Climate-resilient school buildings

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Considerations for climate-resilient schools

1. *Where should schools be built?*
2. *How should school buildings be designed?*
3. *How can school buildings be improved?*

Plus, briefly, our FCDO Programme in Tanzania

Part 1. Where do you build schools?

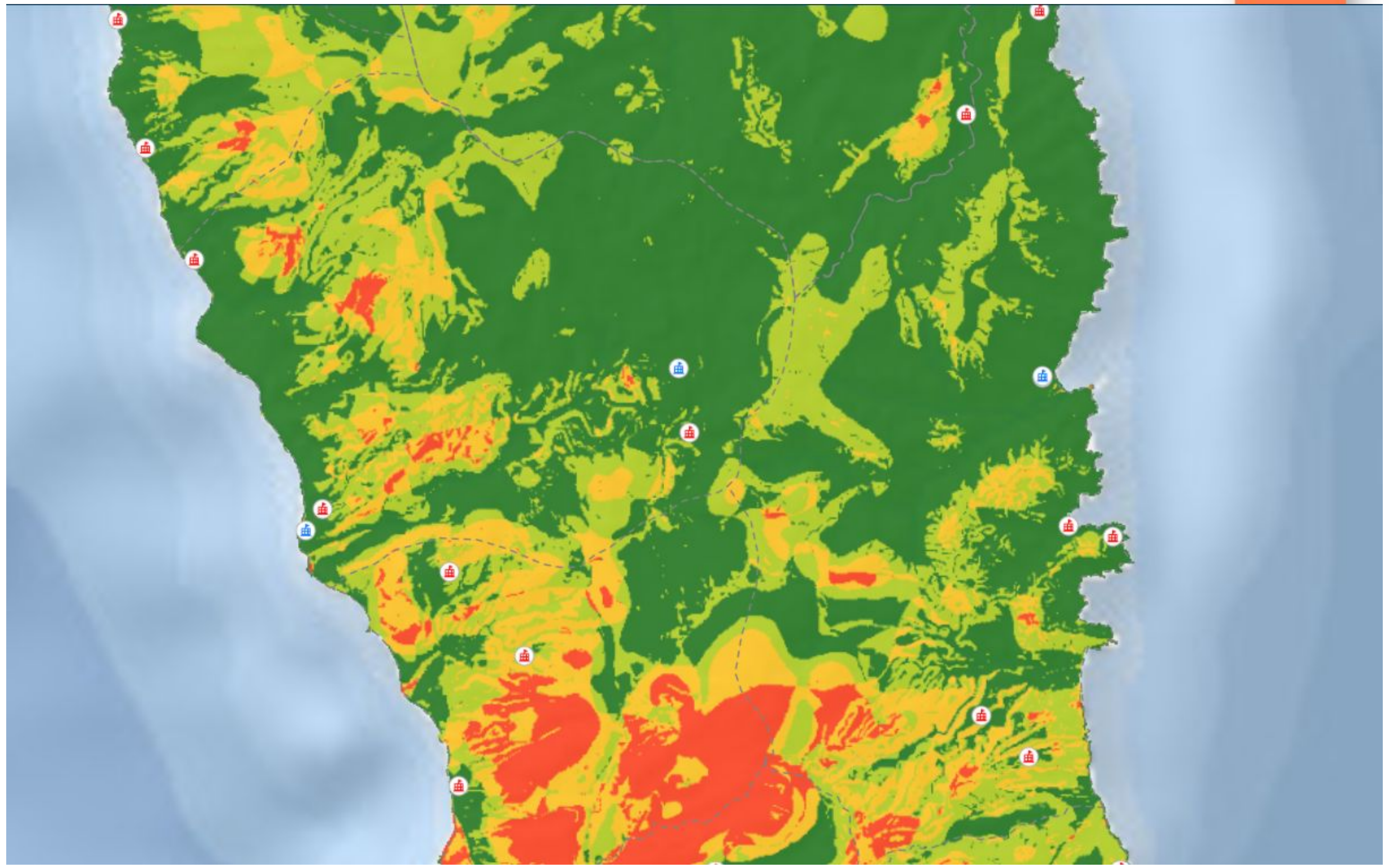
- Schools need to built where they are needed
- Schools need to be built in safe locations

Using geospatial data for school location

Location-based information offers education planners a way in which they can visualise and monitor education-related fields, such as:

- education infrastructure planning (planning where to build new schools or relocate existing schools)
- school bus routing
- school network mapping (mapping schools / education facilities across a country to see how far these are from communities or how far people have to travel to get to school).

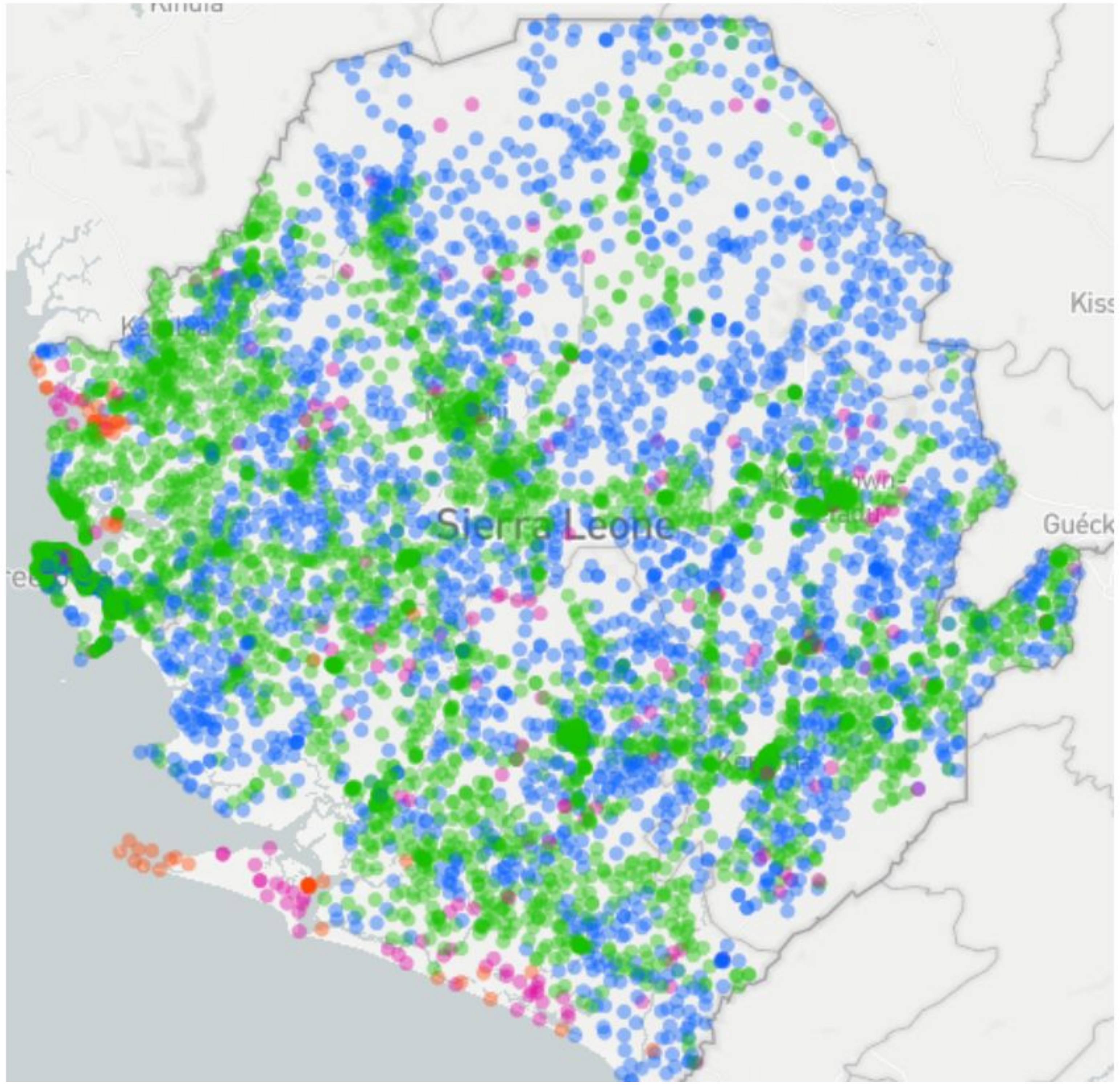
The use of geospatial data and applications and hazard risk can be analysed for better planning and mitigation of disasters' impact, including on education infrastructure



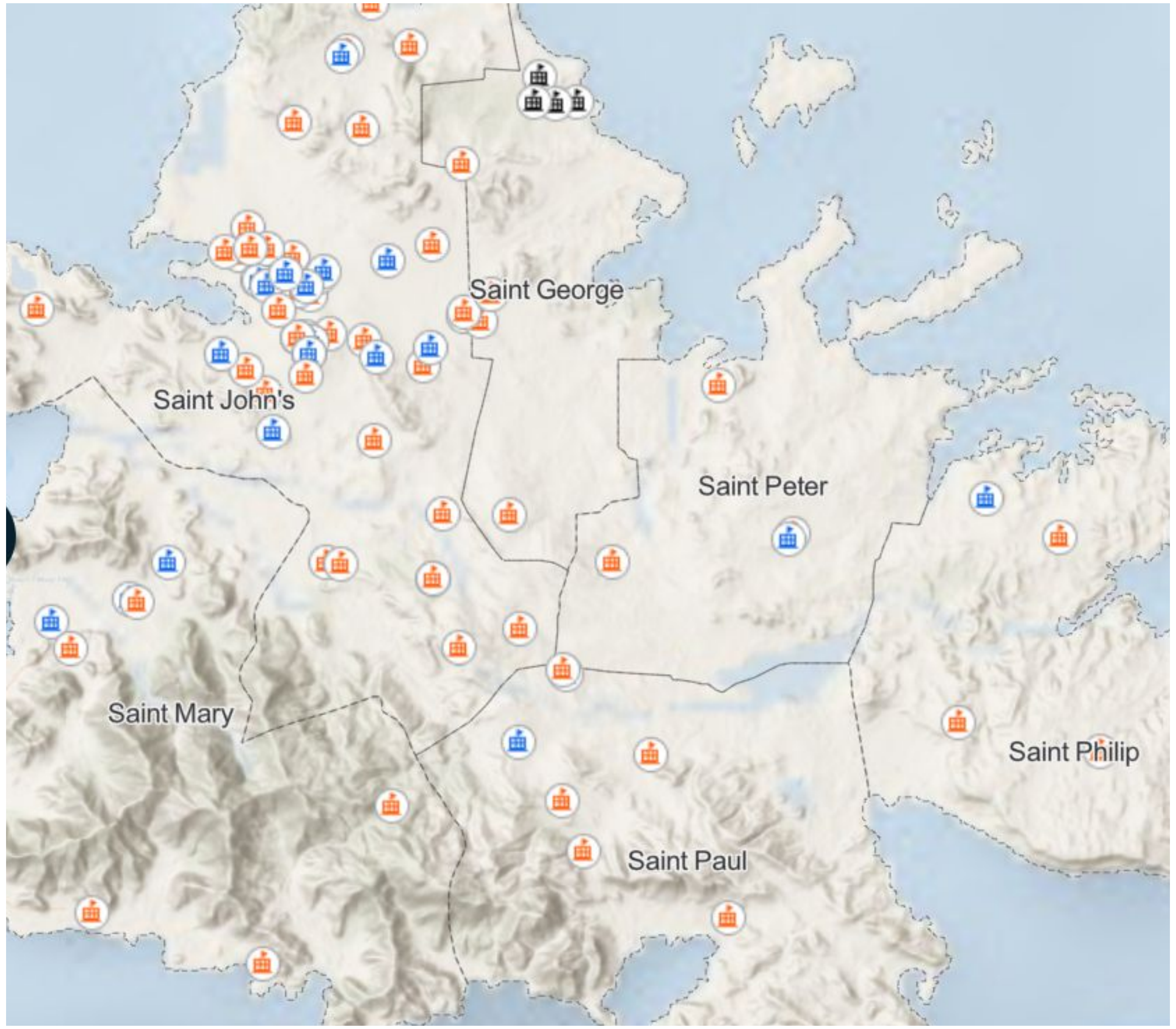
Source: Education Planning in the Caribbean: A project by CDEMA, OpenDevEd and UNOSAT. United Nations Satellite Centre (UNOSAT, 2023)

Mapping school locations

FIGURE 1. A SNAPSHOT FROM DSTI'S EDUCATION DATA HUB, CATEGORISING 10,747 SCHOOLS BY ACCESSIBILITY.



Maps and meaning--Sierra Leone's digital school census and what it means for school-level location and accesibility data collection



Source: Education Planning in the Caribbean: A project by CDEMA, OpenDevEd and UNOSAT. United Nations Satellite Centre (UNOSAT, 2023)

For more information on geospatial analysis, see, e.g. https://www.iiep.unesco.org/en/our-expertise/geospatial-data-educational-planning-and-management

https://educationcommission.org/gis-for-education-working-group/

The Impact of GIS-Supported Teacher Allocation in Sierra Leone https://docs.edtechhub.org/lib/WXBISTFE

Part 2.

How should new schools / school buildings be designed?

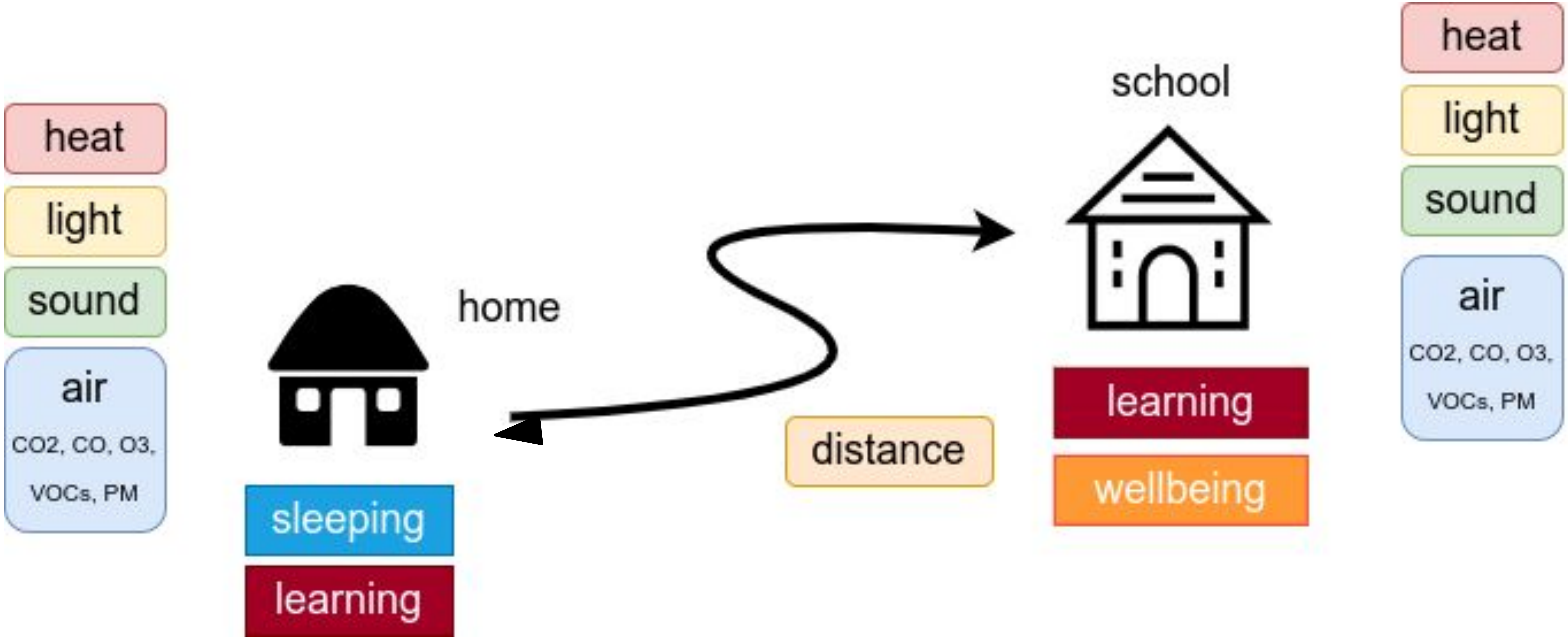
A neglected element of school construction is consideration for indoor environmental quality.

What is indoor environmental quality?

Indoor environmental quality is a measure of various environmental properties that are relevant for safety, well-being and learning

Temperature, humidity, noise level, light, ventilation (CO_2), hazardous substances (VOCs, PM, …)

Environmental factors affecting learning and wellbeing



IEQ in 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 65% upper limit)

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

Temperature and learning attainment

- The question of a conducive physical learning environment is a global concern. For example, in the USA, the publication Effects of Classroom Ventilation Rate and Temperature on Students' Test Scores (Haverinen-Shaughnessy & Shaughnessy, 2015) demonstrates the relation that adequate temperature and ventilation in a classroom have on improving students' test scores. This study shows the ***potential learning outcomes that could be achieved when indoor environmental factors are taken into consideration***.

- Classrooms in Sub-Saharan Africa can often be uncomfortable places to be, let alone to teach and learn in. Sweltering temperatures have proven negative physiological impacts – regardless of children's level of acclimatisation. A meta-analysis estimated that ***learning improvement can be increased by 20% with a temperature reduction of 10°C*** (Wargocki et al., 2019).

- Regarding temperature, research indicates that ***cognitive functioning decreases when the environment is not within the 'zone of thermal comfort'.*** In particular, the rate of performance is often lower at higher temperatures than at lower temperatures (Blaker & Andrew, 2020).

- The paper Classroom Temperature and Learner Absenteeism in Public Primary Schools in the Eastern Cape, South Africa (Pule et al., 2021) notes links between absenteeism and indoor schooling temperatures, suggesting that the lower the temperature, the higher the students' absenteeism. Even though absenteeism can be attributed to many factors, the study considers ***reaching a thermal comfort level fundamental for the planning and design of a school.***

- The focus on temperature is particularly significant for ***Africa*** due to the ***likelihood of rising temperatures due to global warming***, with projected intense heat extremes and overall temperature increases (Kapwata et al., 2018).

Part 2. (continued)

How should new schools / school buildings be designed?

Layout

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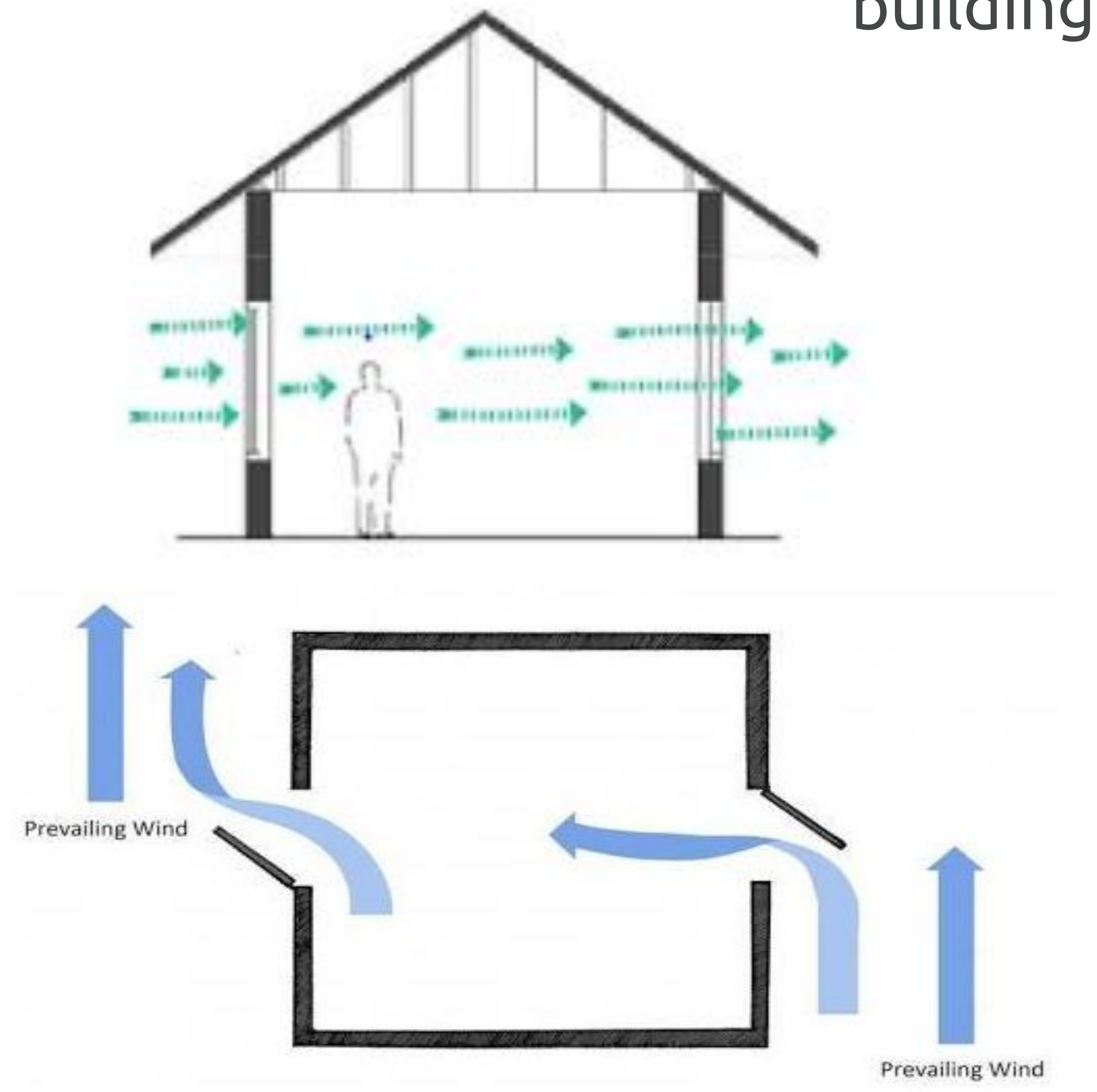
Cross ventilation

Building is 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.

However, natural ventilation alone is unlikely to be sufficient

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

Catriona Forbes (2023). UKFIET.

Materials

Carbon smart schools

Without the use of mechanical systems, interior spaces that are more pleasant than the surrounding environment have been built using **locally accessible tools** and **renewable materials.**

Main Challenge

Most governments in low-income countries have standard, approved school designs, which makes it difficult to encourage stakeholders to see traditional construction techniques and low-cost, locally sourced materials as valuable.

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Interlocking Stabilized Soil Blocks (ISSB)

ISSBs have favourable properties at favourable cost.

- ISSB is a compressed earth block, mixed with a little cement and air-cured.
- These blocks are made without removing any trees.
- Buildings can be constructed more quickly thanks to the interlocking characteristic, which requires significantly less mortar between courses.
- ISSBs replace the need for burnt bricks and require no firewood, which is one of the environmental benefits

Haileybury Youth Trust Uganda. (2021). https://hytuganda.com/

ISSB:Properties

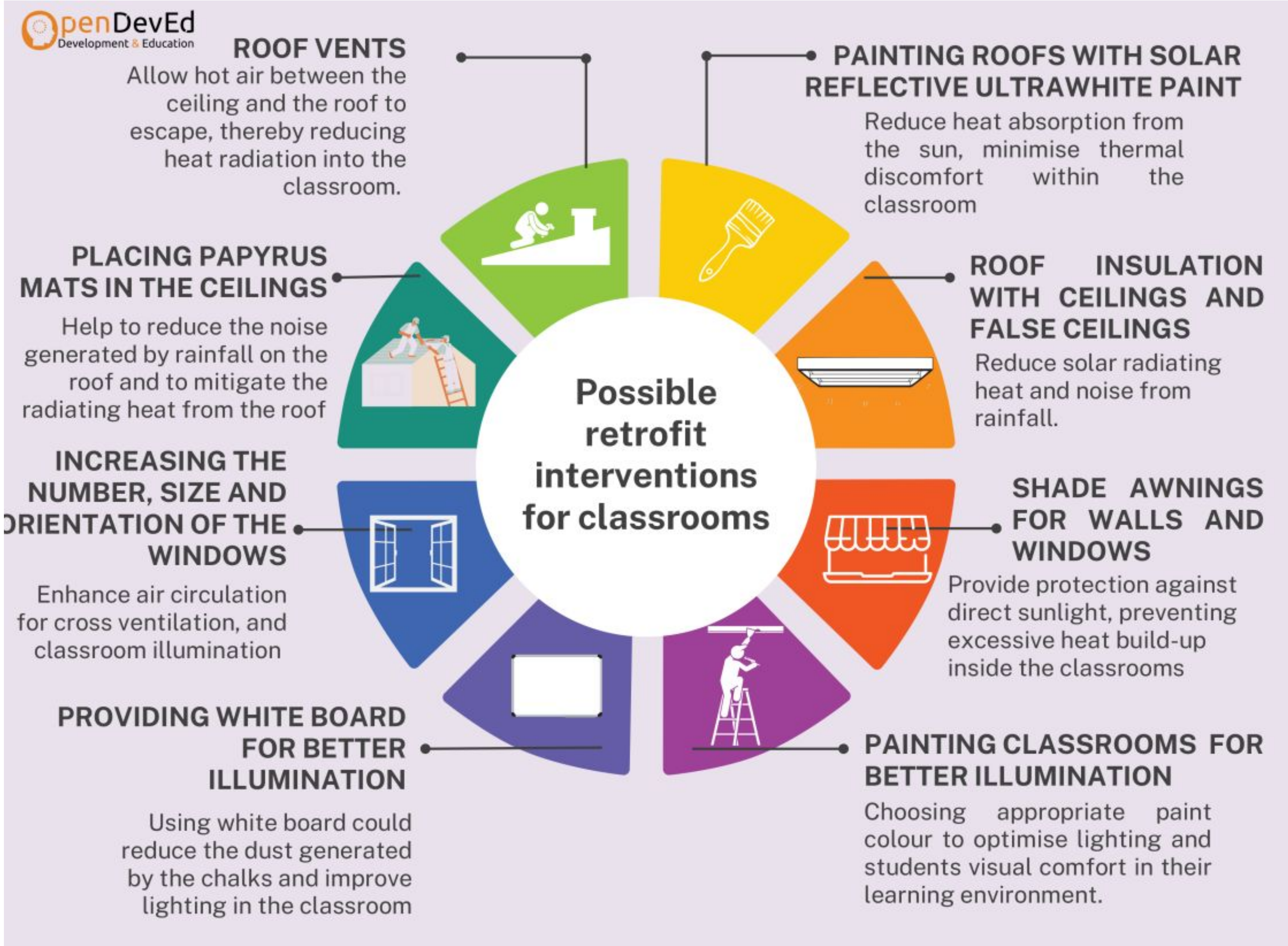
ISSBs have favourable properties

… at favourable cost.

Properties	Interlocking Stabilised Soil Block	Sun-dried Mud Block	Burned Clay Brick	Stabilised Soil Blockb	Concrete Masonry Unit
GENERAL INFO					
Block Apperance					
Wall Apperance (not rendered)					
Dimension (L x W x H) (cm)	26.5 x 14 x 10 cm	25 x 15 x 7 cm to 40 x 20 x 15	20 x 10 x 10 cm	29 x 14 x 11.5 cm	40 x 20 x 20 cm
Weight (kg)	8-10 kg	5-18 kg	4-5 kg	8-10 kg	12-14 kg
Texture	Smooth and flat	rough and powdery	rough and powdery	smooth and flat	coarse and flat
Blocks needed to make up a sq.m.	35	10 to 30	30	21	10
PERFORMANCE					
Wet Compressive Strength (mps)	1 - 4	0 - 5	0.5 - 6	1 - 4	0.7 - 5
Thermal Insulation (W/m C)	0.8 - 1.4	0.4 - 0.8	0.7 - 1.3	0.8 - 1.4	1 - 1.7
Density (kg/m3)	1700 - 2200	1200 - 1700	1400 - 2400	1700 - 2200	1700 - 2200
AVG. PRICE (2009)					
Per Block (UgS)	350	50	150	400	3000
Per Sq Meter	35000	10000	55000	45000	75000

Nambatya, M. M. (2015). Investigating the Rationale for Material Selection in Tropical Housing Projects in Uganda – a Case for Interlocking Stabilised Soil Blocks (ISSB) Technology. University of Cambridge.

Part 3.
What approaches could be taken to adapt existing school buildings to climate change?



Source: OpenDevEd

Roof colour

White Paint intervention (WPI), including specialised reflective paints (‘ultra-white’).

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

Painting buildings with specialised roof paint can reduce temperatures inside the buildings by 4.5°C compared to the outside air temperature

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

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.

Radiant barrier on the roof

Propst, D. (2019). *Creating temperate indoor environments in the schools, hospitals, and ministry buildings we design*. https://emiworld.org/emi-tech/rd-radiant-heat-and-indoor-environments

Micro-forests

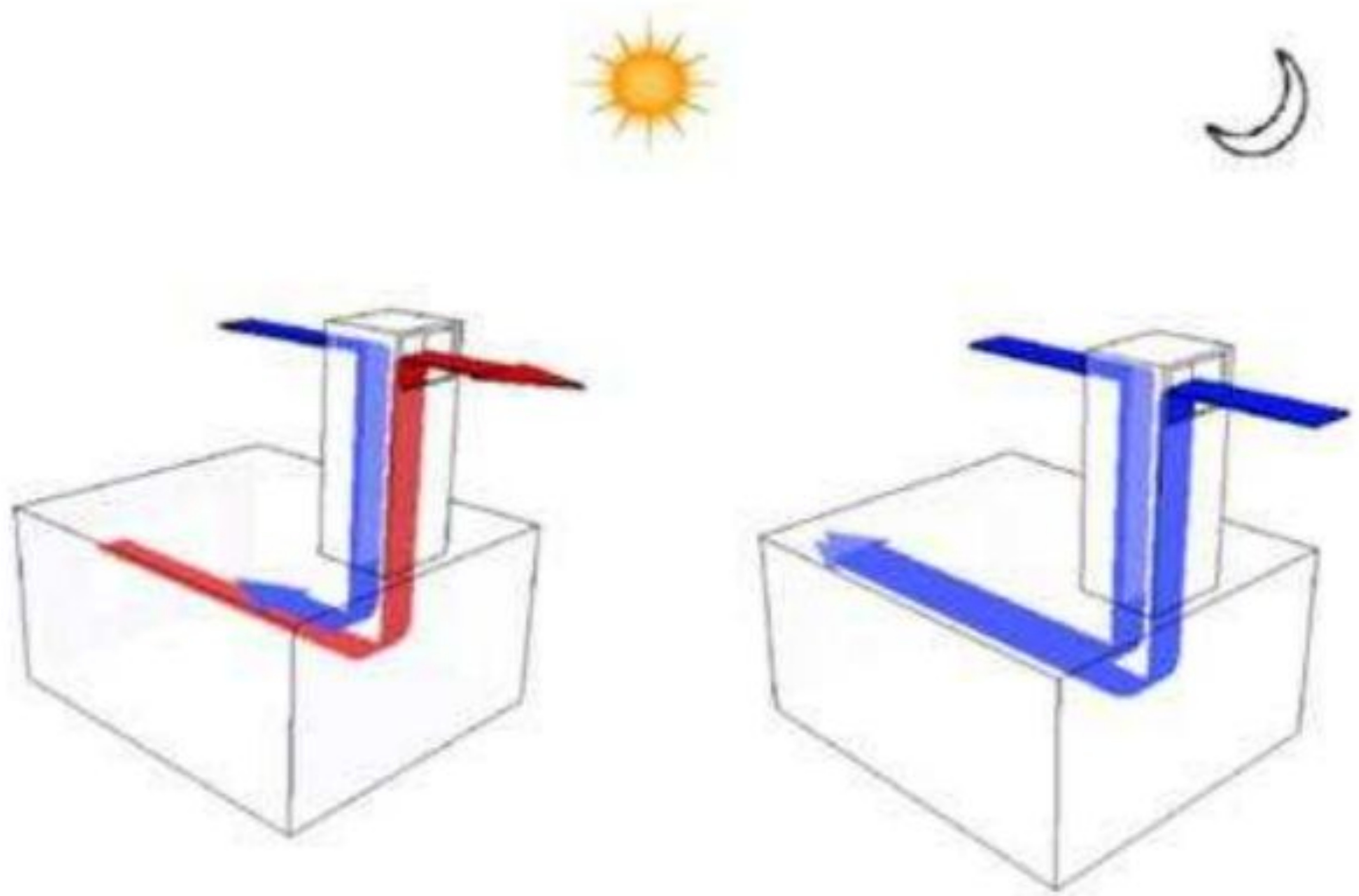
Micro-forests are **small, dense, biodiverse** forests that grow fast in urban and rural areas alike.

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, Tanzania

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.

Part 4.

Our work in Tanzania:

FCDO Improving Learning through Classroom Experience

How are we going to do that?

Data collection

1. Comfort survey
2. Walkthrough survey
3. School building scan
4. Environmental data

Analysis

Analyse data collected

Explore retrofits suitable for each classroom

Modelling retrofits

Determine suitable retrofits for each classroom

Implementation

Implement retrofits in selected classrooms

Evaluation

Assess impact of retrofits on students through environmental data collection and surveys

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.

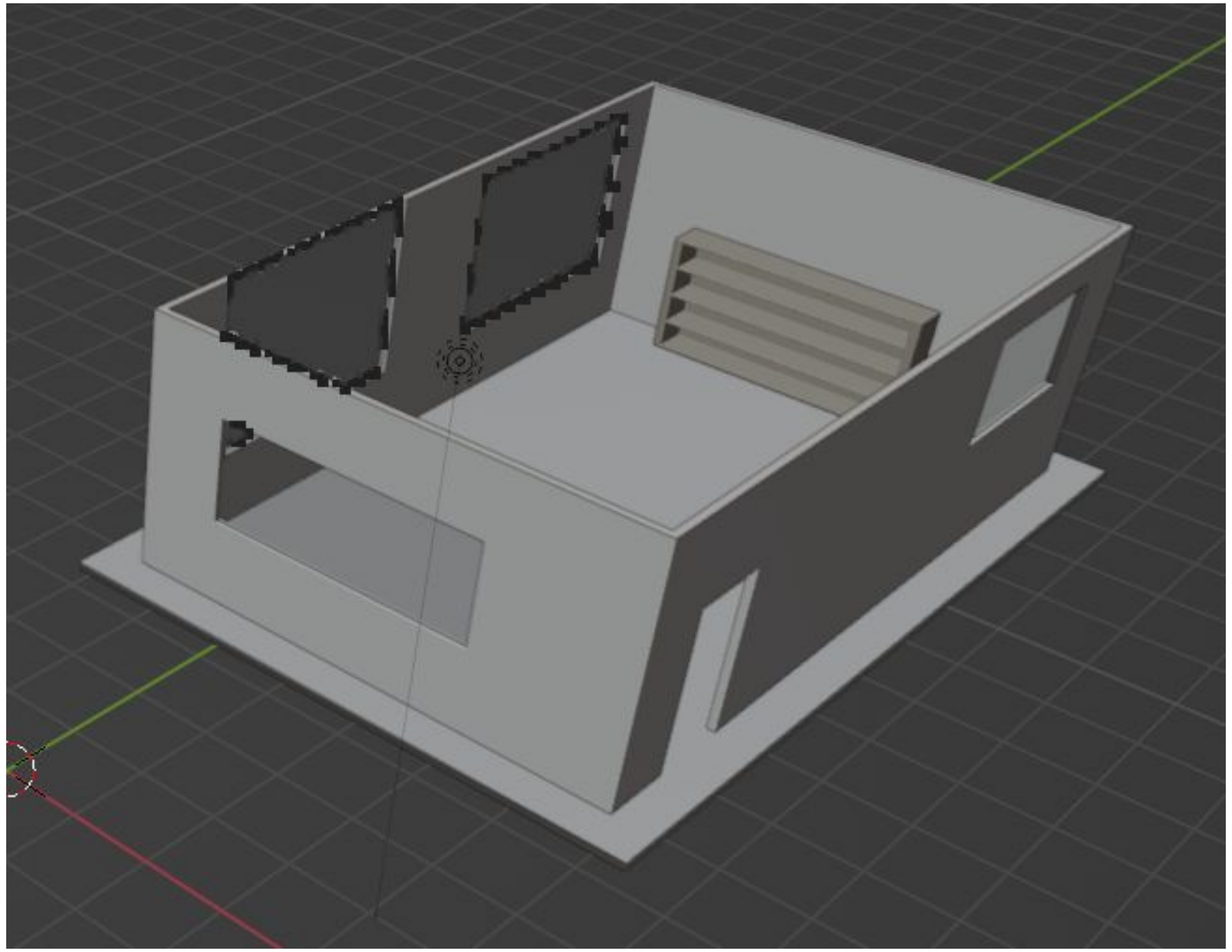
Walkthrough survey

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.



Source: OpenDevEd

Building scan



Source: OpenDevEd

Source: OpenDevEd

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

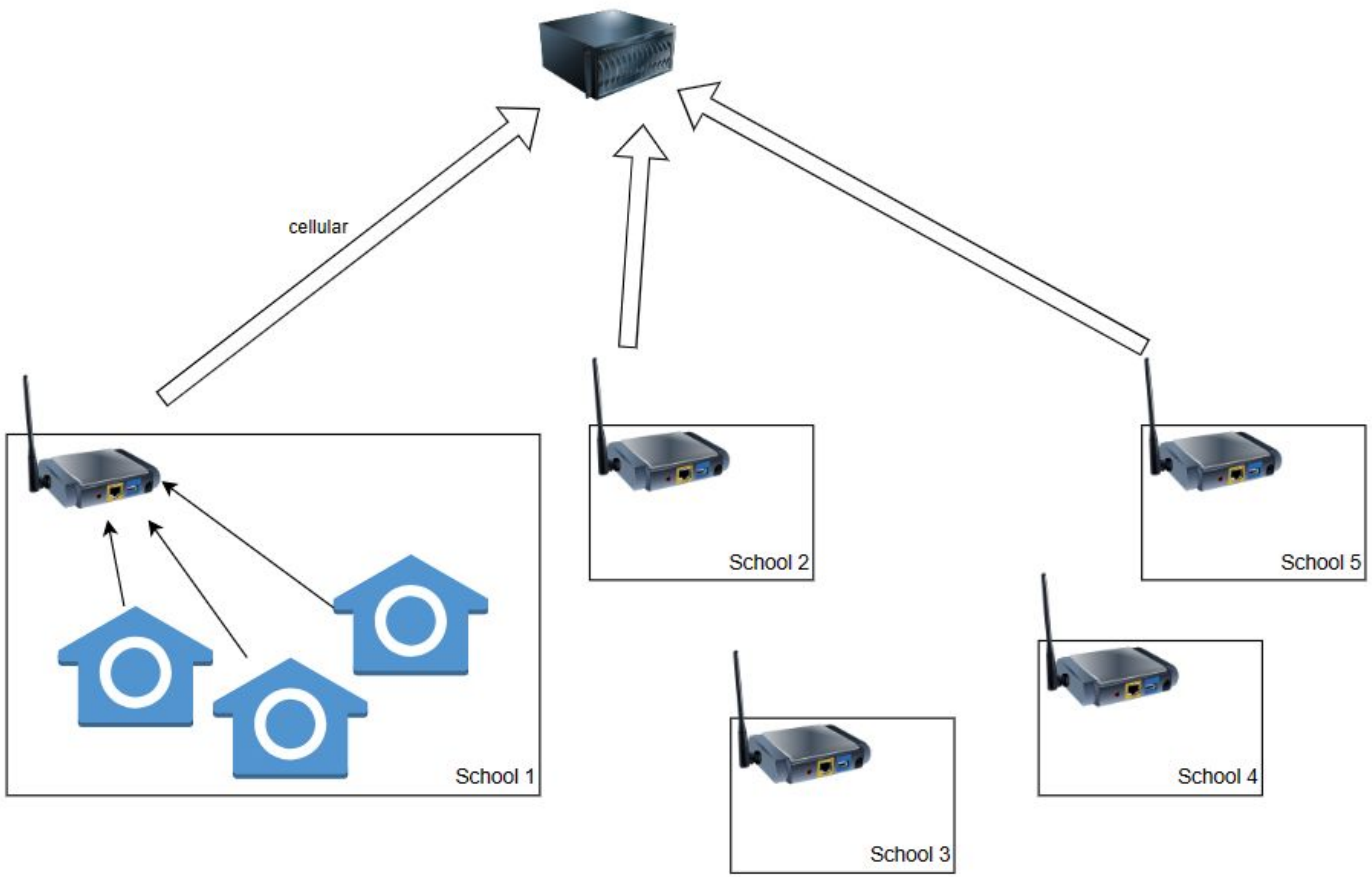
Environmental data

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 the back 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**

Source: OpenDevEd

Observations classrooms' conditions

High temperatures and noise levels are an issue, but also:

- Pollutants observed in several classrooms (wood burning in kitchen) / unpleasant smells coming from the toilets.
- Some classroom roofs are in rusty conditions and let water pass through
- In most of the classrooms, walls are peeling and present cracks
- In some classrooms, sunlight hits the students directly, making it difficult to concentrate.
- There are a limited number of toilets, considering the number of students and water system gets broken very frequently
- All older classrooms have broken floors as well as bathrooms
- Overcrowding, lack of furniture, …

Possible retrofits for the study

Temperature:

Reflective paint

Source: Green A Consultants

Sound:

Papyrus mat

Source: Referential image - MASS Design Group

Light

Shade covers using local wood

Source: Referential image- Sovereign play equipment

Mirror films

Source: MEER

Greenwood covering

Source: Referential image - Sound reduction systems

Shade covers using Danpalon

Source: Project Shade covers for Sierra Leone

Evidence

https://climate.educationevidence.io

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- ☐ Modelling (10)
- ☐ OpenDevEd work (13) ›
- ☐ Retrofits (43)
- ☐ School building (31)

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Abstracts

Thermal energy storage enhanced windcatcher system for hybrid cooling and ventilation in buildings

Eso, O. - 2023

Climate, Enviroment and Education

Fab Inc, Laterite, & Open Development and Education - 2023 - Tanzania Education Donors-Partners working group, Tanzania

Presentation for the Tanzania Education Donors-Partners working group – session on Education, Climate and Environment.

Potential collaborators

Regime Projects

Building company with experience in projects implemented in Dar es Salaam, Tanzania.

HEMPEL

Global supplier of coatings and paints. Hempel foundation has different project supporting education.

GreenA Consultants

Among their multiple green solutions, Green A provides a sustainable ***passive cooling solution*** for people who do not have the economical means to access mechanical cooling options. They were part of the project "Cool roofs"-Rwanda

DUNIA the sustainable design co.

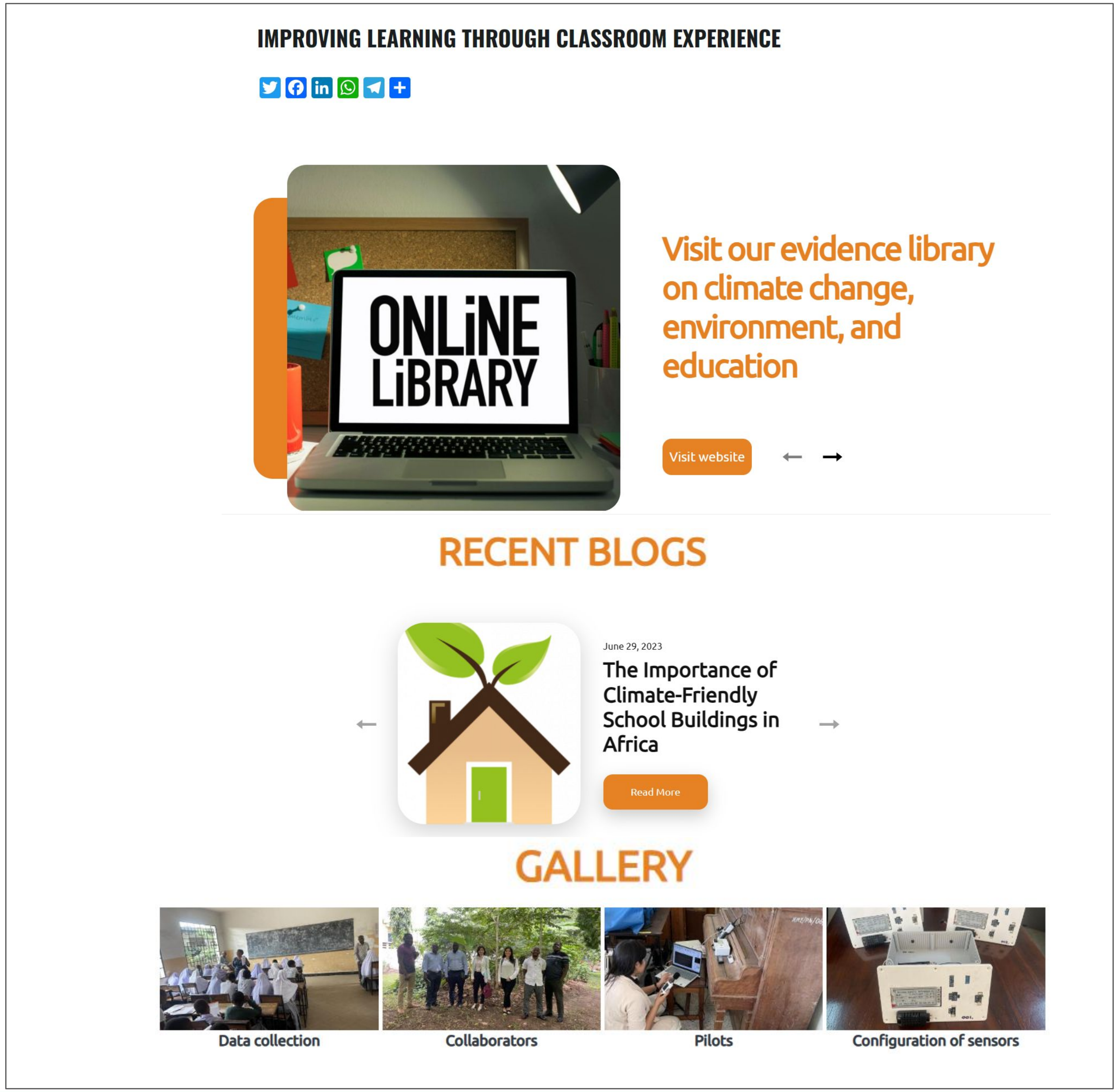
Dunia designs furniture uses a material called Greenwood that it's created completely from low-grade plastic waste. It is cleaned and shredded before being formed in greenwood plank. These planks are then used by our carpenters as a ***wood substitute.***

MEER

Mirrors for Earth's Energy Rebalancing (MEER) takes action to address the high temperature issues by implementing ***reflective film technology on rooftops***. This innovative approach has significantly reduced indoor temperatures, providing a safer and more comfortable environment for those affected by the heat.

Communications

Website for the project: www.opendeved.net/ilce/



Thanks

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