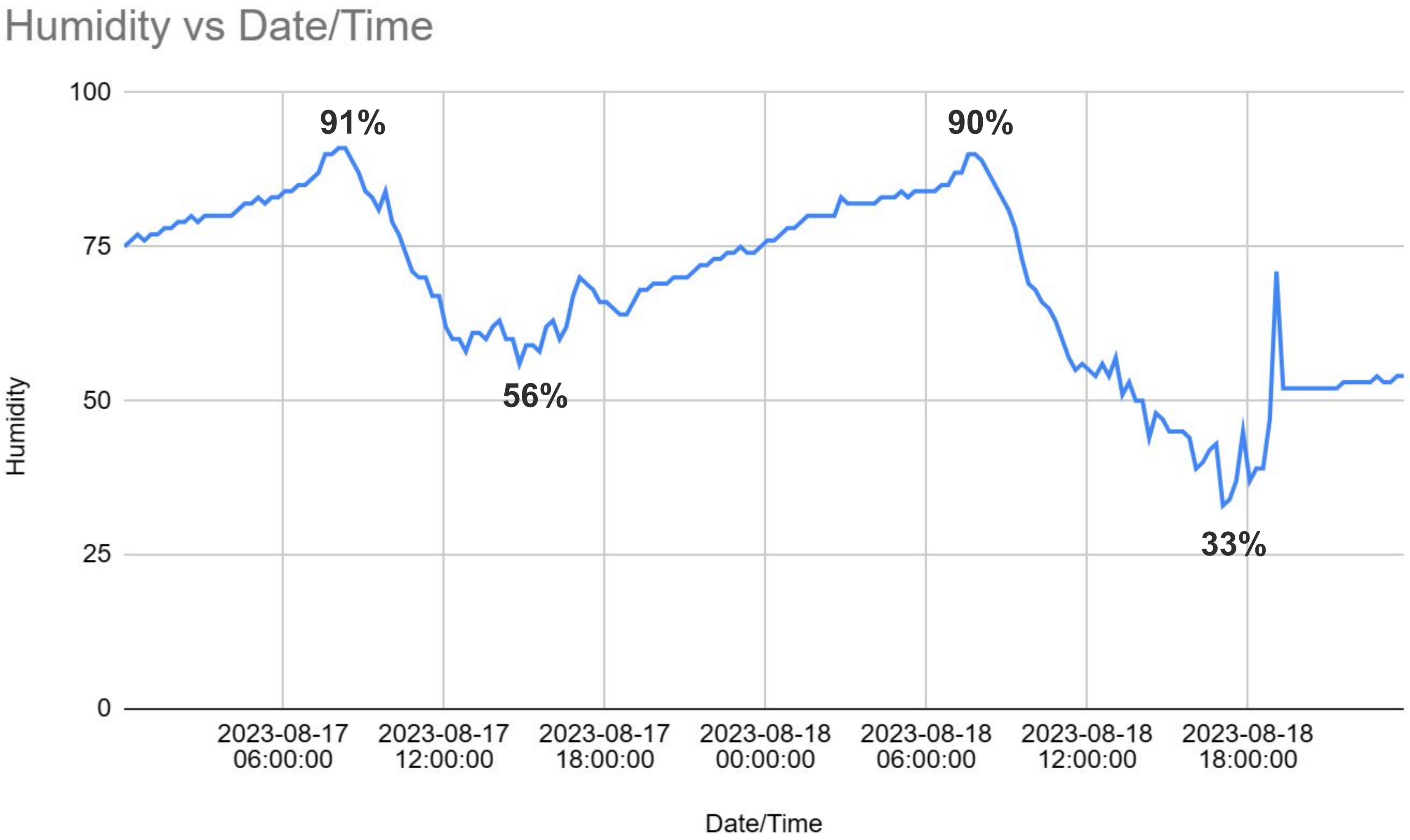


Duration of measurements: 2 days



Even though temperature measurements were at certain moments above temperature levels recommended for a classroom, over 60% of students indicate that they "like it as it is now"

Preliminary insights (humidity)



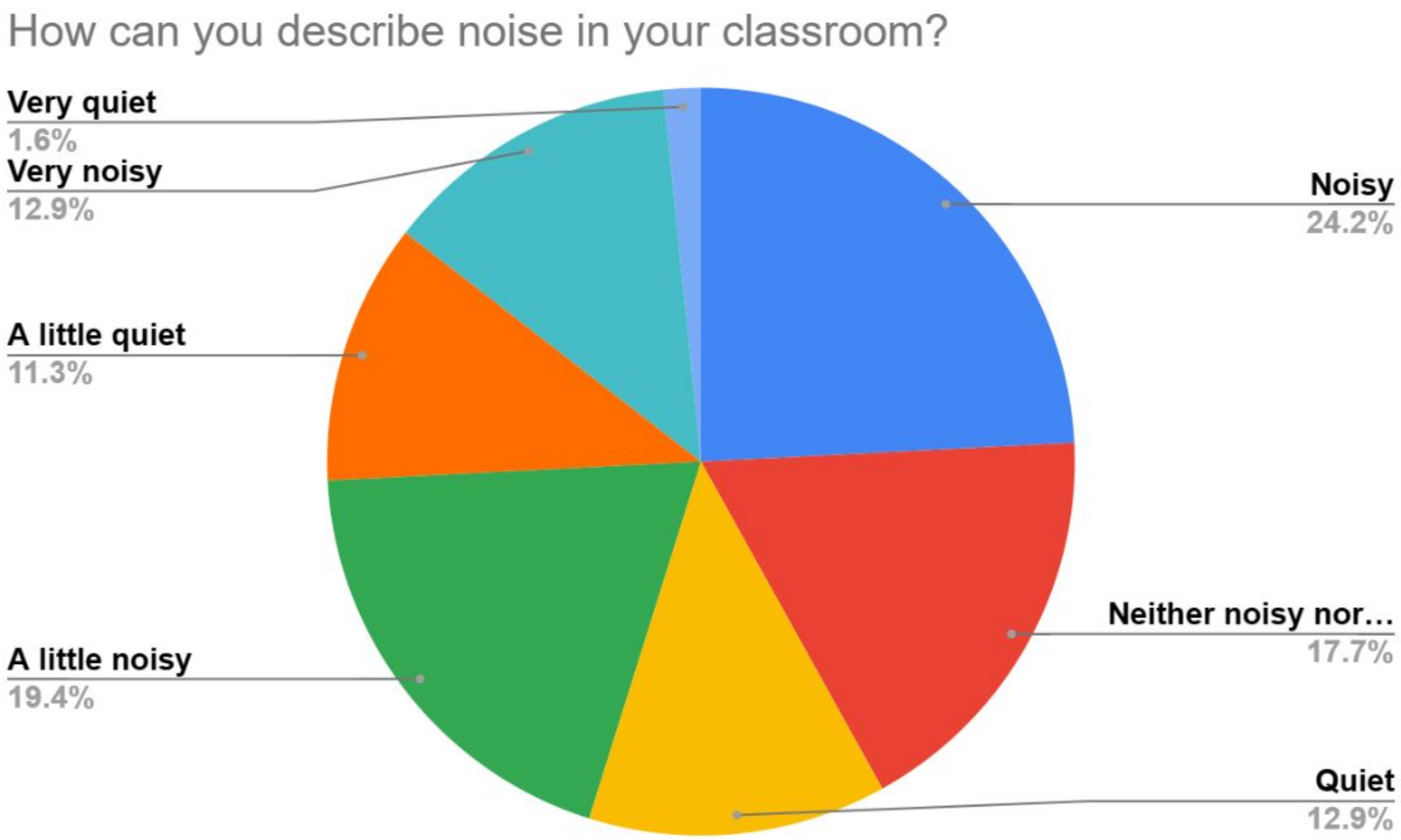
Duration of measurements: 2 days

Peaks of humidity seem to occur around 8 a.m. (start of school day)

Between 30% and 60% of indoor humidity level is considered optimum for comfort and avoiding negative health impacts.

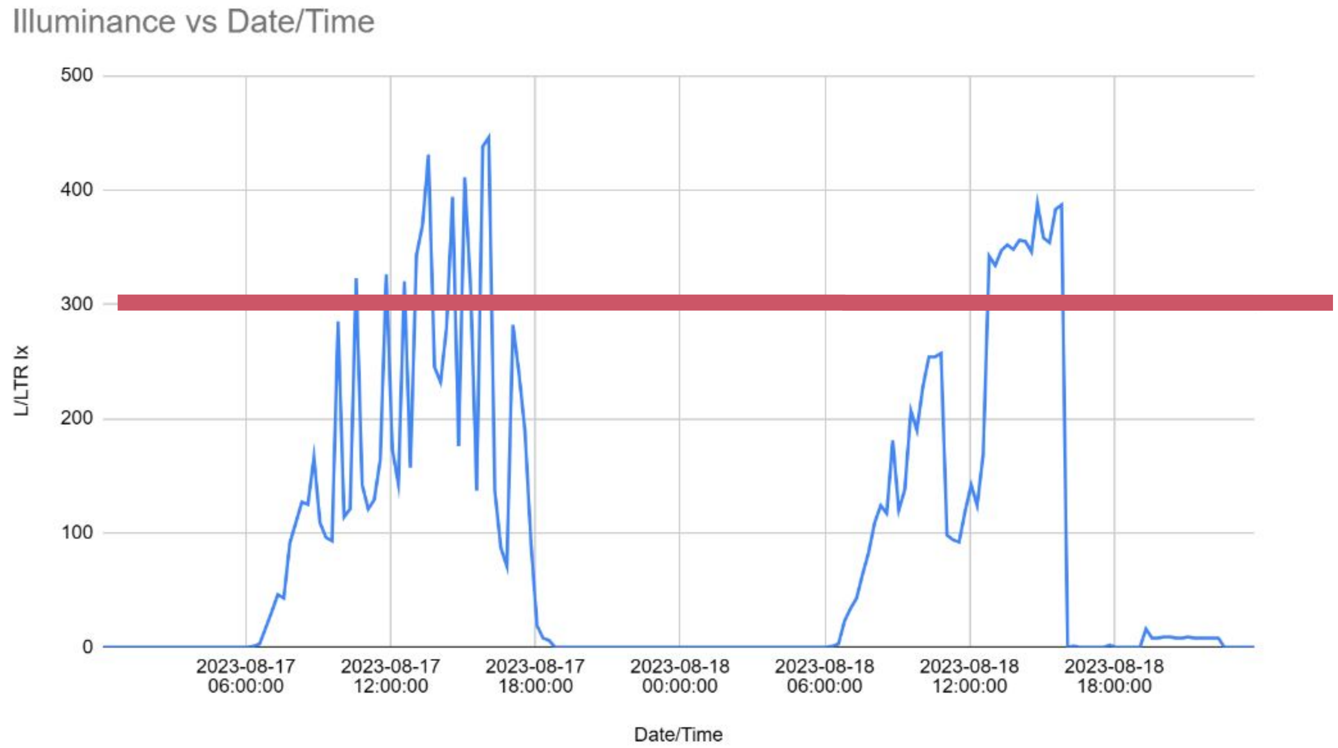
It's observed that levels of humidity over 60% occur between midnight and 11 a.m.

Preliminary insights (acoustics)

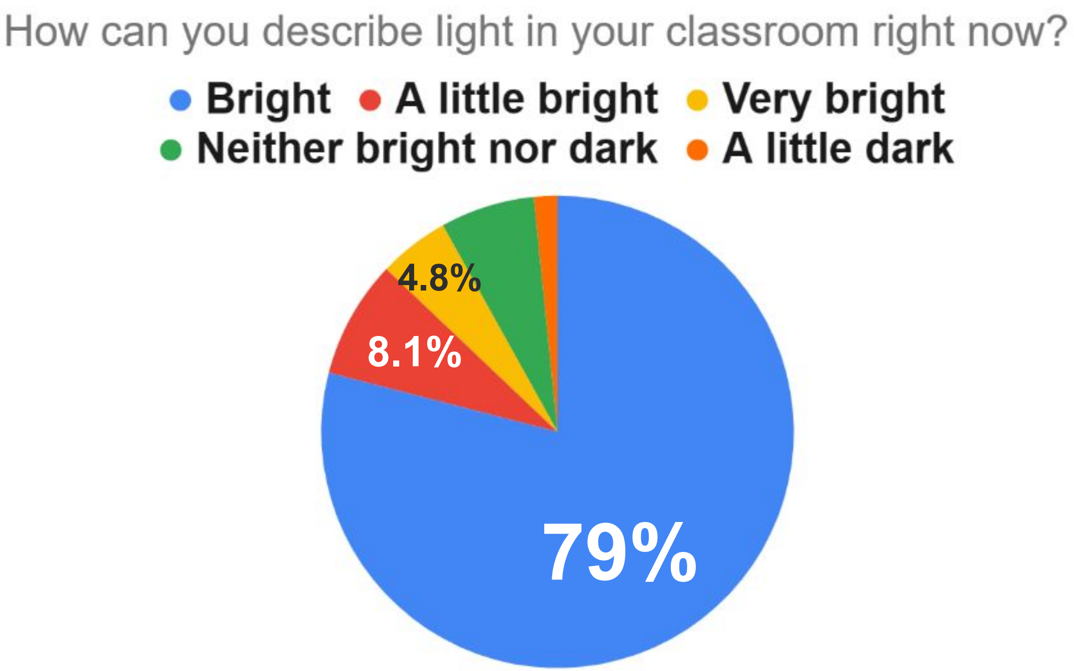


Over 50% of students find their classroom "a little noisy" to "very noisy"

Preliminary insights (illuminance)



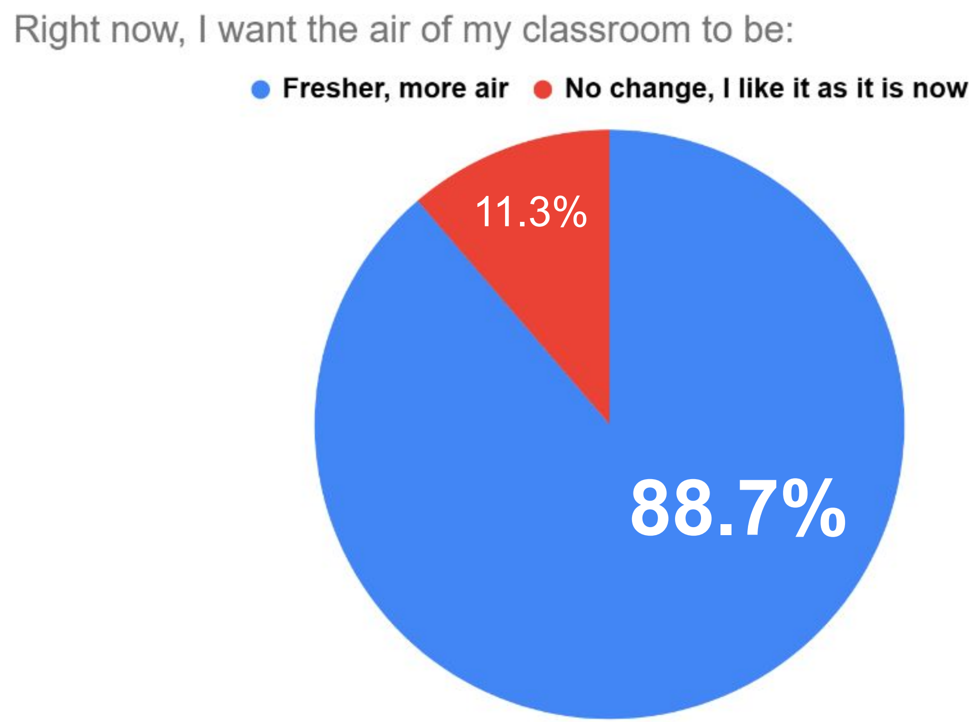
Duration of measurements: 2 days

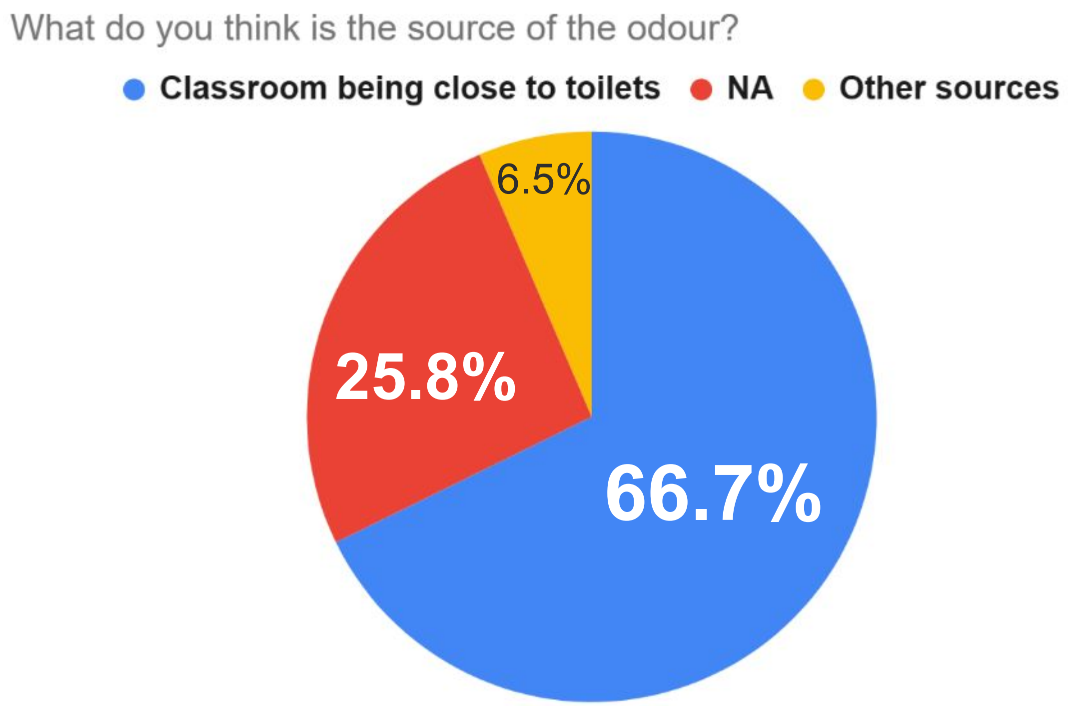


*Levels of light **over 300 Lux** seem to occur **between 10 a.m. and 4 p.m.** (most of the school day)*

*Over 90% of students find their school to be **"a little bright"** to **"very bright"***

Preliminary insights (air freshness/ventilation)





Ventilation seems to be ***insufficient*** *for students*

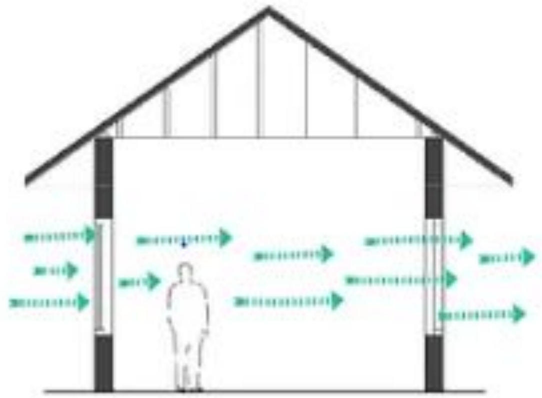
Out of 47 students indicating sensing a bad smell in the classroom, 31 students indicate it is because of the ***classroom being close to the toilets***

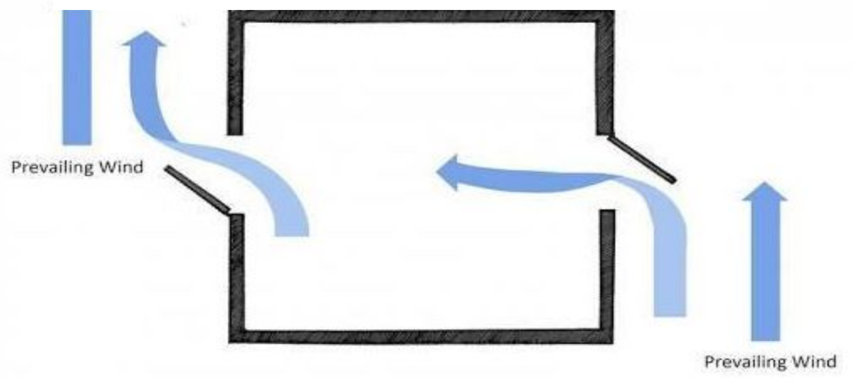
'Knowing' is important, but once we know, what do we do?

Possible approaches for retrofitting schools for better indoor environmental quality

Option 1. Cross ventilation

Only natural ventilation is unlikely to be sufficient to bring thermal comfort to students





Consist of a building designed with **openings**, such as windows, on opposite sides or facades. When wind blows against the building, it creates areas of high and low pressure.

The **pressure** difference created by wind causes air to flow through the building, facilitating natural ventilation.

The **effectiveness** of cross ventilation depends on factors such as the size and placement of openings, building orientation, local wind patterns, and the presence of obstructions.

A proper design can maximize the **benefits** of cross ventilation and enhance natural ventilation within the building.

Monge-Barrio, A., Bes-Rastrollo, M., Dorregaray-Oyaregui, S., González-Martínez, P., Martin-Calvo, N., López-Hernández, D., Arriazu-Ramos, A., & Sánchez-Ostiz, A. (2021). *Encouraging natural ventilation to improve indoor environmental conditions at schools. Case studies in the north of Spain before and during COVID.*
https://doi.org/10.1016/j.enbuild.2021.111567

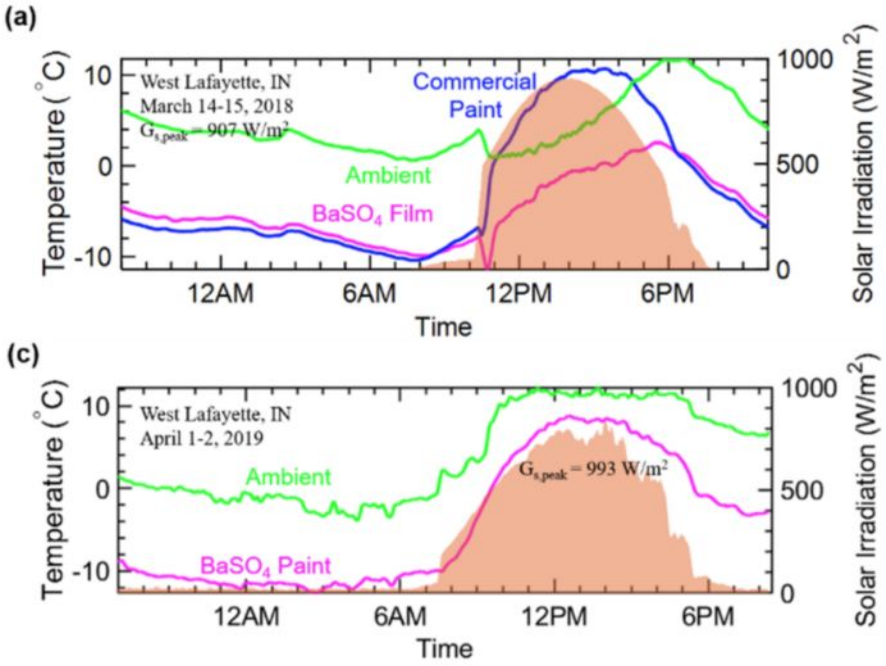
Option 2. Roof colour

White Paint intervention (WPI) could be improved, by adding Barium Sulphate.

Proctor, J. (2022). *Should we paint all classroom roofs white to improve learning in Tanzania?* EdTech Hub. https://doi.org/10.53832/edtechhub.0122

This **paint** is effective at reflecting the solar radiation hitting buildings back into space.

Painting buildings with white barium sulphate paint can reduce temperatures inside the buildings by 4.5°C compared to the outside air temperature



Li, X., Peoples, J., Yao, P., & Ruan, X. (2021). Ultrawhite BaSO4 Paints and Films for Remarkable Daytime Subambient Radiative Cooling. *ACS Applied Materials & Interfaces*, *13*(18), 21733–21739. https://doi.org/10.1021/acsami.1c02368

Option 3. *Sun shading techniques*

To **prevent** windows and walls from passive solar heating, when it is not desired, it must always be protected from direct solar components.

Ishaq, M., & Alibaba, H. (2017). Effects Of Shading Device On Thermal Comfort Of Residential Building In Northern Nigeria. *International Journal of Scientific and Engineering Research*, *8*.

Decision on integration of shading elements can have an effect on the thermal comfort level of a closed space.

Achieving **shading** from solar radiation can be done in different ways. Some examples are:

- Recessing the external envelope of the building
- Integration of fixed external blinds or louvers.
- Permanent shading provided by vegetation or existing buildings.
- Integrating reflective canvas, earthen pot, vegetation on the roof.

Option 4. *Micro-forests*

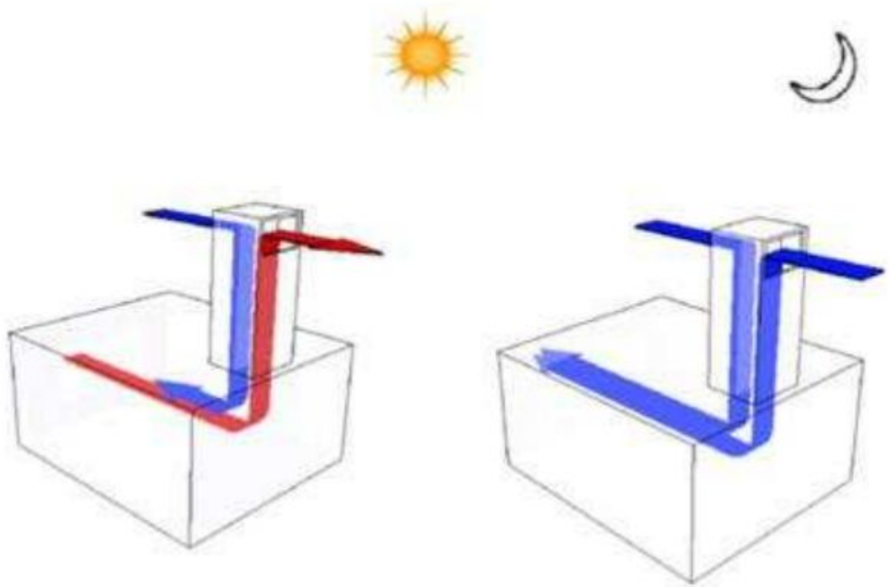
Micro-forests are **small, dense, biodiverse** forests that grow fast in urban and rural areas alike.

They stimulate biodiversity, absorb carbon dioxide from the atmosphere, provide shading for the school community, and offer a space for students to learn about the environment through practical lessons.

Some government schools in Tanzania are already putting this intervention into practice. The impact of this intervention on students' comfort remains to be investigated.

A micro-forest at Nzasa Secondary School

Option 5. *Wind catcher system*



Jomehzadeh, F., Nejat, P., Calautit, J.K. et al. (2016) A review on windcatcher for passive cooling and natural ventilation in buildings, Part 1: Indoor air quality and thermal comfort assessment. Renewable and Sustainable Energy Reviews, 70. pp. 736-756. ISSN 1364-0321

Wind catcher systems (or wind towers) are an **environmentally friendly** and sustainable system which aims to combat the climate crisis, while improving indoor air quality and thermal comfort inside the buildings.

These are used to cool buildings; they have been proven to be a cost-effective, easy to implement, and reliable solution for passive cooling that requires almost negligible energy to operate.

In some climates, such 'passive' wind catcher systems appear to be insufficient for adequate ventilation. Experiments are currently underway to augment 'passive' wind catcher systems with a small solar-powered fan and a low-cost heat storage facility.

Next steps

- *Analysis of data collected*
- *Implementation of retrofits in schools selected*
- *Assessment of the impact of the interventions on students*

Continue the dissemination and advocating for better policies regarding the regulation of school buildings

Conclusion

Climate change is a pressing global issue with far-reaching consequences. Collective action is essential to mitigate its impacts and create a sustainable future for generations to come.

Much remains to be investigated in East Africa

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Practical considerations (and experience)

Climate smart / learning and friendly builds

Malawi and Sierra Leone


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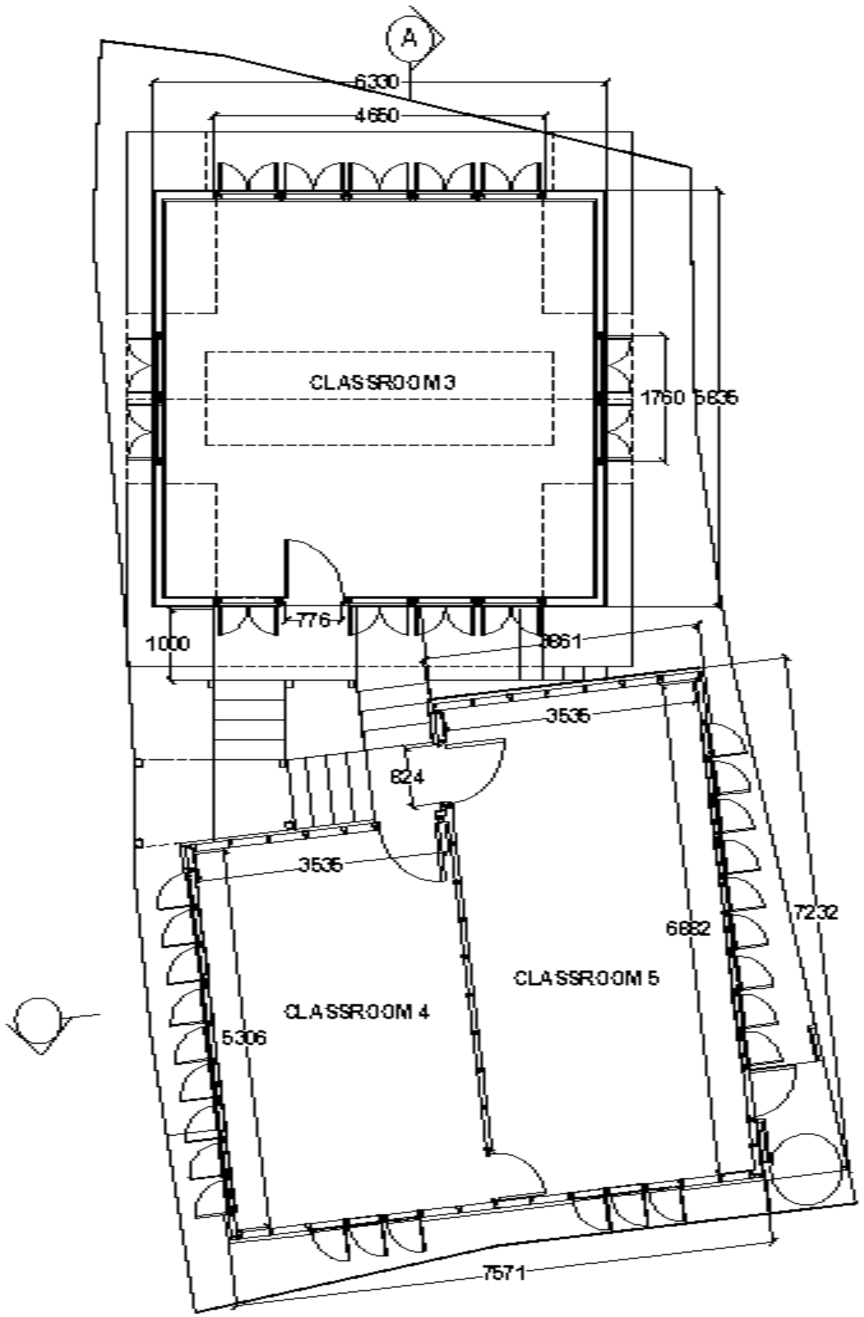
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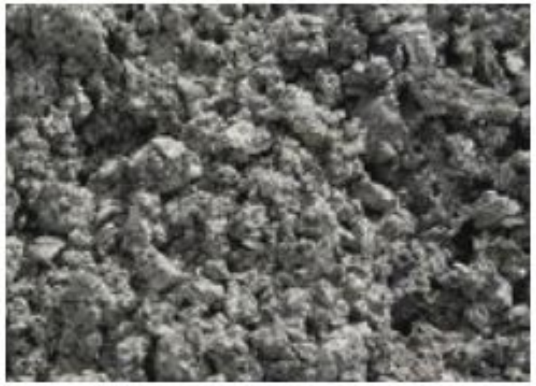


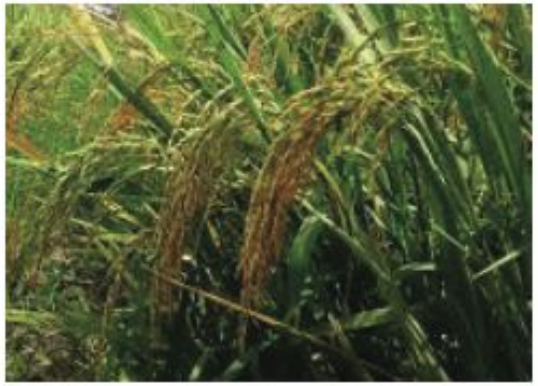


SECTION	AIM	DESIGN FEATURE	MINIMUM CRITERIA (All must be met)	✓	ADDITIONAL GUIDANCE
2.1 Space	All classrooms must have sufficient space for students to be able to learn and work comfortably and effectively.	Height	2.1.1 Minimum floor-to-ceiling height at lowest point 2.5m.		An increased height of 3m is preferable for airflow.
		Primary classroom	2.1.2 Space of $1m^2$ per pupil.		$2m^2$ per pupil with a volume of $7m^3$ per occupant.
			2.1.3 Maximum number of pupils per classroom = 45		Classrooms should allow enough space for a range of teaching/learning styles, including group work.
		Secondary classroom	2.1.3 Space of $1.5m^2$ per pupil		$2.9m^2$ per pupil
		School facilities	2.1.4 Storage of $1m^2$ per classroom		Head teacher's office of $16m^2$ Staffroom of $2m^2$ per staff. ICT classroom of $62m^2$ / 30 pupils Art classroom of $83\text{-}104m^2$ / 30 pupils Science classroom of $69\text{-}90m^2$ / 30 pupils (plus $0.5m^2$ storage per workspace) Primary school hall of $140m^2$ Secondary school hall of $200\text{-}300m^2$ Storage of 5m2 per teaching department (subject)
					Layout of the buildings on the site and the spaces in a building should consider allowing for future expansion and adaptation of the buildings at a minimal cost.
	School grounds must have sufficient outdoor spaces for play, socialising, learning and sports.	School grounds	2.1.5 Playground of at least $2m^2$ per pupil.		Total site area (excluding building footprints); • Primary 30x(number of pupils)+$1800m^2$ • Secondary 45x(number of pupils)+$8000m^2$


Grafton