Improving Learning Through Classroom Experience

The impact of climate change on education: An evidence synthesis focused on classroom experience in hot climates

Björn Haßler

Olamide Eso

Xuzel Villavicencio

Eunice William Jengo

Chris McBurnie

May 2024

https://doi.org/10.53832/opendeved.1139

About this document

Recommended citation

Haßler, B., Eso, O., Villavicencio, X., Jengo, E., & McBurnie, Chris (2024). *The impact of climate change on education: An evidence synthesis focused on classroom experience in hot climates* [Improving Learning Through Classroom Experience in East Africa]. Open Development & Education.
https://doi.org/10.53832/opendeved.1139

Contents

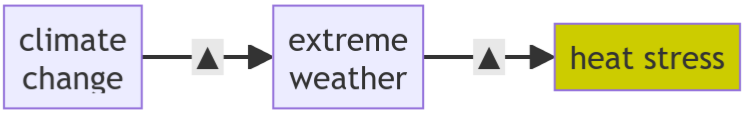
Figures

1. Introduction

In low- and middle-income countries, populations are disproportionately vulnerable to climate change and face major challenges in building resilience to environmental catastrophes. In the education sector, the effect of climate change is multifaceted, ranging from weather-related learning disruptions to compromised access to education as a result of displacement and resource scarcity (↑Education Cannot Wait, 2020; ↑Internal Displacement Monitoring Centre, 2020; ↑Sims, 2021; ↑Venegas Marin et al., 2024). These adverse effects are pervasive, exacerbate existing inequalities, and perpetuate cycles of poverty.

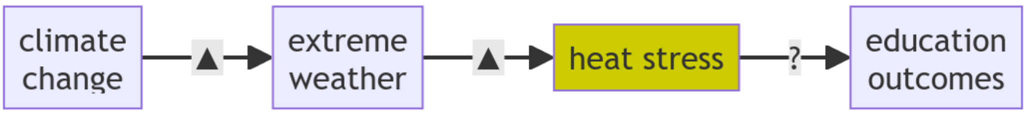
Despite a significant body of evidence focusing on climate change and its effect in various sectors, the impact of climate change on education is not fully understood. For example, we have insights into how climate change leads to extreme weather events (↑Stott, 2016). The figure below illustrates this relationship: climate change leads to more extreme weather events, which, as one of the consequences, leads to more heat stress.

Figure 1.1. The relationship between climate change and temperatures



However, we need a better understanding of how climate change, and the multiple impacts of climate change, affect education (↑Venegas Marin et al., 2024), that is to say how, e.g., heat stress impacts learning outcomes, as illustrated in the following figure.

Figure 1.2. The relationship between climate change and education



Immediate action is needed to determine how climate change affects educational contexts and how to tackle climate-related challenges within educational contexts (↑GADRRRES, 2022; ↑Kousky, 2016).

To illustrate this, at the time of writing this report (March), the Government of South Sudan announced school closures as a result of a heat wave:

> *"According to the Ministry of Environment and Forestry advisory, most parts of South Sudan are experiencing a heat wave. It is forecasted that the heat wave will last at least two weeks. High temperatures of 41 °C – 45 °C*

> *are expected this week.* […] *The Government has decided to take the following measures:* […] *Close down all schools with effect from Monday, 18 March 2024.* […] *(parents) should also monitor children, especially the young ones, for signs of heat exhaustion and heatstroke"* (↑AP, 2024; ↑NTV,↑Sudan Tribune, 2024; UGANDA, 2024).

Notably, the government also highlighted the potential for action.

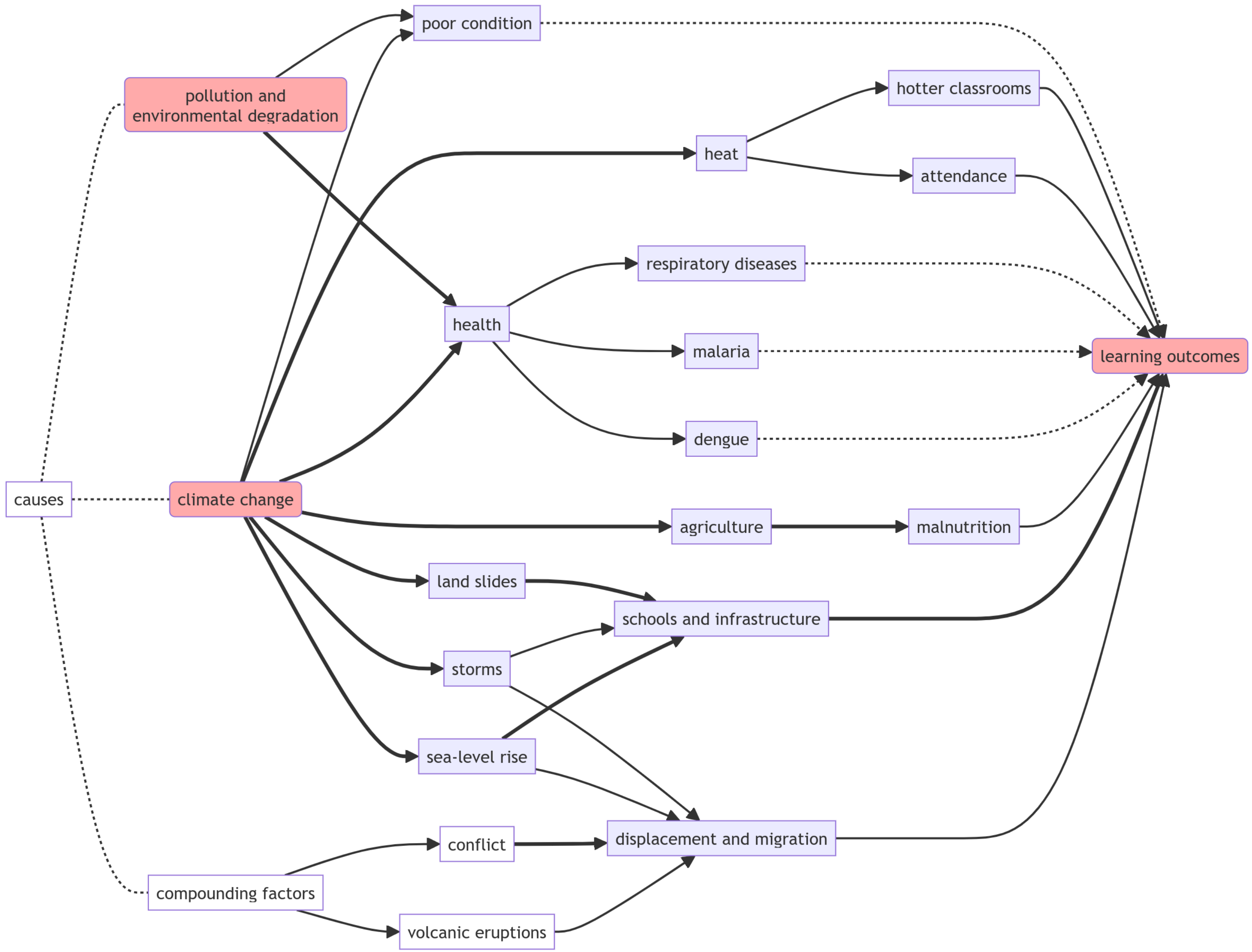
> *"Practical, feasible, and often low-cost interventions at the individual, community, organisational, governmental and societal levels, can save lives."*

In some sub-Saharan African countries, like Tanzania and Burkina Faso, schools are already exploring or delivering low-cost interventions to adapt to environmental changes. The interventions include planting micro forests to increase shade, painting roofs white to reflect solar radiation, creating vents to ensure a flow of cool air in schools, and using bamboo mats for better sound insulation (↑Bangay, 2023; ↑Borràs, 2024; ↑Ecophon, 2022; ↑Tanzania: Keevill, 2023).

Notably, these interventions build on decades of practice in energy-efficient construction. In the late 1990s and early 2000s, for example, policymakers in the United Kingdom and the United States developed programmes to incentivise the use of renewable energy, natural shading, and improved insulation to create healthier, more effective learning environments (↑Department of Environment, Transport and Regions, 1997; ↑National Renewable Energy Laboratory, 2002). Prior to this guidance, Korean researchers led field experiments to investigate levels of thermal comfort in schools (↑Lee & Lee, 1986).

Our paper synthesises the evidence on the impact of climate change on primary and secondary education and summarises evidence on feasible, low-cost interventions to build climate resilience at different levels of the education sector. Where possible, the paper presents literature from sub-Saharan Africa. However, the synthesis considers research from a range of hot climates globally – overall, the evidence base is scarce, necessitating drawing on all available evidence.

Figure 1.3. Situating our review



1.1. Focus of our synthesis

The diagram above illustrates a range of possible relationships between causes and the impact on learning. Our synthesis focuses on a small subset of these. In particular, our synthesis focuses on how modifications to the school built environment can positively impact classroom experience to improve learning. We investigate the following physical aspects of classroom experience:

- Temperature
- Lighting
- Noise (sound/acoustics)
- Air quality.

Each of these physical aspects of classroom experience interact to shape the overall comfort, wellbeing, and – ultimately – performance of students (↑Ragpala, 2021; ↑Yang & Moon, 2019).

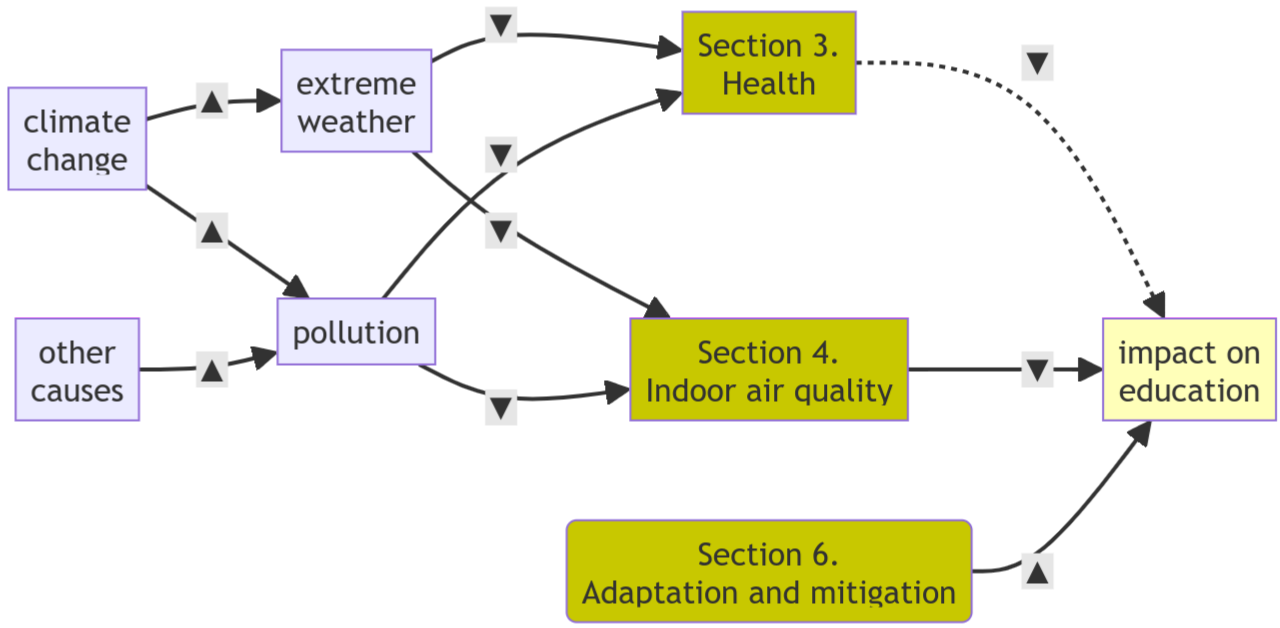
1.2. Outline of the study

Our synthesis examines evidence and case studies from across the globe, with a focus on low- and middle-income countries, offering insights that link climate change to education outcomes and highlighting evidence of effective approaches to adaptation, resilience, and environmental sustainability in education. The paper reviews the evidence as follows:

- **Section 3** looks at the impact of climate change on health, illustrating the evidence available and concerns about how health problems impact learning outcomes.
- **Section 4** considers the impact of climate change on education, investigating the relationship between climate change, indoor environmental quality, and learning outcomes.
- **Section 5** provides contextual information on the challenges in Tanzania.
- **Section 6** reviews evidence on approaches to adaptation, resilience, and environmental sustainability in education.

These sections can be visually represented as follows.

Figure 1.4. A diagram of the structure of our evidence synthesis



2. Methodology

As our evidence library shows, the evidence base on education and climate change in low- and middle-income countries is limited. To address this issue in the area of climate change and health, researchers have used theory-driven realist approaches (↑Berrang-Ford et al., 2015). For this study, we conducted a theory-driven, realistic systematic review to source papers with relevant, high-quality evidence (Pawson et al., 2005). As part of this approach, we set out to define the causal pathways between climate change and learning outcomes (e.g., education / economics: ↑Bates & Glennerster, 2017; ↑Harn et al., 2013; ↑Ludwig et al., 2011; ↑Sharples et al., 2019; ↑Sims et al., 2021; and in implementation science: ↑Albers et al., 2020; ↑Allison, 2023; ↑Lurvink et al., 2022). We outline our approach and process below.

2.1. Our approach

2.1.1. Search and identification

We employed an automated, cross-database search strategy as 'best practice' for systematic reviews in education. To do so, we used AI-based tools to automate the search process (see ↑Haßler et al., 2024 for a review of AI tools for evidence synthesis). We searched for academic papers, grey literature, and doctoral theses on open-access databases (e.g., OpenAlex, DOAJ, ERIC), free databases (e.g., Google Scholar), and proprietary databases (e.g., Scopus, Web of Science, ProQuest).

This approach was motivated by the observation that "no database contains the complete set of published materials" (↑Xiao & Watson, 2017: p.11). By utilising multiple databases, we could access a wider range of sources, increasing the likelihood of identifying relevant studies that may be overlooked by relying on a single database.

2.1.2. Keyword inventory

To identify suitable studies for the synthesis, we drew on and updated a pre-existing inventory of keywords for systematic literature reviews on education and climate change (climate.educationevidence.io). The inventory combines terms related to climate change and education, school buildings, and indoor environmental quality. We searched for keywords in the titles and abstracts of studies, coding and organising studies based on their publication status, geographic focus, and population.

2.1.3. Deduplication

As searches across multiple databases will source duplicate papers, we used our existing software packages – including natural language processing – to identify duplicates within and across databases. At the end of this process, we had a 'long list' of studies that passed the initial screening.

2.1.4. Eligibility screening

Two reviewers reviewed the abstracts of all studies on the long list, coding studies into 'high', 'medium', and 'low' relevance categories. Here, relevance referred to the extent to which a study aligned with our focus on the impact of climate change on the school built environment and learning outcomes. At this stage, medium- and high-relevance studies were included in a shortlist.

2.1.5. Quality screening

Two reviewers assessed the full text of shortlisted studies for quality. The reviewers coded the studies according to the following classifications:

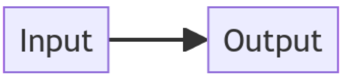
Figure 2.1. Full-text quality screening classifications

High	Methods are clearly indicated, methods are explicitly implemented (e.g., sample data is clearly specified), and conclusions are clearly derived from the data
Medium	Methods are clearly indicated, but the conclusions raise concerns
Low	No obvious methods indicated

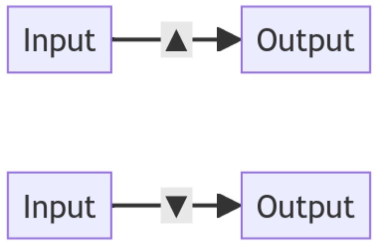
A final set of high-relevance, high-quality publications will be selected for inclusion

2.1.6. Theory building and visualisation of causal relationships

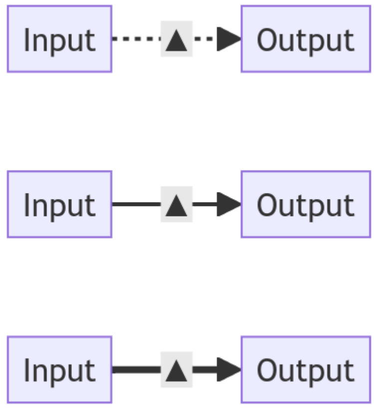
Throughout this report, we use ↑causal loop diagrams to map out the causal pathways between climate change and learning (↑Haßler et al., 2021n). Causal loop diagrams outline both direct and indirect causal pathways and relationships. Thicker arrows represent connections with stronger evidence; dotted arrows show more tenuous connections. The following diagram illustrates in Input which leads to an Output:



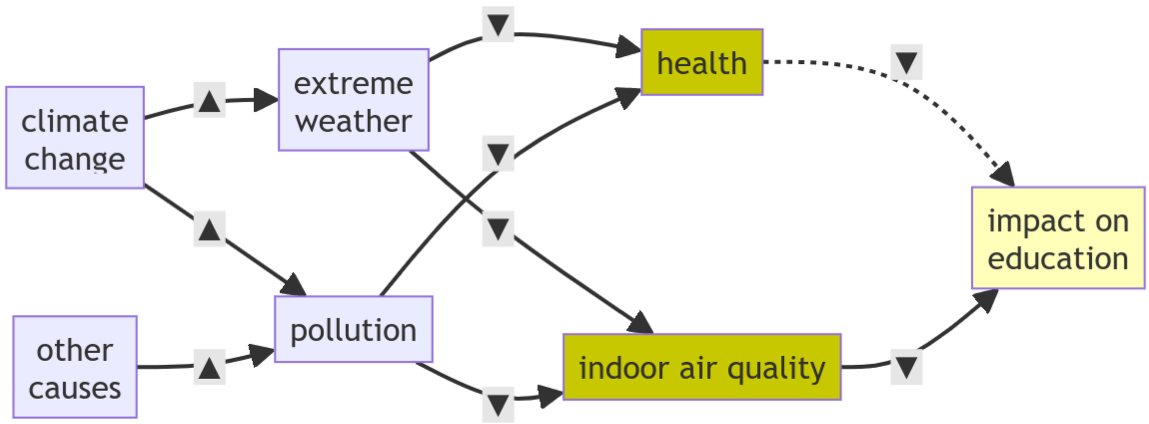
We add a solid upward-pointing triangle (▲) to indicate a positive relationship: If the input increases, the output also increases. We add a solid downward-pointing triangle (▼) to indicate the opposite direction: When the Input increases, the output decreases. The following diagrams illustrate this:



At times, we also use dashed lines to indicate delayed/weaker/less certain influences, as well as thicker lines to indicate stronger/more certain influences. The following diagram shows the three line styles:



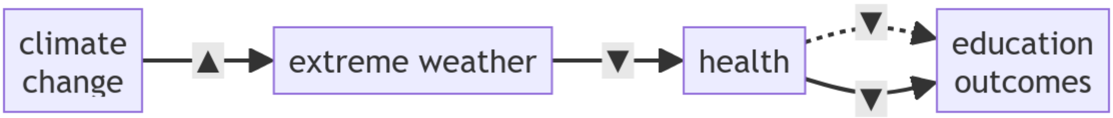
Revisiting Figure 1.4, we see that the figure indicates that climate change leads to increased extreme weather events, which in turn influences health and indoor air quality. Those in turn impact education.



3. The impact of climate change on health

To illustrate the causal chain of how climate change influences education, this section considers an indirect relationship: the impact of climate change on health, as outlined in Figure 3.1 below. Climate change leads to more extreme wealther events, negatively impacting health, including children's health. This has both direct and indirect negative influences on education outcomes.

Figure 3.1. Climate change, extreme weather, health, and education

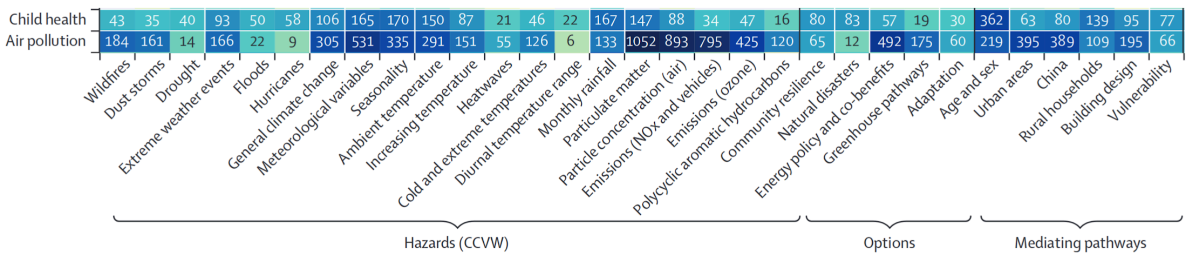


We have chosen to begin our report by illustrating this specific causal chain. For health more information is available on the impact of climate change than tharee is for the impact on school infrastructure (discussed in the remainder of this review).

↑Berrang-Ford et al. (2021) used machine learning methods to map 15,963 studies on climate change and health outcomes, published between 2013 and 2019. This review found several knowledge gaps, including the impact of climate change on mental health, undernutrition, and maternal / child health. Even though societies in low- and middle-income countries face more climate-related health challenges than societies in high-income countries, the literature has a disproportionate focus on high-income countries.

Despite the under-representation of low- and middle-income countries in the literature, global evidence offers rich insights. Figure 3.2. was adapted from ↑Berrang-Ford et al. to map publications by climate hazards and health risks / impact. We focused on two health risks / impacts relevant to learning: child health and air pollution.

Figure 3.2. A map of publications by climate hazards and health risks. Adapted from ↑Berrang-Ford et al. (2021)



Meanwhile, other reviews on climate change and health outcomes augment our understanding of this relationship (e.g., ↑Ames, et al., 2023; ↑Ammannm, et al.; 2021;↑Berrang-Ford, et al., 2015; ↑Berrang-Ford, et al., 2021; ↑Callaghan, et al., 2020; ↑Chevance, et al., 2023; ↑Chevance, et al., 2024; ↑Essamlali, et al., 2024; ↑Flores, et al., 2023; ↑Haddaway, et al., 2020; ↑Koch, et al., 2022; ↑Luyten, et al., 2023; ↑Ncongwane et al., 2021; ↑Oladimeji, et al., 2023; ↑Palmeiro-Silva, et al., 2023; ↑Palutikof, et al., 2023; ↑Phalkey, et al., 2015; ↑Tham et al., 2020). For example, ↑Ncongwane et al.'s (2021) systematic review on the impact of heat stress on health in sub-Saharan Africa emphasised the need for more vulnerability assessments, greater exploration of personal exposure risks, further investigation into the effects of urban heat islands on health, and the study of heat adaptation. ↑Tham et al. (2020) contributed to this discourse by identifying 22 studies that showed high indoor temperatures worsen respiratory symptoms, diabetes, and core symptoms of schizophrenia and dementia.

This review shows that climate change will impact health, including children's health, with an impact children's education. However, the direct impact on climate change on education is less well understood; we now turn to this.

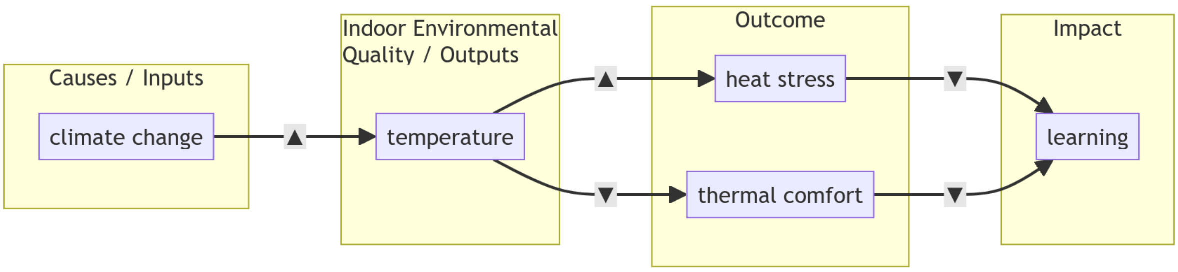
4. The impact of climate change on education

This section examines the evidence on how the impact of climate change, such as global warming, affects indoor environmental conditions in school buildings.

4.1. The impact of climate change on school infrastructure

Manu studies show a significant connection between climate change, school indoor environmental quality, and the classroom experience of students (↑Ahmed, 2017; ↑Baker, 2012; ↑Barbic et al., 2022; ↑Brink et al., 2020; ↑Hoque & Weil, 2016; ↑Rance et al., 2023;↑Sarbu & Pacurar, 2015; ↑Wang & Degol, 2016; ↑Xiong et al., 2018). As illustrated below, climate change lead to extreme weather events that negatively impact indoor comfort levels in schools which, in turn, negatively impact student learning (↑Brink et al., 2020; ↑Kousky, 2016; ↑Toftum et al., 2021).

Figure 4.1. The impact of climate change impact on classroom experience



Extreme weather events – heatwaves, wildfires, cyclones, flooding – have directly impacted education facilities, forcing policymakers to reconsider whether schools can continuously provide a safe and healthy environment for learning (↑Chalupka & Anderko, 2019; ↑David et al., 2018). In many low- and middle-income countries, these events have led to the destruction of schools and educational infrastructure (↑Venegas Marin et al., 2024; ↑World Bank, 2022).

In addition to damaging school buildings, climate change has made classrooms an unconducive space for teaching and learning (↑Davidson, 2024; ↑Sheffield et al., 2017). In Nigeria, ↑Andrew (2017) showed that extreme weather events had damaged schools, increased pollution-related illnesses, and caused excessive heat in classrooms. In Zambia, ↑Mpanza & Muluka (2023) found that schools faced similar challenges with climate change.

Moreover, ↑Dong et al. (2023) demonstrated that the effect of climate change on school buildings and the experiences of students varies across regions. The poorest countries will likely be most affected, with the Gambia experiencing an average of at least 209 hot days per year and the Netherlands experiencing a maximum of 2 hot days per year (↑Venegas Marin et al., 2024). This finding shows that climatic conditions influence school comfort levels more significantly in some regions than others.

4.2. The impact of indoor environmental quality on student comfort

Indoor environmental quality (IEQ) refers to the conditions of a building and the effect of these conditions on the building's occupants. Different components of the indoor school environment, such as temperature and lighting, can interact to influence the overall well-being and performance of students (↑Pule et al., 2021; ↑Ragpala, 2021; ↑Yang & Moon, 2019).

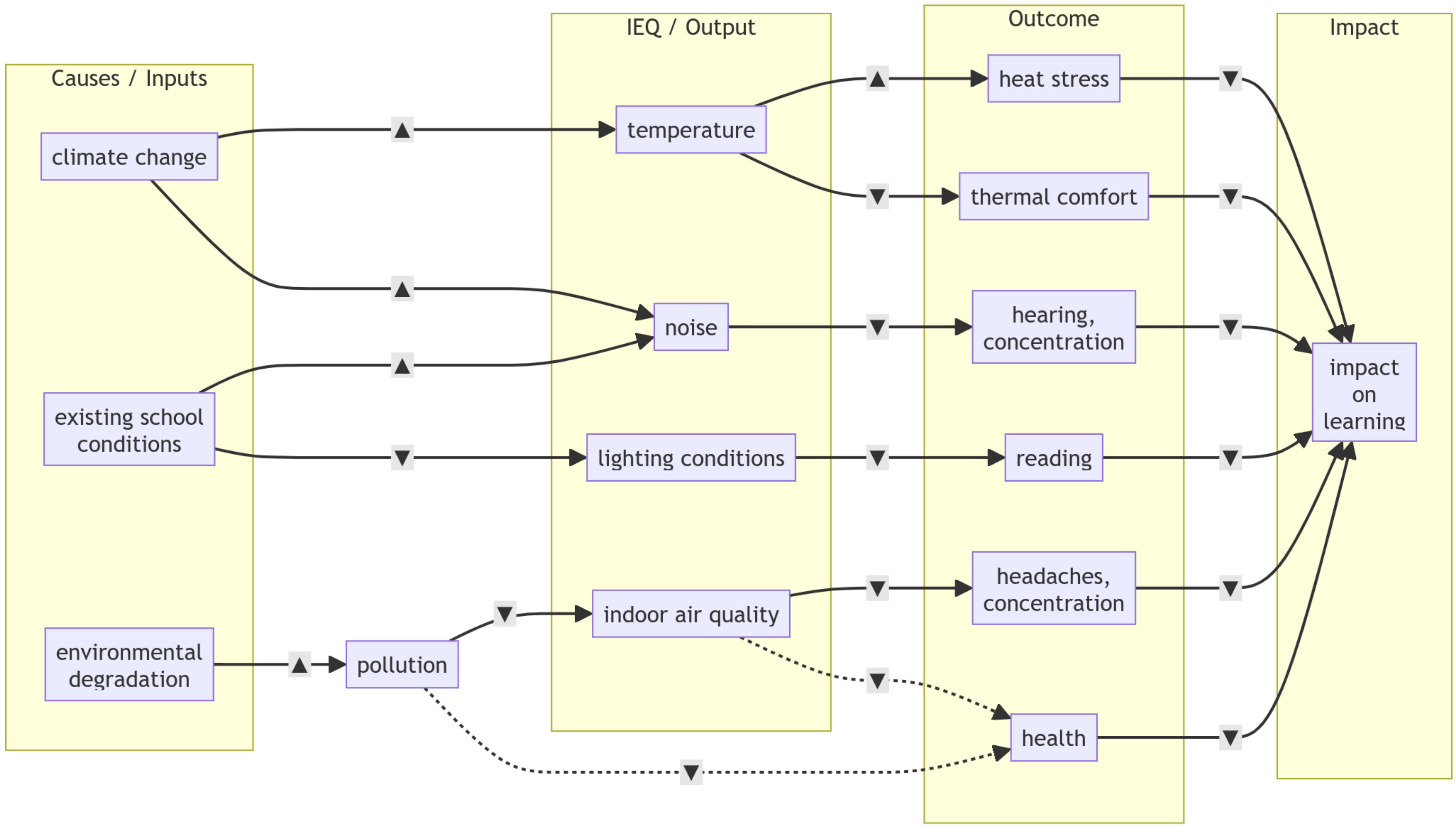
As such, individual design choices when building classrooms can have a significant cumulative impact on the overall comfort and suitability of a learning environment (↑Ahmad et al., 2015; ↑Blaker & Andrew, 2020; ↑Hoque & Weil, 2016; ↑Kükrer & Eskin, 2021; ↑Mendell & Heath, 2005). Figure 4.2. below illustrates how regulating indoor environmental quality factors – temperature, lighting, sound, and air quality – is crucial in creating a conducive learning environment (↑Ahmed, 2017; ↑Bangay, 2023; ↑Barrett et al., 2015; ↑Cartieaux et al., 2011).

Students can experience distractions, high levels of discomfort, and adverse health outcomes as a result of poor indoor environmental quality (↑Mendell & Heath, 2005; ↑Wargocki & Wyon, 2017). In a range of contexts, for instance, excessive noise has contributed to fatigue, concentration issues, and mental health challenges among students (↑Castro-Martínez, 2016; ↑Persinger et al., 1999).

Moreover, ↑Yeganeh et al. (2018) conducted a systematic review that found heat stress can lead to an 8% drop in cognitive performance. In line with this review, ↑Barbic et al. (2022) demonstrated that thermal discomfort can negatively impact the verbal and reasoning abilities of learners. Similarly, high indoor temperatures in schools have been associated with discomfort and headaches in Cameroon, India, and Nigeria (↑Dapi et al., 2010; ↑Mustapha et al., 2022; ↑Tasgaonkar et al., 2022; ↑Toyinbo et al., 2019).

Notably, students and teachers tend to have different 'optimal temperature zones' that reflect their age, gender, and time spent in different climates (↑Ahmed et al., 2022; ↑Zivin & Shrader, 2016). In Nigeria, ↑Munonye et al. (2023) found children felt most comfortable at 27.4 °C whereas teachers felt most comfortable at 29.4 °C. Importantly, poor indoor environmental quality can negatively affect the instructional practice of teachers, which, in turn, negatively affects student performance (↑Kok et al., 2015; ↑Mendell & Heath, 2005; Ortsa & Ndidiamaka, 2021; ↑Wang & Degol, 2016). These findings highlight the need to consider the thermal comfort of teachers and pupils in the design of school buildings (↑te Kulve et al., 2020).

Figure 4.2. The relationship between climate change, indoor environmental quality (IEQ), and learning

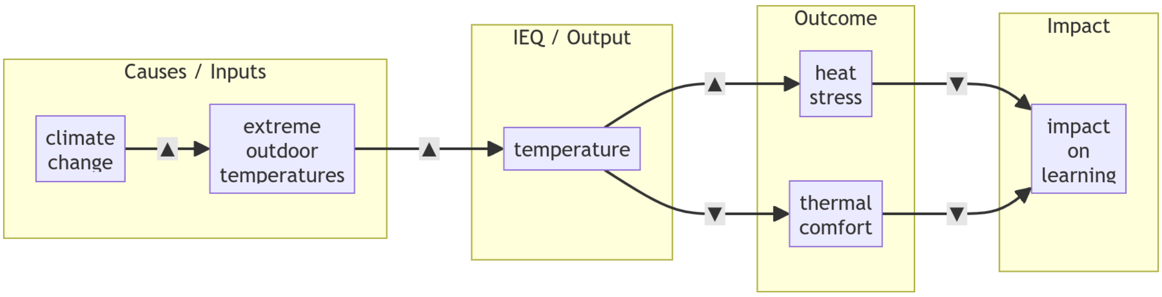


4.3. The impact of temperature on learning outcomes

As highlighted in the introduction (Section 1), climate change has increased the frequency of extreme weather events and led to higher temperatures which, in turn, have raised temperatures in schools (↑Stott, 2016). Today, more than one-third of learners worldwide are exposed to extreme temperatures that contribute to low levels of thermal comfort and high heat stress among students and teachers (↑Abdullah et al., 2023; ↑Cramer et al., 2022; Mustapha et al., 2022; ↑Singh et al., 2019; ↑Tasgaonkar et al., 2022; ↑UNICEF, 2021).

As discussed below, evidence links extreme indoor temperatures with low student attendance, high teacher absenteeism, poor cognitive performance, and worse learning outcomes (↑Barbic et al., 2019; ↑Boix-Vilella et al., 2021; ↑Dupont et al., 2023; ↑Simmons et al., 2008; ↑Toftum et al., 2021; ↑Wargocki et al., 2019). Figure 4.3 outlines the impact of climate change on the temperature and resilience of school buildings, as well as the impact of higher indoor temperatures on learning outcomes.

Figure 4.3. The impact of extreme outdoor temperatures on learning



Students in many low- and middle-income countries have experienced school closures as a result of heatwaves. Between 2015 and 2021, schools in Afghanistan, Bolivia, Ethiopia, India, Malaysia, Malawi, Somalia, South Sudan, and Zimbabwe variously closed for extended periods because of extreme heat (↑Venegas Marin et al., 2024). In Malawi, for example, a heatwave in 2015 forced more than 40% of schools to close and over 137,000 students to drop out of school (↑World Bank, 2016).

Over time, high temperatures can lead to worse cognitive performance and notable learning loss (↑Blaker & Andrew, 2020; ↑Yeganeh et al., 2018). In an analysis of test scores in 58 countries, ↑Park et al. (2020) found that each day of school in hot classrooms lowers learning and exam scores. In the hottest municipalities of Brazil, the average student loses 1% of learning each year because of heat exposure (↑Venegas Marin et al., 2024). Moreover, researchers observed a similar relationship between high temperatures and diminished students outcomes in Cameroon, India, Kenya, South Korea, the Philippines, and the United States (↑Bigueja et al., 2022;

↑Cho, 2017; ↑Dapi et al., 2010; ↑Garg et al., 2020; Korir, 2021; ↑Roach & Whitney, 2021).

Importantly, exposure to high temperatures on exam days negatively affects student performance (↑Park, 2022). In Vietnam, ↑Vu (2022) demonstrated that the average scores on university entrance exams decreased for every 1 °C increase in temperature on test days. Similarly, ↑Zhang et al. (2024) and ↑Zivin et al. (2020) found that students in China achieve lower scores on standardised mathematics tests and the college entrance exams on hotter days. In line with these conclusions, ↑Porras-Salazar et al. (2018) found that the academic performance of students in Costa Rica improved when indoor temperatures dropped from 30 °C to 25 °C.

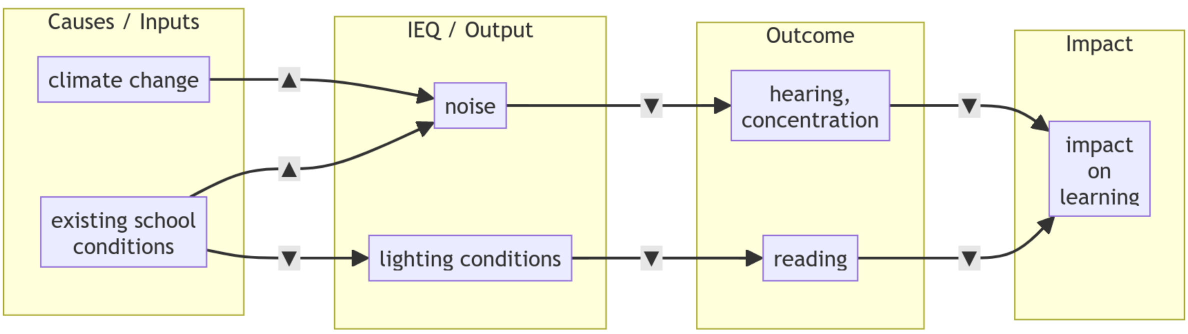
Similarly, extreme cold temperatures can cause disruptions in schooling and inhibit learning (↑Hyndman et al., 2024). In South Africa, for instance, ↑Pule et al. (2021) found that student absenteeism was highest when indoor temperatures dropped below 15 °C. In Mongolia, Groppo & Kraehnert (2017) showed that children in regions subjected to the most severe winter storms are less likely to complete basic education than their peers.

4.4. The impact of light variability on learning outcomes

Different standards can be used to define acceptable or minimum standards for lighting conditions in schools. For comparability across studies, this synthesis refers to lux, which measures the amount of light that hits or passes through a surface. Notably, international standards recommend lighting levels of between 300 lux and 500 lux for a regular classroom environment (↑Chartered Institution of Building Services Engineers, 2011; ↑European Committee for Standardization, 2002).

Climate change can cause extreme and shifting daylight patterns. The variability of natural lighting can negatively affect indoor lighting in classrooms, causing visual discomfort for teachers and students, and potentially impacting learning outcomes, as illustrated in Figure 4.4. below (↑Magero et al., 2023; ↑The Society of Light and Lighting, 2011).

Figure 4.4. The impact of natural light variability on learning



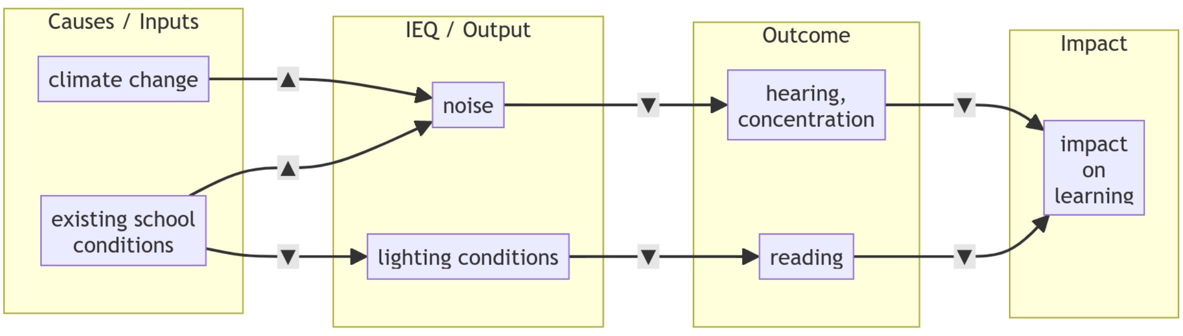
Suitable lighting levels in schools can improve concentration, reduce eye strain and headaches, and improve student learning (↑Küller & Lindsten, 1992; ↑Sleegers et al., 2013). In Kenya, ↑Magero et al. (2023) demonstrated that installing curtains or blinds, increasing the number of windows, and adjusting student seating plans can improve the quality of lighting and visual comfort. In a study of 180 classrooms in Nigeria, ↑Ibhadode et al. (2019) showed that only 14% of students had adequate lighting at their desks, while the majority of classrooms lacked suitable lighting for the board. Here, students struggled to read and faced additional health risks in poorly lit, or overly sun-exposed, classrooms (↑Ibhadode et al., 2019). This issue had the greatest impact on children with poor eyesight or visual impairments, introducing a layer of inequity.

In a study of 21,000 fifth-grade students in the United States, ↑Heschong (1999) found children in classes with more natural light performed better on standardised tests than peers in classes with less natural light. For example, children who studied in classrooms with larger windows, skylights, and more natural light throughout the academic year made the most progress in literacy and numeracy (↑Heschong,1999).

4.5. The impact of noise on learning outcomes

Excessive noise in the classroom can negatively affect learning (↑Klatte et al., 2013; ↑Rogers et al., 2006). Climate change can increase noise levels in classrooms as a result of more frequent and severe weather events like storms, heavy rain, and high winds (↑Bangay, 2023; ↑Ecophon, 2022; ↑Souza, 2021). Figure 4.5. below models the relationship between climate change and related noise levels and learning outcomes.

Figure 4.5. The impact of extreme outdoor noise on learning



In a literature review on the impact of noise on learning, ↑Klatte et al. (2013) found that excessive noise in classroom settings led to worse speech perception, listening comprehension, and performance in verbal tasks. Moreover, long-term exposure to higher levels of ambient noise – traffic, aircraft, storms – has been associated with impaired language skills among students (↑Klatte et al., 2013; ↑Pujol et al., 2013). These findings align with the ↑World Health Organisation's (2010) guidance on noise, which notes that high noise levels can lead to hearing loss, communication difficulties, and reduced academic performance.

In a study in eight Malaysian primary schools, ↑Ismail et al. (2020) found that noise levels in classrooms exceeded international standards. Here, excessive noise levels disrupted the teaching and learning process as students missed important verbal cues from teachers (↑Ismail et al., 2020). In Indonesia, ↑Buchari (2017) found that excessive noise in the classroom negatively affects the socioemotional well-being of students who experienced dizziness and aural discomfort. As in Malaysia, loud classrooms had a negative impact on teacher–student communication and the performance of learners (↑Buchari, 2017).

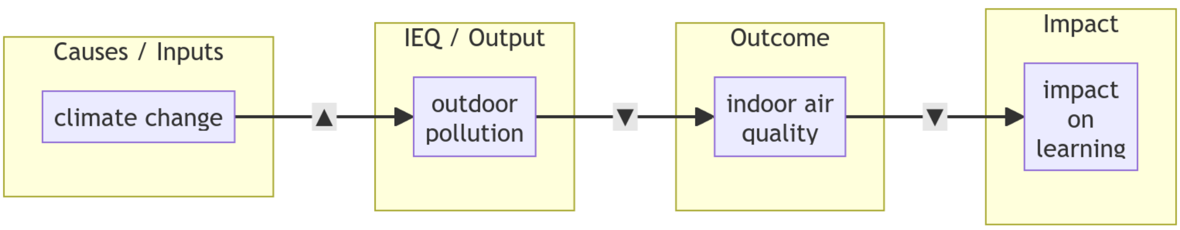
In addition to storms and heavy rains, overcrowded classrooms can generate noise that negatively affects teaching and learning (↑Gilavand & Jamshidnezhad, 2016; ↑Likuru & Mwila, 2022). In Brazil, ↑Levandoski & Zannin (2022) suggested that noise originating from students in overcrowded classrooms had the greatest impact on teaching. In Pakistan, ↑Siddiqui (2018) demonstrated that high levels of noise from overcrowding disrupted lesson delivery, impaired communication among students, and limited the ability of teachers to maintain discipline in the classroom.

Importantly, excessive levels of noise can have a greater impact on marginalised students. In South Africa, for example, ↑Goldschagg & Bekker, 2021 showed that excessive noise has a greater impact on second-language learners who have higher language processing demands. This conclusion aligns with evidence from ↑Rogers et al.'s (2006) study on the impact of noise on bilingual students in the United States and ↑Lecumberri et al.'s (2010) systematic literature review on the effect of noise on second-language learners. Meanwhile, ↑van Reenen & Karusseit (2017) emphasised that excessive classroom noise is particularly problematic for students with sensory and learning impairments.

4.6. The impact of air pollution on learning outcomes

Climate change and increased greenhouse gas emissions lead to poor indoor air quality in schools, which impacts children's learning (↑Chatzidiakou et al., 2012; ↑Kalisa et al., 2023;↑Marcotte, 2017; ↑Miller & Vela, 2013; ↑Perisco, 2019). Figure 4.6. below depicts the relationship between air pollution and learning outcomes.

Figure 4.6. The impact of air pollution on learning



In a systematic literature review, ↑Stenson et al. (2021) highlighted the detrimental effect of air pollution on the academic performance of children and adolescents in schools. Similarly, ↑Marcotte (2017) demonstrated that higher levels of pollen and fine particulate matter lead to lower foundational literacy and numeracy outcomes. ↑Wargocki et al. (2022) note that improving classroom air quality reduces student absenteeism while improving cognitive skills and academic performance.

In the United States, ↑Persico & Venator (2019) examined how learning outcomes changed when factories emitting harmful pollutants either opened or closed within a mile of schools. Here, students exposed to new forms of air pollution performed worse on standardised tests and exhibited behavioural disorders that resulted in suspension from school (↑Persico & Venator, 2019). Similarly, ↑Heissel et al. (2019) found that students in schools downwind from highways had lower test scores, more behavioural disorders, and higher levels of absenteeism, than students in schools upwind from highways. Moreover, ↑Gilraine & Zheng (2022) used satellite data and tested schools from 10,000 U.S. school districts to show that student test scores decrease for every additional unit of air pollution. Importantly, air pollution tends to have the greatest impact on students who are more likely to attend schools in deprived, industrial areas (↑Bernardi & Keivabu, 2023).

In low- and middle-income countries, schools have faced similar challenges with air pollution. In Chile, high concentrations of air pollution increased respiratory illness, student absenteeism, and behavioural issues (↑Miller & Vela, 2013). Interventions to improve air quality have been projected to result in statistically significant test score gains in reading and mathematics (↑Miller & Vela, 2013). In Iran, short-term exposure to high levels of particulate matter on exam days has been associated with lower test scores (↑Amanzadeh et al., 2020). Notably, studies from Brazil, China, India, Israel, and South Africa validate the relationship between air pollution and higher rates of student absenteeism and worse learning outcomes (↑Balakrishnan & Tsaneva, 2021; ↑Carneiro et al., 2021; ↑Chen et al., 2017; ↑Lavy et al., 2014; ↑Van Der Walt et al., 2024; ↑Zhang et al., 2018)

Importantly, students are more vulnerable to air pollution than teachers because they have higher respiration rates. In a systematic review, for instance, ↑Sadrizadeh et al. (2022) noted that indoor air pollution affects pupils' learning and productivity more than adults.

5. The impact of climate change on education: Tanzania

To illustrate the applicability of the evidence presented in the previous section, we now consider those issues in the context of a specific county: Tanzania.

Tanzania is the largest country in East Africa, bordered by Kenya, Uganda, Burundi, Rwanda, the Democratic Republic of Congo, Zambia, Malawi, and Mozambique. Tanzania has four climatic zones: the hot, humid coastal plain; the semi-arid zone of the central plateau; the humid lake regions; and the temperate highland areas (↑Climate Technology Centre & Network, 2018). In the highland areas, temperatures range from 10° C to 20° C during the cold and hot seasons. In other parts of the country, temperatures do not drop below 20° C. The hottest periods are November and February (25° C to 31° C), and the coldest periods are May and August (15° C to 20° C). The country experiences two rainy seasons: long rains from March to May and short rains in November and December (↑Ministry of Foreign Affairs and East African Cooperation, 2018).

5.1. School buildings

It is unclear whether the guidelines for constructing schools in Tanzania, including classrooms, toilets, and teachers' offices, are applied in both rural and urban areas. Notably, school buildings in rural areas are often reported to be in poor condition, with collapsing structures, leaking roofs, cracked walls and floors, and inadequate lighting and windows in classrooms and teachers' houses (↑Ministry of Education, Science and Technology, 2020).

The government's decision to build new classrooms in Tanzania reflects a need to reduce overcrowding and enhance access to other facilities within the school. In 2022, for example, 15,000 new classrooms were constructed for secondary schools to accommodate incoming Form 1 students from primary schools (↑Ministry of Finance, 2022). According to ↑Proctor (2022), most classrooms in Tanzania are built in blocks of two or three using locally made bricks and mortar, with timber-framed roofs covered in corrugated iron.

In 2001, a major school project was undertaken in Tanzania to build 300 classrooms in 30 schools in Dar es Salaam. The project took into consideration the climate conditions in Dar es Salaam when selecting the building materials. Despite not being satisfied with the quality of locally available building materials, the project had to use them to reduce maintenance costs (↑Japan International Cooperation Agency, 2001)

In 2021, two government primary schools in Shimbwe village, Kilimanjaro, built in 1948 and 1978, were renovated by C-re-aid, an architectural NGO dedicated to exploring the possibilities of responsible building practices and materials to promote long-term socioeconomic and environmental improvement across East Africa. The schools earmarked for renovation had leaking roofs, termite-infested timber, and deteriorated floors, which made it difficult to clean, as seen in Figure 5.1.

Figure 5.1. Classroom at Shimbwe Chini Primary School before renovation. Source: ↑C-re-aid (2021)

During the rainy season, the classrooms became cold because of a lack of ceilings and glass windows. Further renovations took place in other parts of the schools such as the toilets, teachers' houses, and school kitchen, as shown in Figure 5.2.

Figure 5.2. Old and new kitchens at Shimbe Chini Primary School. Source: ↑C-re-aid (2021).

Here, C-re-aid aimed to renovate rather than build new buildings to reduce the environmental impact of construction and lower costs. Techniques used included reusing building materials from the old building, using Compressed Earth Blocks, and applying low-cost limewash as a low-cost alternative to paint (↑C-re-aid, 2021).

5.2. Impact of climate hazards on school infrastructure

The effects of climate change are evident in Tanzania, with droughts and floods destroying houses, schools, and infrastructure, and displacing people in different regions (↑National Bureau of Statistics, 2020). The extreme impacts of climate change have affected education, leading to school closures to protect students from natural disasters. In one village, for example, three classrooms in a school collapsed during a torrential rainstorm in 2017, leading to overcrowded classes as more than 100 students had to share a classroom (↑The Rafiki Village Project, 2017).

In 2019, schools in the northeastern part of the country (i.e., Unguja, Pemba, and Zanzibar) were closed as a result of heavy rainfall that lasted for seven days and caused serious flooding and destruction of infrastructure (↑Tanzania Meteorological Association, 2019).

In 2022, strong winds blew off the roof of four classrooms in Handeni district (see Figure 7.3.), causing 300 students to miss seven days of school. Across Tanzania, such incidents have caused significant damage to schools and resulted in many students missing out on their studies (↑Tanzania Meteorological Association, 2022). These are just a few recorded incidents, but much larger numbers of students are likely to miss school in the future due to these kinds of events.

Figure 5.3. Damaged roofs at Luye Primary School in Handeni-Tanga. Source: **↑Tanzania Meteorological Association (2022)**.

6. Climate adaptation strategies in low- and middle-income countries

Unless major reductions in greenhouse gas emissions are achieved in the next few decades, human-induced climate change will continue to cause extreme weather events, such as heatwaves, heavy rainfall, droughts, and tropical cyclones (↑Lahn, 2020). As extreme weather events are likely to continue to occur, the vulnerability of schools will increase. Extreme weather events can – and will – damage school buildings, disrupt the delivery of education services, and strain the already limited resources of educational institutions.

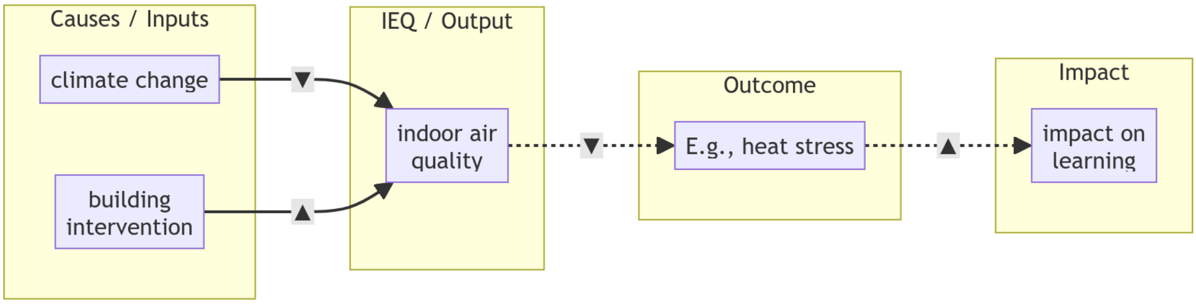
In many low- and middle-income countries, central policymakers rely on outdated infrastructure planning models and mechanically apply standard norms relating to location, space, and acceptable classroom sizes when building schools in diverse agro climatic zones (↑Forbes, 2022; ↑Theunynck, 2009). For example, classrooms in East Africa typically have roofs made from sheet metal that conduct and amplify heat and noise in the rainy season.

Figure 6.1. The typical structure of the rafters and roof in Tanzanian schools

In this context, adapting and climate-proofing the built environment is crucial for bolstering the resilience of schools and mitigating the impact of climate change on education systems, as illustrated in Figure 6.2 below. Adaptation strategies for enhancing the physical infrastructure of schools can involve retrofitting buildings to withstand extreme weather, installing renewable energy systems to decrease dependence on fossil fuels, and implementing water harvesting and conservation techniques to ensure access to clean water (↑Haßler et al., 2024).

For a visual impression of ↑Clegg and Sandeman (2019) is a useful resource.

Figure 6.2. The impact of climate adaptation strategies on learning



6.1. Retrofitting existing schools in low- and middle-income countries

Anecdotal evidence shows that modifications to school buildings can improve the student learning experience. Passive environmental systems use renewable energy sources, like the sun and wind, to illuminate, cool, and ventilate buildings without the need for electric devices. In turn, these systems can create more comfortable, resilient, and energy-efficient buildings (↑Al-Yasiri & Szabó, 2021; Baba et al., 2023).

In Malaysia, for instance, ↑Alwi et al. (2022) demonstrates how passive environmental systems can improve the climate resilience of schools. Passive interventions could include painting the roofs of schools, increasing natural ventilation, extending roof overhangs, and reducing the window-to-wall ratio by 30% (↑Alwi et al., 2022; ↑Baba et al., 2023; ↑Heracleous et al., 2021).

However, there is a lack of research on the impact of infrastructural development on student learning, as well as on implementing improvements in a sustainable and cost-effective manner (↑Haßler et al., 2022). In this context, this section explores emerging evidence on passive retrofitting interventions in low- and middle-income countries.

6.1.1. Temperature control through modified school roofs

In hot climates, heat radiation from the underside of school roofs is a significant factor raising classroom temperatures (↑Haßler et al., 2022). In East Africa, for example, roofs are typically made of corrugated iron sheets that are heated by the sun, which heats up classrooms (↑Clegg & Sandeman, 2019).

Research indicates that painting the exterior of buildings white can reflect solar radiation and reduce indoor temperatures (Androutsopoulos et al., 2017; ↑Parnell, 2021). In Tanzania, for example, ↑Proctor (2022) found that painting roofs of schools white decreased average classroom temperatures by approximately 3.7 °C during the school day, with a maximum reduction of 5 °C. This intervention proved to be almost twice as effective as painting the roofs of schools blue.

Scientists have experimented with mixing white latex paint with barium sulphate, which is a white powder that achieves reflectance levels of around 99%. ↑Knighton & Bugbee (2005) found that this combination achieved a higher level of reflectance. ↑Parnell (2021), however, warns that the extraction and conversion of raw barite ore consumes a significant amount of energy that results in a substantial carbon footprint.

However, ↑MEER (2023) has highlighted the disadvantages of using white paint for cooling purposes. For example, white roof paint can quickly degrade within six months, as high humidity and intense heat limit the durability of paint applications. Moreover, paint contains a substantial amount of toxic organic compounds, which is highly problematic if drinking water is collected from roof. Instead of white paint, ↑MEER (2023) proposes mirror films as an alternative. The reflective film is coated with an abrasion-resistant layer that provides protection against scratches, as well as resistance to extreme weather conditions. ↑MEER (2023) projects that the film can have a lifespan of at least ten years.

Separately, ↑Propst (2019) evaluated the installation of sandwich panel systems, which consist of a thin aluminium sheet installed as a heat barrier between an exposed metal roof and an underside roof. Sandwich panel systems can reduce the temperature of underside roof panels by as much as 28 °C (↑Propst, 2019). Overall, ↑Propst (2019) found that sandwich panel systems reduce indoor temperatures more than either painted or unpainted single-panel metal roofs.

6.1.2. Installing shading devices

↑Hashemi & Khatami (2017) identified solar heat as a principal cause of residential building warming. Direct sunlight on windows can lead to overheating in buildings as glazing functions as a heat trap by allowing short-wave solar radiation to enter and preventing long-wave thermal radiation from escaping (↑Clegg & Sandeman, 2019). Glass types impact the rate of solar heat transmission. In low- and middle-income countries, however, the prohibitive cost of alternative forms of glazing often rules out this solution (↑Hashemi & Khatami, 2017). Where school buildings in sub-Saharan Africa have retained the original window panes, or where new classrooms with window panes are built, shading devices need to be incorporated to stop direct solar radiation from causing overheating (↑Brunoro, 2007; ↑Clegg & Sandeman, 2019; ↑Oughton et al., 2015).

Shading devices can be either internal or external, and either horizontal or vertical. Typically, internal shading devices positioned behind glass windows can only reflect a proportion of solar radiation, with the remainder being absorbed, and re-radiated into the room (↑Dudzińska, 2021). Conversely, external shading devices shield the window from direct solar radiation, reducing heat transfer. External shading devices generally exhibit an efficiency in reducing solar heat gain that surpasses that of internal shading devices by up to 30% (↑Al-Yasiri & Szabó, 2021; ↑Hashemi & Khatami, 2017). As a result, the use of horizontal external shading for windows facing north and south, and the use of vertical shading for windows facing east and west is commonly advised (↑Brunoro, 2007).

Even though external shading is generally more effective, it tends to be more costly than internal shading, which can be a limitation for implementing this solution in low- and middle-income countries (↑Sciurpi, 2014). Moreover, external shading devices alone cannot ensure optimal thermal conditions in schools in tropical climates (↑Hashemi & Khatami, 2017).

An alternative approach to shading classrooms entails either transplanting suitable trees or planting trees that can rapidly grow (Bigueja et al., 2022; ↑Haßler et al., 2022). Trees can also act as windbreaks, which can become a sustainable way of controlling classroom temperature. Before selecting which trees to plant, special consideration should be given to the tree roots and how they grow in order to avoid compromising the building infrastructure.

6.1.3. Improving sound insulation

Some sub-Saharan African schools have installed horizontal ceiling boards to offer further insulation from the heat and the noise of seasonal rains. ↑Tangjuank & Kumfu (2011) suggest the use of 'papyrus mats' to insulate the ceiling may be an an effective form of sound insulation. These mats appear to both insulate the roof and enhance the acoustic quality of the classroom by reducing rain noise; however, there are questions around the durability of the mats (↑Haßler et al., 2022).

Additionally, ↑Propst (2019) suggests that the use of sandwich panel systems (see Section 6.1.1.), with materials such as corrugated roofs, and the addition of a middle flat roofing sheet, such as an aluminium radiant barrier, can further decrease rain noise in indoor enclosures.

6.2. Constructing climate-resilient school buildings

6.2.1. Using environmentally friendly materials in construction

In sub-Saharan Africa, governments typically use standardised designs and similar construction materials to build schools across diverse climates. Here, cement and either fired or burnt bricks are the most common wall materials because of their availability and low cost. However, these bricks are frequently of low quality, and the wood burning methods used for firing the brick kilns have resulted in significant deforestation.

With growing concerns about climate change, governments are investigating more environmentally friendly building materials (↑Nambatya, 2024). For example, the United Nations has endorsed the use Interlocking Stabilised Soil Blocks (ISSBs) as an affordable building material in sub-Saharan Africa (↑UN Habitat, 2020). ISSBs are made with subsoils mixed with cement and sand compressed using specialised machinery (↑Haßler et al., 2022). Importantly, ISSBs are more cost-effective than conventional sandcrete blocks as the mortarless walling system made possible with ISSBs reduces the need for cement, concrete, reinforcement, and other industrial materials (↑Obafemi et al., 2022).

For ISSBs to become fully integrated in the constructions of new schools in Africa, it is essential for promoters to understand local perceptions of ISSB technology and prioritise client education (↑Nambatya, 2015). Enhancing client understanding of ISSBs as a sustainable and cost-effective construction material is crucial to their adoption (↑Nambatya, 2015; ↑Obafemi et al., 2022).

6.2.2. Using green roofing to cool indoor enclosures

A significant amount of heat from the sun enters buildings through the roofs (↑Al-Yasiri & Szabó, 2021). Green roofing is a new approach to reducing heat transmission that involves covering a waterproof membrane on the roof with a layer of grass or plants. ↑Jaffal et al. (2012) demonstrate that green roofing can reduce indoor air temperature by approximately 2 °C. Additional advantages of green roofing include oxygen generation, which enhances the air quality in the immediate vicinity of the structure (↑Al-Yasiri & Szabó, 2021).

While the results are promising, it is important to assess implementation costs in sub-Saharan Africa and whether schools can feasibly apply this technique for cooling roofs.

6.2.3. Improving ventilation in classrooms

Mechanical air conditioning is rarely used in African schools, so classrooms need to be designed to maximise natural ventilation. Here, considerations include local temperature levels, building orientations, and how buildings are used

Natural ventilation contributes to a healthier classroom environment by improving air quality, eliminating odours, ensuring adequate oxygen levels, enhancing thermal comfort, and saving energy when planned and maintained appropriately (↑Clegg & Sandeman, 2019). In the United States, ↑Haverinen-Shaughnessy & Shaughnessy (2015) demonstrated that improvements to ventilation and the regulation of classroom temperature can improve student test scores

Importantly, cross-ventilation demonstrates superior performance in reducing indoor air temperatures than single-sided ventilation.

Openings intended for natural ventilation are most effective when placed at the highest point of buildings (↑Clegg & Sandeman, 2019). In dry and warm climates, wind catchers – or wind towers or wind scoops – use vents or apertures arranged at different heights to capture and direct prevailing winds into the inner areas of a building. Traditional wind catcher designs do not require mechanical fans to deliver fresh, clean air to buildings (↑Al-Yasiri & Szabó, 2021). A natural cooling effect is produced as the wind enters the structure and creates a pressure differential that improves air circulation and reduces interior temperatures.

Modern versions of wind catchers incorporate sensors, dampers, and an automated ceiling ventilator. This system allows adjustments to be made to airflow, humidity, temperature, noise levels, and CO_2 concentrations based on the requirements of a space (↑Saadatian et al., 2012). Moreover, ↑Ahmed et al. (2021) suggest that the integration of wind catchers with water evaporation cooling systems can achieve high ventilation rates and maintain indoor temperatures approximately 8 °C cooler than outdoor temperatures in warm weather conditions (over 35 °C). Lastly, ↑Eso et al. (2022) developed a solar fan-assisted multi-directional wind catcher that can provide a steady and constant reduction in indoor air temperature of up to 2.64 °C over a period of 4–6 hours in tropical locations.

7. Conclusion

Climate change has significantly affected – and will continue to significantly affect – the school built environment and the classroom experience of children. Floods, heat waves, and other extreme weather events have disrupted education service delivery and, in some cases, destroyed schools. Moreover, climate change has led to high temperatures, loud noise, and air pollution in schools which have impacted the comfort and well-being of learners.

In turn, extreme weather and an uncomfortable classroom environment appear to have a negative effect on learning. Many studies have reported that extreme levels of heat, noise, light, and air pollution can impede the cognitive performance of learners and impair student outcomes. Exposure to extreme climatic conditions in the classroom can have a cumulative impact on learning over a long period as well as an immediate, short-day impact on test days.

Importantly, children in low- and middle-income countries will be the most affected by the impacts of climate change. Within these countries, children from low-income households, children with disabilities, and children in remote areas currently have less access to conducive learning environments. In other words, climate change has a disproportionate effect on the education of the most marginalised children in the most marginalised countries.

Emerging evidence indicates that low-cost, passive environmental systems can increase the adaptive capacity of school buildings and improve the classroom experience of students. For example, schools can install micro films on the roofs of existing buildings to reflect solar heat or plant micro forests to expand shade coverage. Meanwhile, governments can explore the use of environmentally friendly materials and wind catchers in new builds. Successful climate adaptation efforts require the involvement of local stakeholders in decision-making processes and the use of vernacular architectural practices to meet the needs of communities.

Despite promising case studies, the literature on climate change adaptation in the education sector – and the literature on the climate resilience of the school built environment in particular – remains sparse (↑Haßler et al., 2024). Further research is required to validate if and how climate change and climate adaptation strategies affect learning and equity in low- and middle-income countries.

8. Bibliography

This bibliography is available digitally in our evidence library at https://docs.opendeved.net/lib/R35VEHID

‘We don’t need air con’: how Burkina Faso builds schools that stay cool in 40C heat. (2024, February 29). *The Guardian*. https://www.theguardian.com/environment/2024/feb/29/we-dont-need-air-con-how-burkina-faso-builds-schools-that-stay-cool-in-40c-heat. (details)

이주영, & 이경회. (1986). 교실온열환경의 쾌적범위설정모델에 관한 연구 (A Study on the Model Setting of Thermal Comfort Zone in Elementary School Classroom). 대한건축학회 학술발표대회 논문집 - 계획계, *6*(1), 279–282. https://www.dbpia.co.kr/Article/NODE00354696. (details)

Abdullah, I. A., Salisu, A. S., & Dahiru, A. (2023). Determining the adaptive thermal comfort and preference votes of children in public primary schools in the hot semi-arid climatic zone of Nigeria. *J. Human Centered Technol*, *2*, 1–10. https://doi.org/10.11113/humentech.v2n2.48. (details)

Ahmad, S. S., Shaari, M. F., Hashim, R., & Kariminia, S. (2015). Conducive Attributes of Physical Learning Environment at Preschool Level for Slow Learners. *Procedia - Social and Behavioral Sciences*, *201*, 110–120. https://doi.org/10.1016/j.sbspro.2015.08.138. Available from https://www.sciencedirect.com/science/article/pii/S1877042815047862. (details)

Ahmed, R. M. (2017). *The Effects of Indoor Temperature and CO2 levels as an Indicator for Ventilation Rates on Cognitive Performance of Adult Female Students in Saudi Arabia* [Doctoral, UCL (University College London)]. https://discovery.ucl.ac.uk/id/eprint/10037938/. (details)

Ahmed, R., Ucci, M., Mumovic, D., & Bagkeris, E. (2022). Effects of thermal sensation and acclimatization on cognitive performance of adult female students in Saudi Arabia using multivariable-multilevel statistical modeling. *Indoor Air*, *32*(2), e13005. https://doi.org/10.1111/ina.13005. (details)

Ahmed, T., Kumar, P., & Mottet, L. (2021). *Natural ventilation in warm climates: the challenges of thermal comfort, heatwave resilience and indoor air quality*. https://doi.org/10.1016/j.rser.2020.110669. Available from https://reader.elsevier.com/reader/sd/pii/S1364032120309539?token=183F81A887E215B2E0392D55D8391088D6FFFFFC723DA136E350C1BD293E6CED1F6F47AE98AF91CD7219F16B1D34C9CD&originRegion=eu-west-1&originCreation=20230320123313. (details)

Al-Yasiri, Q., & Szabó, M. (2021). A short review on passive strategies applied to minimise the building cooling loads in hot locations. *Analecta Technica Szegedinensia*, *15*(2), 20–30. https://doi.org/10.14232/analecta.2021.2.20-30. Available from https://www.analecta.hu/index.php/analecta/article/view/39299. (details)

Albers, B., Shlonsky, A., & Mildon, R. (Eds.). (2020). *Implementation Science 3.0*. Springer. (details)

Allison, C. (2023). *Guidance note on using implementation research in education* (Building Evidence in Education (BE2)). London: Foreign, Commonwealth & Development Office, prepared for Building Evidence in Education (BE2). https://www.edu-links.org/sites/default/files/media/file/Guidance_Note_on_Using_Implementation_Research_in_Education.pdf. (details)

Alwi, N. M., Flor, J.-F., Anuar, N. H. K., Mohamad, J., Hanafi, N. N. H., Muhammad, N. H., Zain, M. H. K. M., & Nasir, M. R. M. (2022). Retrofitting measures for climate resilience: Enhancing the solar performance of Malaysian school buildings with passive design concepts. *IOP Conference Series: Earth and Environmental Science*, *1102*(1), 012014–012014. https://doi.org/10.1088/1755-1315/1102/1/012014. (details)

Amanzadeh, N., Vesal, M., & Ardestani, S. F. F. (2020). The impact of short-term exposure to ambient air pollution on test scores in Iran. *Population and Environment*, *41*(3), 253–285. https://doi.org/10.1007/s11111-019-00335-4. (details)

Ames, H., Kornør, H., Evensen, L. H., Lidal, I. B., Hafstad, E., Hestevik, C. H., Jardim, P. S. J., & Hval, G. (2023). Conducting a systematic review in six weeks – experiences with and evaluation of an intensive team pilot project. *Research Square (Research Square)*. https://doi.org/10.21203/rs.3.rs-3058440/v1. (details)

Ammann, P., Dietler, D., & Winkler, M. S. (2021). Health impact assessment and climate change: A scoping review. *The Journal of Climate Change and Health*, *3*, 100045–100045. https://doi.org/10.1016/j.joclim.2021.100045. (details)

Andrew, O. B. (2017). *Basic Challenges of Climate Change and Implications for Quality Education in Nigeria*. https://www.iiste.org/Journals/index.php/JRDM/article/download/39910/41029. (details)

Androutsopoulos, A. V., Stavrakakis, G. M., & Damasiotis, M. (2017). *Cool roof impacts on a school-building thermal and energy performance in Athens, Greece*. International Conference on Sustainable synergies from buildings to the urban scale. https://doi.org/10.1016/j.proenv.2017.03.103. Available from https://www.sciencedirect.com/science/article/pii/S187802961730107X. (details)

Baba, F. M., Ge, H., Wang, L., & Zmeureanu, R. (2023). Assessing and mitigating overheating risk in existing Canadian school buildings under extreme current and future climates. *Energy and Buildings*, *279*, 112710–112710. https://doi.org/10.1016/j.enbuild.2022.112710. (details)

Baba, F. M., Ge, H., Zmeureanu, R., & Wang, L. (2023). Optimizing overheating, lighting, and heating energy performances in Canadian school for climate change adaptation: Sensitivity analysis and multi-objective optimization methodology. *Building and Environment*, *237*, 110336–110336. https://doi.org/10.1016/j.buildenv.2023.110336. (details)

Baker, L., & Bernstein, H. (2012). *The Impact of School Buildings on Student Health and Performance*. https://vgbc.vn/wp-content/uploads/2019/06/McGrawHill_ImpactOnHealth.pdf. (details)

Balakrishnan, U., & Tsaneva, M. (2021). Air pollution and academic performance: Evidence from India. *World Development*, *146*, 105553–105553. https://doi.org/10.1016/j.worlddev.2021.105553. (details)

Bangay, C. (2023, December 11). *Lots of snakes but where are the ladders? Building environment-smart learning friendly schools responsive to extreme weather.* https://www.globalpartnership.org/blog/lots-snakes-where-are-ladders-building-environment-smart-learning-friendly-schools-responsive. (details)

Barbic, F., Minonzio, M., Cairo, B., Shiffer, D., Cerina, L., Verzeletti, P., Badilini, F., Vaglio, M., Porta, A., Santambrogio, M. D., Gatti, R., Rigo, S., Bisoglio, A., & Furlan, R. (2022). Effects of a cool classroom microclimate on cardiac autonomic control and cognitive performances in undergraduate students. *Science of the Total Environment*, *808*, 152005–152005. https://doi.org/10.1016/j.scitotenv.2021.152005. (details)

Barbic, F., Minonzio, M., Cairo, B., Shiffer, D., DiPasquale, A. G., Cerina, L., Vatteroni, A., Urechie, V., Verzeletti, P., Badilini, F., Vaglio, M., Iatrino, R., Porta, A., Santambrogio, M. D., Gatti, R., & Furlan, R. (2019). Effects of different classroom temperatures on cardiac autonomic control and cognitive performances in undergraduate students. *Physiological Measurement*, *40*(5), 054005–054005. https://doi.org/10.1088/1361-6579/ab1816. (details)

Barrett, P., Davies, F., Zhang, Y., & Barrett, L. (2015). The impact of classroom design on pupils' learning: Final results of a holistic, multi-level analysis. *Building and Environment*, *89*, 118–133. https://doi.org/10.1016/j.buildenv.2015.02.013. Available from https://www.sciencedirect.com/science/article/pii/S0360132315000700. (details)

Bates, M. A., & Glennerster, R. (2017). The Generalizability Puzzle. *Stanford Social Innovation Review*. https://ssir.org/articles/entry/the_generalizability_puzzle. (details)

Bernardi, F., & Keivabu, R. C. (2023). *Poor air at school and educational inequalities by family socioeconomic status*. https://doi.org/10.4054/mpidr-wp-2023-014. (details)

Berrang-Ford, L., Pearce, T., & Ford, J. D. (2015). Systematic review approaches for climate change adaptation research. *Regional Environmental Change*, *15*(5), 755–769. https://doi.org/10.1007/s10113-014-0708-7. Available from http://link.springer.com/10.1007/s10113-014-0708-7. (details)

Berrang-Ford, L., Sietsma, A. J., Callaghan, M., Minx, J. C., Scheelbeek, P. F., Haddaway, N. R., Haines, A., & Dangour, A. D. (2021). Systematic mapping of global research on climate and health: a machine learning review. *The Lancet Planetary Health*, *5*(8), e514–e525. https://doi.org/10.1016/S2542-5196(21)00179-0. Available from https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(21)00179-0/fulltext. (details)

Bigueja, M. C., Tabardillo, R. A., Amoroso, S. E., & Tabardillo, J. D. (2022). *The Effects of Air Temperature to the Cognitive Performance of Grade Five Pupils*. (details)

Blaker, A., & Andrew, B. (2020). *Effects of Classroom Environment on Learning*. 甲南大学マネジメント創造学部HSMR編集委員会. https://doi.org/10.14990/00003653. (details)

Boix-Vilella, S., Saiz-Clar, E., León-Zarceño, E., & Serrano, M. A. (2021). Influence of Air Temperature on School Teachers' Mood and the Perception of Students' Behavior. *Sustainability*, *13*(17), 9707. https://doi.org/10.3390/su13179707. (details)

Brink, H. W., Loomans, M. M., Mobach, M. P., & Kort, H. S. M. (2020). Classrooms' indoor environmental conditions affecting the academic achievement of students and teachers in higher education: A systematic literature review. *Indoor Air*, *31*(2), 405–425. https://doi.org/10.1111/ina.12745. (details)

Brunoro, S. (2007). *Sustainable technologies in the refurbishment of existing building envelopes in Italy*. (details)

Buchari, & Matondang, N. (2017). *The impact of noise level on students' learning performance at state elementary school in Medan*. 040002.

https://doi.org/10.1063/1.4985498. Available from https://pubs.aip.org/aip/acp/article/815290. (details)

C-re-aid. (2021, January 30). School renovations in rural Tanzania with C-re-aid. *Field Study of the World*. https://www.fieldstudyoftheworld.com/school-renovations-in-rural-tanzania-with-c-re-aid/. (details)

Callaghan, M., Minx, J. C., & Forster, P. M. (2020). A topography of climate change research. *Nature Climate Change*, *10*(2), 118–123. https://doi.org/10.1038/s41558-019-0684-5. (details)

Carneiro, J. M., Cole, M. A., & Strobl, E. (2021). The Effects of Air Pollution on Students' Cognitive Performance: Evidence from Brazilian University Entrance Tests. *Journal of the Association of Environmental and Resource Economists*, *8*(6), 1051–1077. https://doi.org/10.1086/714671. (details)

Cartieaux, E., Rzepka, M.-A., & Cuny, D. (2011). Qualité de l'air à l'intérieur des écoles. *Archives de Pédiatrie*, *18*(7), 789–796. https://doi.org/10.1016/j.arcped.2011.04.020. Available from https://linkinghub.elsevier.com/retrieve/pii/S0929693X11001928. (details)

Castro-Martínez, J. (2016). Effects of classroom-acoustic change on the attention level of university students. *Interdisciplinaria*, *33*, 201–214. https://doi.org/10.16888/interd.2016.33.2.1. (details)

Causal loop diagram. (2023). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Causal_loop_diagram&oldid=1192291490. Available from https://en.wikipedia.org/w/index.php?title=Causal_loop_diagram&oldid=1192291490. Available under Creative Commons Attribution-ShareAlike License. (details)

Chalupka, S., & Anderko, L. (2019). Climate Change and Schools: Implications for Children's Health and Safety. *Creative Nursing*, *25*(3), 249–257. https://doi.org/10.1891/1078-4535.25.3.249. (details)

Chartered Institution of Building Services Engineers. (2011). *Lighting for Education*. https://www.cibse.org/knowledge-research/knowledge-portal-search/lighting-guide-05-lighting-for-education-2011. (details)

Chatzidiakou, L., Mumovic, D., & Summerfield, A. J. (2012). What do we know about indoor air quality in school classrooms? A critical review of the literature. *Intelligent Buildings International*, *4*(4), 228–259. https://doi.org/10.1080/17508975.2012.725530. (details)

Chen, X., Zhang, X., & Zhang, X. (2017). *Smog in Our Brains: Gender Differences in the Impact of Exposure to Air Pollution on Cognitive Performance*. https://doi.org/10.2139/ssrn.2940618. (details)

Chevance, G., Minor, K., Vielma, C., Campi, E., O'Callaghan-Gordo, C., Basagaña, X., Ballester, J., & Bernard, P. (2023). A systematic review of ambient heat and sleep in a warming climate. *MedRxiv (Cold Spring Harbor Laboratory)*. https://doi.org/10.1101/2023.03.28.23287841. (details)

Chevance, G., Minor, K., Vielma, C., Campi, E., O'Callaghan-Gordo, C., Basagaña, X., Ballester, J., & Bernard, P. (2024). A systematic review of ambient heat and sleep in a warming climate. *Sleep Medicine Reviews*, 101915–101915. https://doi.org/10.1016/j.smrv.2024.101915. (details)

Cho, H. (2017). The effects of summer heat on academic achievement: A cohort analysis. *Journal of Environmental Economics and Management*, *83*, 185–196. https://doi.org/10.1016/j.jeem.2017.03.005. (details)

Clegg, P., & Sandeman, I. (2019, February 27). A manifesto for climate responsive design. *Proceedings of a Conference on Raising Awareness of Climate Responsive Design in East Africa*. https://fcbstudios.com/practice/explore/manifesto-for-climate-responsive-design/. (details)

Climate Technology Centre & Network. (2018). *Technical market review: country profile: Tanzania*. (details)

Cramer, M. N., Gagnon, D., Laitano, O., & Crandall, C. G. (2022). Human temperature regulation under heat stress in health, disease, and injury. *Physiological Reviews*, *102*(4), 1907–1989. https://doi.org/10.1152/physrev.00047.2021. Available from https://journals.physiology.org/doi/full/10.1152/physrev.00047.2021. (details)

Dapi, L. N., Rocklöv, J., Nguefack-Tsague, G., Tetanye, E., & Kjellstrom, T. (2010). Heat impact on schoolchildren in Cameroon, Africa: potential health threat from climate change. *Global Health Action*, *3*(1), 5610. https://doi.org/10.3402/gha.v3i0.5610. Available from https://www.tandfonline.com/doi/full/10.3402/gha.v3i0.5610. (details)

David, C. C., Monterola, S. L. C., Paguirigan, A. A., Legara, E. F., Tarun, A., Batac, R. C., & Osorio, J. P. (2018). School hazard vulnerability and student learning. *International Journal of Educational Research*, *92*, 20–29. https://doi.org/10.1016/j.ijer.2018.07.005. (details)

Davidson, E. (2024). *Resilience of the higher education sector to future climates: A systematic review of predicted building energy performance and modelling* *approaches*. https://api.elsevier.com/content/abstract/scopus_id/85183777351. (details)

Department of the environment, transport and the regions. (1997). *Energy efficient refurbishment of schools*. https://www.greensuffolk.org/app/uploads/2021/05/Energy-efficient-refurbishment-for-schools.pdf. (details)

Dong, J., Schwartz, Y., Korolija, I., & Mumovic, D. (2023). The impact of climate change on cognitive performance of children in English school stock: A simulation study. *Building and Environment*, *243*, 110607. https://doi.org/10.1016/j.buildenv.2023.110607. Available from https://www.sciencedirect.com/science/article/pii/S0360132323006340. (details)

Dudzińska, A. (2021). Efficiency of Solar Shading Devices to Improve Thermal Comfort in a Sports Hall. *Energies*, *14*(12), 3535. https://doi.org/10.3390/en14123535. Available from https://www.mdpi.com/1996-1073/14/12/3535. (details)

Dupont, L., Bouckaert, F., & Detraux, J. (2023). [The impact of high indoor temperatures on cognitive performance within the work setting: a systematic review]. *Tijdschrift Voor Psychiatrie*, *65*(5), 316–322. (details)

Ecophon. (n.d.). *5 tips to improve school acoustics*. Retrieved March 20, 2023, from https://ecophon.com/uk/articles/knowledge/5-tips-for-a-better-sound-environment-in-schools/. (details)

Education Cannot Wait. (2020). *Stronger Together in Crises*. https://www.educationcannotwait.org/annual-report/pdfs/ECW2019-Annual-Results-Report.pdf. (details)

Eso, O., Darkwa, J., & Calautit, J. (2022). *Integrated Phase Change Material windcatcher system for hybrid cooling and ventilation in tropical building*. World Energy Storage Conference, Istanbul, Turkiye. (details)

Essamlali, I., Nhaila, H., & Khaïli, M. E. (2024). Supervised Machine Learning Approaches for Predicting Key Pollutants and for the Sustainable Enhancement of Urban Air Quality: A Systematic Review. *Sustainability*, *16*(3), 976–976. https://doi.org/10.3390/su16030976. (details)

European Committee for Standardization. (2002). *Light and lighting*. https://www.ageta.lt/app/webroot/files/uploads/filemanager/File/info/EN_12464-1.pdf. (details)

Flores, E. C., Brown, L. J., Kakuma, R., Eaton, J., & Dangour, A. D. (2023). Mental health and wellbeing outcomes of climate change mitigation and adaptation strategies: A systematic review. *Environmental Research Letters*, *19*(1), 014056–014056. https://doi.org/10.1088/1748-9326/ad153f. (details)

Forbes, C. (2022). *Carbon-smart schools mitigate climate change and improve learning*. https://www.globalpartnership.org/blog/carbon-smart-schools-mitigate-climate-change-and-improve-learning. (details)

GADRRRES. (2022). *Comprehensive School Safety Framework 2022-2030: for Child Rights and Resilience in the Education Sector*. https://gadrrres.net/wp-content/uploads/2023/01/CSSF_2022-2030_EN.pdf. (details)

Garg, T., Jagnani, M., & Taraz, V. (2020). Temperature and Human Capital in India. *Journal of the Association of Environmental and Resource Economists*, *7*(6), 1113–1150. https://doi.org/10.1086/710066. (details)

Gilavand, A., & Jamshidnezhad, A. (2016). *The effect of noise in educational institutions on learning and academic Achievement of Elementary Students in Ahvaz, South- West of Iran*. (details)

Gilraine, M., & Zheng, A. (2022). *Air Pollution and Student Performance in the U.S.https://doi.org/10.3386/w30061*. (details)

Goldschagg, P., & Bekker, T. (2021). Effects of Classroom Noise on Learning: Perceptions of Grade 10–12 Girl Learners. *Africa Education Review*, *17*, 1–19. https://doi.org/10.1080/18146627.2021.2004551. (details)

Groppo, V., & Kraehnert, K. (2017). The impact of extreme weather events on education. *Journal of Population Economics*, *30*(2), 433–472. https://doi.org/10.1007/s00148-016-0628-6. (details)

Haßler, B., El-Serafy, Y., Khalayleh, A., & McBurnie, C. (2021n). *Systemic Mixed-Methods Research — a conceptual framework for scalable EdTech research* (Working Paper No. 9). EdTech Hub. https://doi.org/10.53832/edtechhub.0001. Available from https://docs.edtechhub.org/lib/TD2ASC4G. Available under Creative Commons Attribution 4.0 International. (details)

Haßler, B., Eso, O., Villavicencio Peralta, X. A., & Waziri, N. (2024, March 20). *Impact of Climate Change and Environmental Risks on Learning Outcomes*. 22CCEM. https://doi.org/10.53832/opendeved.1079. Available from https://docs.opendeved.net/lib/R8TU4GMW. Available under Creative Commons Attribution 4.0 International. (details)

Haßler, B., Hassan, M., & Klune, C. (2024). *Using AI to Automate Literature Reviews* [Working paper]. EdTech Hub. https://doi.org/10.53832/edtechhub.1003.

Available from https://docs.edtechhub.org/lib/BVD8JX7V. Available under Creative Commons Attribution 4.0 International. (details)

Haßler, B., Villavicencio Peralta, X. A., Macharia, G., Toyinbo, O., Nambatya, M., Mtebe, J., Schaffer, J., Wargocki, P., & Adam, T. (2022). *Improving Learning Through Classroom Experience in East Africa: Temperature, Lighting, and Sound Quality – Inception report* (Improving Learning Through Classroom Experience in East Africa No. 1). Open Development & Education. https://doi.org/10.53832/opendeved.0286. Available from https://docs.opendeved.net/lib/44YQ4VEG. Available under Creative Commons Attribution 4.0. (details)

Haddaway, N. R., Callaghan, M. W., Collins, A. M., Lamb, W. F., Minx, J. C., Thomas, J., & John, D. (2020). On the use of computer-assistance to facilitate systematic mapping. *Campbell Systematic Reviews*, *16*(4), e1129. https://doi.org/10.1002/cl2.1129. Available from https://onlinelibrary.wiley.com/doi/10.1002/cl2.1129. (details)

Harn, B., Parisi, D., & Stoolmiller, M. (2013). Balancing Fidelity with Flexibility and Fit: What Do We Really Know about Fidelity of Implementation in Schools? *Exceptional Children*, *79*(3), 181–193. https://doi.org/10.1177/001440291307900204. (details)

Hashemi, A., & Khatami, N. (2017). *Effects of solar shading on thermal comfort in low-income tropical housing*. *111*, 235–244. https://www.sciencedirect.com/science/article/pii/S1876610217300462. (details)

Haverinen-Shaughnessy, U., & Shaughnessy, R. J. (2015). Effects of Classroom Ventilation Rate and Temperature on Students' Test Scores. *PLOS ONE*, *10*(8), e0136165. https://doi.org/10.1371/journal.pone.0136165. Available from https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0136165. (details)

Heissel, J., Persico, C., & Simon, D. (2019). *Does Pollution Drive Achievement? The Effect of Traffic Pollution on Academic Performance* (Working Paper No. 25489). National Bureau of Economic Research. https://doi.org/10.3386/w25489. Available from https://www.nber.org/papers/w25489. (details)

Heracleous, C., Michael, A., Savvides, A., & Hayles, C. (2021). Climate change resilience of school premises in Cyprus: An examination of retrofit approaches and their implications on thermal and energy performance. *Journal of Building Engineering*, *44*, 103358–103358. https://doi.org/10.1016/j.jobe.2021.103358. (details)

Heschong, L. (1999). *Daylighting in Schools An Investigation into the Relationship Between Daylighting and Human Performance Condensed Report.* https://doi.org/10.13140/RG.2.2.31498.31683. (details)

Hoque, S., & Weil, B. (2016). The relationship between comfort perceptions and academic performance in university classroom buildings. *Journal of Green Building*, *11*, 108–117. https://doi.org/10.3992/jgb.11.1.108.1. (details)

Hyndman, B., & Button, B. (2024). The influences of extreme cold and storms on schoolchildren. In B. Hyndman & J. Vanos (Eds.), *The Impact of Extreme Weather on School Education* (pp. 60–77). Routledge. https://doi.org/10.4324/9781003103165-4. Available from http://www.scopus.com/inward/record.url?scp=85164027477&partnerID=8YFLogxK. (details)

Ibhadode, O., Ajayi, O. O., Abioye, A. A., Ismaila, J., & Adekunle, A. A. (2019). An evaluation of classroom-illumination: a critical requirement for effective designing and construction of naturally-illuminated schools in Nigeria. *Progress in Industrial Ecology, an International Journal*, *13*(4), 342–372. (details)

Internal Displacement Monitoring Centre. (2020). *The impacts of internal displacement on education in sub-Saharan Africa.* https://www.internal-displacement.org/publications/the-impacts-of-internal-displacement-on-education-in-sub-saharan-africa. (details)

Ismail, N., & Karim, K. (n.d.). *Noise Levels in Malaysia Primary Schools: Are We Meeting the International Standards?* 11. (details)

JICA. (2001). *Japanese project in Tanzania.* https://openjicareport.jica.go.jp/pdf/11665700_03.PDF. (details)

Jaffal, I., Ouldboukhitine, S.-E., & Belarbi, R. (2012). A comprehensive study of the impact of green roofs on building energy performance. *Renewable Energy*, *43*, 157–164. https://doi.org/10.1016/j.renene.2011.12.004. Available from https://www.sciencedirect.com/science/article/pii/S0960148111006604. (details)

Kükrer, E., & Eskin, N. (2021). Effect of design and operational strategies on thermal comfort and productivity in a multipurpose school building. *Journal of Building Engineering*, *44*, 102697. https://doi.org/10.1016/j.jobe.2021.102697. (details)

Küller, R., & Lindsten, C. (1992). Health and behavior of children in classrooms with and without windows. *Journal of Environmental Psychology*, *12*(4), 305–317. https://doi.org/10.1016/S0272-4944(05)80079-9. Available from https://www.sciencedirect.com/science/article/pii/S0272494405800799. (details)

Kalisa, E., Kuuire, V., & Adams, M. (2023). Children's exposure to indoor and outdoor black carbon and particulate matter air pollution at school in Rwanda, Central-East Africa. *Environmental Advances*, *11*, 100334. https://doi.org/10.1016/j.envadv.2022.100334. Available from https://www.sciencedirect.com/science/article/pii/S2666765722001697. (details)

Keevill, K. (2023, April 27). Planting seeds of change: the Tanzanian students and teachers taking climate action into their own hands. *Aga Khan Foundation UK*. https://www.akf.org.uk/planting-seeds-of-change-the-tanzanian-students-and-teachers-taking-climate-action-into-their-own-hands/. (details)

Klatte, M., Bergström, K., & Lachmann, T. (2013). Does noise affect learning? A short review on noise effects on cognitive performance in children. *Frontiers in Psychology*, *4*, 578. https://doi.org/10.3389/fpsyg.2013.00578. Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3757288/. (details)

Knighton, N., & Bugbee, B. (2005). *A Mixture of Barium Sulfate and White Paint is a Low-Cost Substitute Reflectance Standard for Spectralon®*. (details)

Koch, M., Matzke, I., Huhn, S., Gunga, H., Maggioni, M. A., Munga, S., Obor, D., Sié, A., Boudo, V., Bunker, A., Dambach, P., Bärnighausen, T., & Barteit, S. (2022). Wearables for Measuring Health Effects of Climate Change–Induced Weather Extremes: Scoping Review. *Jmir Mhealth and Uhealth*, *10*(9), e39532–e39532. https://doi.org/10.2196/39532. (details)

Kok, H., Mobach, M., & Omta, O. (2015). Predictors of study success from a teacher's perspective of the quality of the built environment. *Management in Education*, *29*(2), 53–62. https://doi.org/10.1177/0892020614553719. (details)

Korir, J. (2021). Effect of Climate Change on Acquisition of Quality Education: A Case Study of Maasai Pastoralists in Narok County, Kenya. *Advances in Social Sciences Research Journal*, *8*(12), 81–92. https://doi.org/10.14738/assrj.812.11314. (details)

Kousky, C. (2016). Impacts of Natural Disasters on Children. *The Future of Children*, *26*(1), 73–92. https://doi.org/10.1353/foc.2016.0004. Available from https://muse.jhu.edu/pub/31/article/641235. (details)

Lahn, B., & Lahn, B. (2021). Changing climate change: The carbon budget and the modifying-work of the IPCC. *Social Studies of Science*, *51*(1), 3–27. https://doi.org/10.1177/0306312720941933. Available from http://journals.sagepub.com/doi/10.1177/0306312720941933. (details)

Lavy, V., Ebenstein, A., & Roth, S. (2014). *The Impact of Short Term Exposure to Ambient Air Pollution on Cognitive Performance and Human Capital Formation*. https://doi.org/10.3386/w20648. (details)

Lecumberri, M. L. G., Cooke, M., & Cutler, A. (2010). Non-native speech perception in adverse conditions: A review. *Speech Communication*, *52*(11), 864–886. https://doi.org/10.1016/j.specom.2010.08.014. Available from https://www.sciencedirect.com/science/article/pii/S0167639310001482. (details)

Levandoski, G., & Zannin, P. H. T. (2022). Quality of life and acoustic comfort in educational environments of curitiba, Brazil. *Journal of Voice*, *36*(3), 436.e9-436.e16. https://doi.org/10.1016/j.jvoice.2020.05.030. Available from https://www.sciencedirect.com/science/article/pii/S0892199720302009. (details)

Likuru, L., & Mwila, P. (2022). Overcrowded Classrooms: Effect on Teaching and Learning Process in Public Secondary Schools in Ilemela Municipality, Tanzania. *Asian Journal of Education and Social Studies*, 75–87. https://doi.org/10.9734/ajess/2022/v30i230744. (details)

Ludwig, J., Kling, J. R., & Mullainathan, S. (2011). Mechanism Experiments and Policy Evaluations. *Journal of Economic Perspectives*, *25*(3), 17–38. https://doi.org/10.1257/jep.25.3.17. Available from https://www.aeaweb.org/articles?id=10.1257/jep.25.3.17. (details)

Lurvink, A.-F., Bangura, Z., Fortune, A., George, A. H., Godwin, K., Mason-Sesay, M., Moseray, D., Tholley, I., Turay, E. B., & Haßler, B. (2022). *No Teacher is an Island: A case study on the enablers and barriers for effective school-based teacher professional development in Sierra Leone*. OpenDevEd. https://doi.org/10.53832/opendeved.0284. Available from https://docs.opendeved.net/lib/N665IBBE. Available under Creative Commons Attribution 4.0 International. (details)

Luyten, A., Winkler, M. S., Ammann, P., & Dietler, D. (2023). Health impact studies of climate change adaptation and mitigation measures – A scoping review. *The Journal of Climate Change and Health*, *9*, 100186–100186. https://doi.org/10.1016/j.joclim.2022.100186. (details)

MEER. (2023). *Heat adaptation proposal*. (details)

MOEST. (2020). *Pre-primary and primary teacher deployment strategy 2019-2021*. https://planipolis.iiep.unesco.org/sites/default/files/ressources/tanzania_ur_pre-primary_and_primary_teacher_deployment_strategy_2019-2021_2020_eng.pdf. (details)

MOF. (2022). *Government budget for 2022-2023*. https://www.mof.go.tz/uploads/documents/en-1676533687-SPEECH%20OF%20GOVERNMENT%20BUDGET%20FOR%202022-23.pdf. (details)

Machol, D. (2024, March 17). South Sudan shutters all schools as it prepares for an extreme heat wave. *AP News*. https://apnews.com/article/south-sudan-schools-closed-heat-wave-b52d535e3ee7284b2832c0cfd14b1167. (details)

Magero, C. V., Nyamari, J., & Mutisya, R. (2023). Visual Comfort and Discomfort in public boarding secondary Schools in Nairobi City County, Kenya. *East African Journal of Health and Science*, *6*(1), 62–84. https://doi.org/10.37284/eajhs.6.1.1123. Available from https://journals.eanso.org/index.php/eajhs/article/view/1123. (details)

Marcotte, D. E. (2017). Something in the air? Air quality and children's educational outcomes. *Economics of Education Review*, *56*, 141–151. https://doi.org/10.1016/j.econedurev.2016.12.003. Available from https://www.sciencedirect.com/science/article/pii/S0272775716303703. (details)

Mendell, M. J., & Heath, G. A. (2005). Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature. *Indoor Air*, *15*(1), 27–52. https://doi.org/10.1111/j.1600-0668.2004.00320.x. (details)

Miller, S., & Vela, M. (2013). The Effects of Air Pollution on Educational Outcomes: Evidence from Chile. *Social Science Research Network*. https://doi.org/10.2139/ssrn.2370257. (details)

Ministry of Foreign Affairs and East African Cooperation. (2018). *Tanzania Country Profile*. https://www.foreign.go.tz/tanzania/category/country-profile. (details)

Mpanza, C. T., & Muluka, W. (2023). The Impact of Climate Change on Quality Education Delivery: A Case Study of Four Selected Secondary Schools in Kabwe District, Zambia. *International Journal of Research and Innovation in Social Science*, *VII*(V), 1588–1594. https://doi.org/10.47772/ijriss.2023.70621. (details)

Munonye, C., Ngobili, M., Umeora, C., Oluchi, I., Maduka, N., & Onwuzuligbo, C. (2023). Comparative Analysis of Comfort Temperature of School Children and Their Teachers. *Research & Development*, *4*(1), 27–39. https://doi.org/10.11648/j.rd.20230401.15. Available from https://www.sciencepg.com/article/10.11648/j.rd.20230401.15. (details)

Mustapha, T. D., Hassan, A. S., Nasir, M. H. A., & Onubi, H. O. (2022). An investigation of thermal comfort in classrooms in the tropical Savanna climate. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, *29*(1), 62–75. https://doi.org/10.37934/araset.29.1.6275. Available from https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/article/view/1372. (details)

Mustapha, T., Hassan, A., Abdul Nasir, M., & Onubi, H. (2022). An Investigation of Thermal Comfort in Classrooms in the Tropical Savanna Climate. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, *29*, 62–75. https://doi.org/10.37934/araset.29.1.6275. (details)

NTV UGANDA [@ntvuganda]. (2024, March 17). *UPDATE: The government of the republic of South Sudan has ordered the closure of all schools starting from Monday, 18th, March 2024 due to the high temperatures. According to the country's health ministry, there are reported cases of death resulting from high heat #NTVNews https://t.co/8s6Vr71yK1* [Tweet]. Twitter. https://twitter.com/ntvuganda/status/1769339136484184441. (details)

Nambatya, M. (2024). School Buildings Infrastructure in East Africa. *Google Docs*. https://docs.google.com/document/d/1ebhajT8jxDxzt_q6mEjdLf4cWpBvdhkfpWo5DGfNcHs/edit?usp=gmail&ts=664fae17&usp_dm=false&usp=embed_facebook. Available from https://docs.google.com/document/d/1ebhajT8jxDxzt_q6mEjdLf4cWpBvdhkfpWo5DGfNcHs/edit?usp=gmail&ts=664fae17&usp_dm=false&usp=embed_facebook. (details)

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* [MPhil in Engineering for Sustainable Development]. University of Cambridge. (details)

National Bureau of Statistics. (2020). *National climate change report*. https://www.nbs.go.tz/nbs/takwimu/Environment/National_%20Climate_Change_Report_2019.pdf. (details)

National Renewable Energy Laboratory. (2002). *Energy design guidelines for high performance schools - cold and dry climates*. https://www.nrel.gov/docs/fy02osti/29104.pdf. (details)

Ncongwane, K. P., Botai, J. O., Sivakumar, V., & Botai, C. M. (2021). A Literature Review of the Impacts of Heat Stress on Human Health across Africa. *Sustainability*, *13*(9), 5312. https://doi.org/10.3390/su13095312. (details)

Obafemi, A. I., Oluwole, A., & Oladipupo, D.-A. (2022). *Comparative cost advantages of Interlocking Stabilised Soil Blocks and Sandcrete Blocks for building construction in South-West Nigeria*. *5*(5). (details)

Oladimeji, K. E., Zungu, L., Chocko, R., Hyera, F. L. M., Nyatela, A., Gumede, S., Dwarka, D., & Lalla-Edward, S. T. (2023). A Rapid Review of Impact Assessment of Climate Change on Health and Mental Well-Being in Africa. *New Voices in Psychology*, *13*. https://doi.org/10.25159/2958-3918/15604. (details)

Ortsa, M. G., & Ndidiamaka, A. J. (2021). Climate Change and Teacher's Performance in Secondary School in Benue State Nigeria. *International Journal of Educational Management and Innovation*, *2*(3), 298. https://doi.org/10.12928/ijemi.v2i3.4106. (details)

Oughton, D., Hodkinson, S., & Brailsford, R. (2015). *Faber & Kell's Heating and Air-Conditioning of Buildings* (11th ed.). Routledge. https://doi.org/10.4324/9780203121290. (details)

Palmeiro-Silva, Y. K., Lescano, A. G., Flores, E. C., E, Y. A., Rojas, L., Chavez-Hermosilla, M., Mora-Rivera, W., & Hartinger, S. M. (2023). Identifying gaps on health impacts, exposures, and vulnerabilities to climate change on human health and wellbeing in South America: a scoping review. *The Lancet Regional Health - Americas*, *26*, 100580–100580. https://doi.org/10.1016/j.lana.2023.100580. (details)

Palutikof, J., Boulter, S., Field, C. B., Mach, K. J., Manning, M., Mastrandrea, M. D., Meyer, L. M., Minx, J., Pereira, J. J., Plattner, G., Ribeiro, S. K., Sokona, Y., Stadler, F., & Swart, R. (2023). Enhancing the review process in global environmental assessments: The case of the IPCC. *Environmental Science & Policy*, *139*, 118–129. https://doi.org/10.1016/j.envsci.2022.10.012. (details)

Park, R. J. (2022). Hot Temperature and High-Stakes Performance. ˜ *The* œ*Journal of Human Resources/*˜ *The* œ*journal of Human Resources*, *57*(2), 400–434. https://doi.org/10.3368/jhr.57.2.0618-9535r3. (details)

Park, R. J., Behrer, A. P., & Goodman, J. (2020). Learning is inhibited by heat exposure, both internationally and within the United States. *Nature Human Behaviour*, *5*(1), 19–27. https://doi.org/10.1038/s41562-020-00959-9. Available from https://www.nature.com/articles/s41562-020-00959-9. (details)

Parnell, A. (2021, June 7). *Cooling buildings by nearly 5oC possible thanks to new whiter-than-white paint*. The Conversation. http://theconversation.com/cooling-buildings-by-nearly-5-c-possible-thanks-to-new-whiter-than-white-paint-160665. (details)

Pawson, R., Greenhalgh, T., Harvey, G., & Walshe, K. (2005). Realist review – a new method of systematic review designed for complex policy interventions. *Journal of Health Services Research & Policy*, *10 Suppl 1*, 21–34. https://doi.org/10.1258/1355819054308530. (details)

Perisco, C. (2019). How exposure to pollution affects educational outcomes and inequality. *Brookings*. https://www.brookings.edu/articles/how-exposure-to-pollution-affects-educational-outcomes-and-inequality/. (details)

Persico, C. L., & Venator, J. (2019). The Effects of Local Industrial Pollution on Students and Schools. *Journal of Human Resources.* https://doi.org/10.3368/jhr.56.2.0518-9511R2. Available from https://jhr.uwpress.org/content/early/2019/08/02/jhr.56.2.0518-9511R2. (details)

Persinger, M. A., Tiller, S. G., & Koren, S. A. (1999). Background sound pressure fluctuations (5 DB) from overhead ventilation systems increase subjective fatigue of university students during three-hour lectures. *Perceptual and Motor Skills*, *88*(2), 451–456. https://doi.org/10.2466/pms.1999.88.2.451. (details)

Phalkey, R., Aranda-Jan, C. B., Marx, S., Höfle, B., & Sauerborn, R. (2015). Systematic review of current efforts to quantify the impacts of climate change on undernutrition. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(33). https://doi.org/10.1073/pnas.1409769112. (details)

Porras-Salazar, J. A., Wyon, D. P., Piderit-Moreno, B., Contreras-Espinoza, S., & Wargocki, P. (2018). Reducing classroom temperature in a tropical climate improved the thermal comfort and the performance of elementary school pupils. *Indoor Air*, *28*(6), 892–904. https://doi.org/10.1111/ina.12501. Available from https://onlinelibrary.wiley.com/doi/10.1111/ina.12501. (details)

Proctor, J. (2022). *Should we paint all classroom roofs white to improve learning in Tanzania?https://doi.org/10.53832/edtechhub.0122.* Available from https://docs.edtechhub.org/lib/Z8B66R9X. (details)

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. (details)

Pujol, S., Levain, J.-P., Houot, H., Petit, R., Berthillier, M., Defrance, J., Lardiès, J., Masselot, C., & Mauny, F. (2013). Association between Ambient Noise Exposure and School Performance of Children Living in An Urban Area: A Cross-Sectional Population-Based Study. *Journal of Urban Health*, *91*(2), 256–271. https://doi.org/10.1007/s11524-013-9843-6. (details)

Pule, V., Mathee, A., Melariri, P., Kapwata, T., Abdelatif, N., Balakrishna, Y., Kunene, Z., Mogotsi, M., Wernecke, B., & Wright, C. (2021). Classroom Temperature and Learner Absenteeism in Public Primary Schools in the Eastern Cape, South Africa. *International Journal of Environmental Research and Public Health*, *18*, 10700. https://doi.org/10.3390/ijerph182010700. (details)

Ragpala, E. (2021). Environmental Factors that Affect the Academic Performance of Senior High School Students during COVID-19 Pandemic. *International Journal of Social Sciences: Current and Future Research Trends*, *11*(1), 1–19. (details)

Rance, G., Dowell, R. C., & Tomlin, D. (2023). The effect of classroom environment on literacy development. *Npj Science of Learning*, *8*(1), 1–10. https://doi.org/10.1038/s41539-023-00157-y. Available from https://www.nature.com/articles/s41539-023-00157-y. (details)

Roach, T., & Whitney, J. (2021). Heat and learning in elementary and middle school. *Education Economics*, *30*(1), 29–46. https://doi.org/10.1080/09645292.2021.1931815. (details)

Rogers, C. L., Lister, J. J., Febo, D. M., Besing, J. M., & Abrams, H. B. (2006). Effects of bilingualism, noise, and reverberation on speech perception by listeners with normal hearing. *Applied Psycholinguistics*, *27*(3), 465–485. https://doi.org/10.1017/S014271640606036X. Available from https://www.cambridge.org/core/journals/applied-psycholinguistics/article/abs/effects-of-bilingualism-noise-and-reverberation-on-speech-perception-by-listeners-with-normal-hearing/884F052D4A8D4672ACB3F492107DA2B1. (details)

Saadatian, O., Haw, L. C., Sopian, K., & Sulaiman, M. Y. (2012). Review of windcatcher technologies. *Renewable and Sustainable Energy Reviews*, *16*(3), 1477–1495. https://doi.org/10.1016/j.rser.2011.11.037. Available from https://ideas.repec.org//a/eee/rensus/v16y2012i3p1477-1495.html. (details)

Sadrizadeh, S., Yao, R., Yuan, F., Awbi, H., Bahnfleth, W., Bi, Y., Cao, G., Croitoru, C., De Dear, R., Haghighat, F., Kumar, P., Malayeri, M., Nasiri, F., Ruud, M., Sadeghian, P., Wargocki, P., Xiong, J., Yu, W., & Li, B. (2022). Indoor air quality and health in schools: A critical review for developing the roadmap for the future school environment. *Journal of Building Engineering*, *57*, 104908. https://doi.org/10.1016/j.jobe.2022.104908. Available from https://linkinghub.elsevier.com/retrieve/pii/S2352710222009202. Available under Creative Commons: Attribution 4.0 (CC-BY). (details)

Sarbu, I., & Pacurar, C. (2015). Experimental and numerical research to assess indoor environment quality and schoolwork performance in university classrooms. *Building and Environment*, *93*, 141–154. https://doi.org/10.1016/j.buildenv.2015.06.022. Available from https://www.sciencedirect.com/science/article/pii/S0360132315300366. (details)

Sciurpi, F. (2014). Transparent Building Envelope: Windows and Shading Devices Typologies for Energy Efficiency Refurbishments. *Green Energy and Technology*. https://www.academia.edu/113570945/Transparent_Building_Envelope_Windows_and_Shading_Devices_Typologies_for_Energy_Efficiency_Refurbishments. (details)

Sharples, J., Albers, B., Fraser, S., & Kime, S. (2019). *Putting Evidence to Work: A School's Guide to Implementation.* https://d2tic4wvo1iusb.cloudfront.net/eef-guidance-reports/implementation/EEF-Active-Ingredients-Summary.pdf?v=1635355218. Available from https://d2tic4wvo1iusb.cloudfront.net/eef-guidance-reports/implementation/EEF-Active-Ingredients-Summary.pdf?v=1635355218. (details)

Sheffield, P. E., Uijttewaal, S. A., Stewart, J., & Galvez, M. P. (2017). Climate change and schools: Environmental hazards and resiliency. *International Journal of Environmental Research and Public Health/International Journal of Environmental Research and Public Health*, *14*(11), 1397. https://doi.org/10.3390/ijerph14111397. Available from https://www.mdpi.com/1660-4601/14/11/1397. (details)

Siddiqui, A. (2018). *Investigating the dilemma of noise within over-crowded classroom of a public sector school Hyderabad, Pakistan.* (details)

Simmons, S. E., Saxby, B. K., McGlone, F., & Jones, D. A. (2008). The effect of passive heating and head cooling on perception, cardiovascular function and cognitive performance in the heat. *European Journal of Applied Physiology*, *104*(2), 271–280. https://doi.org/10.1007/s00421-008-0677-y. (details)

Sims, K. (2021). *Education, Girls' Education and Climate Change* [K4D Emerging Issues Report 29.]. Institute of Development Studies. https://doi.org/10.19088/K4D.2021.044. Available from https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/16523. (details)

Sims, S., Fletcher-Wood, H., O'Mara, A., Cottingham, S., Stansfield, C., Herwegen, J. V., & Anders, J. (2021). *What are the Characteristics of Effective Teacher Professional Development? A Systematic Review and Meta-analysis.* (details)

Singh, M. K., Ooka, R., Rijal, H. B., Kumar, S., Kumar, A., & Mahapatra, S. (2019). Progress in thermal comfort studies in classrooms over last 50 years and way forward. *Energy and Buildings*, *188–189*, 149–174. https://doi.org/10.1016/j.enbuild.2019.01.051. (details)

Sleegers, P. J., Moolenaar, N. M., Galetzka, M., Pruyn, A., Sarroukh, B. E., & van der Zande, B. (2013). Lighting affects students' concentration positively: Findings from three Dutch studies. *Lighting Research & Technology*, *45*(2), 159–175. https://doi.org/10.1177/1477153512446099. (details)

South Sudan announces schools closure as heatwave deepens. (2024, March 17). *Sudan Tribune.* https://sudantribune.com/article283392/. (details)

Souza, E. (2021, May 31). *Poorly designed acoustics in schools affect learning efficiency and well-being.* ArchDaily.

https://www.archdaily.com/924091/poorly-designed-acoustics-in-schools-affect-learning-efficiency-and-well-being. (details)

Stenson, C., Wheeler, A. J., Carver, A., Donaire-Gonzalez, D., Alvarado-Molina, M., Nieuwenhuijsen, M., & Tham, R. (2021). The impact of Traffic-Related air pollution on child and adolescent academic Performance: A systematic review. *Environment International*, *155*, 106696. https://doi.org/10.1016/j.envint.2021.106696. (details)

Stott, P. (2016). How climate change affects extreme weather events. *Science*, *352*(6293), 1517–1518. https://doi.org/10.1126/science.aaf7271. Available from https://www.science.org/doi/10.1126/science.aaf7271. (details)

TMA. (2019). *Climate statement 2019*. https://www.meteo.go.tz/uploads/publications/sw1586868749-Climate_statement_2019.pdf. (details)

TMA. (2022). *Tanzania Climate Statetement 2022*. https://www.meteo.go.tz/uploads/publications/sw1680520682-Tanzania%20Climate%20Statetement%202022.pdf. (details)

Tangjuank, S., & Kumfu, S. (2011). Particle Boards from Papyrus Fibers as Thermal Insulation. *Journal of Applied Sciences*, *11*(14), 2640–2645. https://doi.org/10.3923/jas.2011.2640.2645. Available from https://www.scialert.net/abstract/?doi=jas.2011.2640.2645. (details)

Tasgaonkar, P., Zade, D., Ehsan, S., Gorti, G., Mamnun, N., Siderius, C., & Singh, T. (2022). Indoor heat measurement data from low-income households in rural and urban South Asia. *Scientific Data*, *9*(1), 285. https://doi.org/10.1038/s41597-022-01314-5. Available from https://www.nature.com/articles/s41597-022-01314-5. (details)

Tham, S., Thompson, R., Landeg, O., Murray, K. A., & Waite, T. (2020). Indoor temperature and health: a global systematic review. *Public Health*, *179*, 9–17. https://doi.org/10.1016/j.puhe.2019.09.005. (details)

The Rafiki Village Project. (2017). *The Rafiki Village Project*. The Rafiki Village Project. https://www.rafikivillageproject.org/2021.html. (details)

The society of light and lighting. (2011). *Lighting Guide 05: Lighting for education (2011) | CIBSE*. https://www.cibse.org/knowledge-research/knowledge-portal-search/lighting-guide-05-lighting-for-education-2011. (details)

Theunynck, S. (2009). *School Construction Strategies for Universal Primary Education in Africa: Should Communities Be Empowered to Build Their Schools?* The World

Bank. https://doi.org/10.1596/973-0-8213-7720-8. Available from http://elibrary.worldbank.org/doi/book/10.1596/973-0-8213-7720-8. (details)

Toftum, J., Andersen, R., Prado, J. J. A., Kolstrup, K., Hauberg, D. S., & Clausen, G. (2021). Development of a tool to predict the socio-economic consequences of better air quality and temperature control in classrooms. *Energy and Buildings*, *250*, 111274. https://doi.org/10.1016/j.enbuild.2021.111274. (details)

Toyinbo, O., Phipatanakul, W., Shaughnessy, R., & Haverinen-Shaughnessy, U. (2019). Building and indoor environmental quality assessment of Nigerian primary schools: A pilot study. *Indoor Air*, *29*(3), 510–520. https://doi.org/10.1111/ina.12547. Available from https://onlinelibrary.wiley.com/doi/abs/10.1111/ina.12547. (details)

UN Habitat. (2020). *Interlocking Stabilised Soil Blocks (ISSB): The Eco-friendly Building Material*. https://unhabitat.org/sites/default/files/2020/07/gh077e.pdf. (details)

UNICEF. (2021). *One billion children at 'extremely high risk' of the impacts of the climate crisis*. https://www.unicef.org/press-releases/one-billion-children-extremely-high-risk-impacts-climate-crisis-unicef. (details)

Van Der Walt, R. E., Grobbelaar, S. S., & Booysen, M. J. (2024). 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. *Data in Brief*, *53*, 110045. https://doi.org/10.1016/j.dib.2024.110045. Available from https://linkinghub.elsevier.com/retrieve/pii/S2352340924000192. (details)

Venegas Marin, S., Schwarz, L., & Sabarwal, S. (2024). *The Impact of Climate Change on Education*. https://openknowledge.worldbank.org/entities/publication/761bcf7b-4bb6-4fea-b75b-146603d437bb. (details)

Venegas Marin, S., Schwarz, L., & Sabarwal, S. (2024). Impacts of Extreme Weather Events on Education Outcomes: A Review of Evidence. *The World Bank Research Observer*, lkae001. https://doi.org/10.1093/wbro/lkae001. (details)

Vu, T. M. (2022). Effects of Heat on Mathematics Test Performance in Vietnam. *Asian Economic Journal*, *36*(1), 72–94. https://doi.org/10.1111/asej.12259. (details)

Wang, M.-T., & Degol, J. L. (2016). School Climate: a Review of the Construct, Measurement, and Impact on Student Outcomes. *Educational Psychology Review*, *28*(2), 315–352. https://doi.org/10.1007/s10648-015-9319-1. (details)

Wargocki, P. (2022). Effects of Classroom Air Quality on Learning in Schools. In Y. Zhang, P. K. Hopke, & C. Mandin (Eds.), *Handbook of Indoor Air Quality* (pp. 1447–1459). Springer Nature. https://doi.org/10.1007/978-981-16-7680-2_65. (details)

Wargocki, P., & Wyon, D. P. (2017). Ten questions concerning thermal and indoor air quality effects on the performance of office work and schoolwork. *Building and Environment*, *112*, 359–366. https://doi.org/10.1016/j.buildenv.2016.11.020. Available from https://www.sciencedirect.com/science/article/pii/S0360132316304449. (details)

Wargocki, P., Porras-Salazar, J. A., & Contreras-Espinoza, S. (2019). The relationship between classroom temperature and children's performance in school. *Building and Environment*, *157*, 197–204. https://doi.org/10.1016/j.buildenv.2019.04.046. Available from https://www.sciencedirect.com/science/article/pii/S0360132319302987. (details)

World Bank. (2016). *Malawi Drought Post Disaster Needs Assessment (PDNA).* https://documents1.worldbank.org/curated/en/640011479881661626/pdf/110423-WP-PDNAMalawispreadsFINAL-PUBLIC.pdf. (details)

World Bank. (n.d.). *Securing a Future with Safer Schools: Building Resilience in Pacific Schools* [Text/HTML]. Retrieved June 7, 2024, from https://www.worldbank.org/en/news/feature/2022/05/30/securing-a-future-with-safer-schools-building-resilience-in-pacific-schools. (details)

World Health Organization. (2010). *Noise.* https://www.who.int/europe/news-room/fact-sheets/item/noise. (details)

Xiao, Y., & Watson, M. (2017). Guidance on Conducting a Systematic Literature Review. *Journal of Planning Education and Research*, *39*, 0739456X1772397. https://doi.org/10.1177/0739456x17723971. Available from https://doi.org/10.1177/0739456X17723971. (details)

Xiong, L., Huang, X., Li, J., Mao, P., Wang, X., Wang, R., & Tang, M. (2018). Impact of Indoor Physical Environment on Learning Efficiency in Different Types of Tasks: A 3 × 4 × 3 Full Factorial Design Analysis. *International Journal of Environmental Research and Public Health*, *15*(6), 1256. https://doi.org/10.3390/ijerph15061256. (details)

Yang, W., & Moon, H. J. (2019). Combined effects of acoustic, thermal, and illumination conditions on the comfort of discrete senses and overall indoor environment. *Building and Environment*, *148*, 623–633. https://doi.org/10.1016/j.buildenv.2018.11.040. (details)

Yeganeh, A. J., Reichard, G., McCoy, A. P., Bulbul, T., & Jazizadeh, F. (2018). Correlation of ambient air temperature and cognitive performance: A systematic review and meta-analysis. *Building and Environment*, *143*, 701–716. https://doi.org/10.1016/j.buildenv.2018.07.002. Available from https://www.sciencedirect.com/science/article/pii/S0360132318304104. (details)

Zhang, X., Chen, X., & Zhang, X. (2018). The impact of exposure to air pollution on cognitive performance. *Proceedings of the National Academy of Sciences of the United States of America*, *115*(37), 9193–9197. https://doi.org/10.1073/pnas.1809474115. (details)

Zhang, X., Chen, X., & Zhang, X. (2024). Temperature and Low-Stakes Cognitive Performance. *Journal of the Association of Environmental and Resource Economists*, *11*(1), 75–96. https://doi.org/10.1086/726007. (details)

Zivin, J. G., & Shrader, J. (2016). Temperature Extremes, Health, and Human Capital. *Future of Children/˜ The œFuture of Children*, *26*(1), 31–50. https://doi.org/10.1353/foc.2016.0002. (details)

Zivin, J. G., Song, Y., Tang, Q., & Zhang, P. (2020). Temperature and high-stakes cognitive performance: Evidence from the national college entrance examination in China. *Journal of Environmental Economics and Management*, *104*, 102365–102365. https://doi.org/10.1016/j.jeem.2020.102365. (details)

te Kulve, M., Hellwig, R. T., van Dijken, F., & Boerstra, A. (2020). What about children? Implications from their subjective perception and the risk of overheating in schools. *Windsor Conference 2020: Resilient Comfort*, 216–223. (details)

van Reenen, C., & Karusseit, C. (2017). Classroom acoustics as a consideration for inclusive education in South Africa. *The South African Journal of Communication Disorders*, *64*(1), 550. https://doi.org/10.4102/sajcd.v64i1.550. Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5843241/. (details)