



**Air\_Sun + Climate**

Power for Innovation

## AIR QUALITY

Introduction of Air Quality into Climate Education

**Erasmus+**

Enriching lives, opening minds.

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## 1. Introduction of Air Quality in Climate Education

Climate change education has evolved significantly in recent years, driven by the urgency of the global climate crisis and the need for innovative, interdisciplinary learning approaches. Modern curricula around the world not only aim to build scientific literacy but also empower learners to become active contributors to climate action. This evolution is reflected in the integration of climate-related topics into both formal and informal education, employing hands-on projects, real-world data, and participatory learning methods to help students understand the complexities of climate change and its multifaceted impacts.

### Current Focus Topics in Climate Change Education

#### 1. Effective Learning Methodologies and Educational Practices

Educators are increasingly focusing on inquiry-based and experiential learning that bridges theory and practice. Innovative approaches such as problem-based learning, project-based learning, and simulation exercises are now commonplace. For example, students might engage in interactive experiments where they measure local temperature and air quality data or simulate the impacts of extreme weather events to explore adaptation strategies. These methodologies are supported by research that underscores how active participation enhances retention and critical thinking in climate science.

#### 2. Sustainable Development and Adaptation Strategies

Courses now emphasize the interconnectedness of sustainability, adaptation, and climate change mitigation. Students learn about renewable energy technologies, sustainable urban planning, and resilience planning. An exemplary focus is on case studies that analyze how cities are implementing green infrastructure to mitigate urban heat islands—a topic that not only reinforces practical knowledge but also showcases successful climate policy interventions .

#### 3. Youth Empowerment and Transformative Education

Recognizing young people as pivotal agents of change, many programs are designed to cultivate leadership, critical thinking, and innovative problem-solving skills. Initiatives like Erasmus+ projects empower students by involving them in transnational research and community-based projects. These programs encourage youth to engage with policy-makers, thereby fostering a generation that is both informed and motivated to contribute to future climate solutions .

#### 4. Energy Literacy and Systems Thinking

As a core component of climate change education, energy literacy helps students understand energy sources, efficiency, and the environmental impacts of energy consumption. Curricula now incorporate modules on how energy systems work and their role in climate dynamics. Interactive simulations, where students can model energy flows and study the effects of various

policy interventions, are increasingly popular. These tools promote a systems-thinking approach, illustrating the interdependencies between energy, economy, and natural ecosystems.

## 5. Integration of Local and Global Perspectives

An important trend in the current educational landscape is the melding of local case studies with global trends. This dual approach allows students to witness the localized effects of climate change—such as air quality issues in urban centers like Los Angeles, Beijing, or New Delhi—while understanding how these issues are connected to broader global environmental processes. This type of curriculum not only highlights regional diversity in climate impacts but also fosters interdisciplinary collaboration focused on developing tailored, community-specific responses.

## Air Quality: A Gateway to Climate Literacy

At the forefront of modern climate change education lies an increasing emphasis on real-world applications, hands-on learning, and curricula that bridge the gap between theory and practice. Today's innovative programs incorporate the science of air quality as a means to not only illustrate local environmental challenges but also to shed light on the broader dynamics of global climate change. As national education systems around the world increasingly recognize the urgency of these issues, they are integrating air quality topics using cutting-edge tools—ranging from microcontroller-based sensor platforms like Arduino and Raspberry Pi to interactive digital resources such as OpenSenseMap and sensor calibration guides. These resources equip students to gather, analyze, and interpret data in a manner that transforms abstract environmental concepts into tangible learning experiences<sup>1</sup>.

Across different national curricula, the infusion of air quality into science and environmental studies is emerging as a key component of sustainability education. For instance, UNESCO's "Greening Every Curriculum" initiative lays out a comprehensive roadmap for embedding climate change and sustainability concepts—including detailed examinations of air pollutants—into educational programmes at all levels. This initiative advocates for a curriculum that not only delivers quality content but also inspires action through hands-on, project-based learning<sup>2</sup>. In parallel, the United Kingdom has made significant strides in this area. National curriculum reforms in England have begun to foreground climate change and sustainability by incorporating real-world data collection and analysis into classroom activities. Research detailing these changes emphasizes that teachers are leveraging local case studies—such as the urban heat island effect in densely populated cities—to illustrate complex

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<sup>1</sup> OpenSenseMap. Retrieved from [<https://opensensemap.org/>](<https://opensensemap.org/>)

<sup>2</sup> UNESCO. (2024). Greening Every Curriculum – Guidance for Quality Climate Change Education. Retrieved from [<https://www.unesco.org/en/sustainable-development/education/greening-future/curriculum>](<https://www.unesco.org/en/sustainable-development/education/greening-future/curriculum>)

environmental phenomena<sup>3</sup>. Such efforts demonstrate how air quality science can effectively serve as a bridge between local environmental observations and global climatic trends.

Likewise, countries like Finland and the Netherlands are adapting their curricula to focus more on environmental issues, where air quality monitoring plays a pivotal role. In these nations, lesson plans often integrate traditional scientific experimentation with emerging digital tools, enabling students to construct their own sensor networks and interpret the resulting data through advanced analytical software. The approach cultivates critical thinking by encouraging students to correlate measured pollutant levels with meteorological data and seasonal variability. This kind of integrative learning not only deepens scientific understanding but also promotes an active citizenship geared toward environmental stewardship, as learners discuss how air quality impacts public health and urban planning [4]<sup>4</sup>.

Moreover, the US Next Generation Science Standards (NGSS) and other regional frameworks have also begun to emphasize the importance of understanding environmental processes. Although often not stated explicitly as “air quality education,” these standards incorporate elements of data collection, systems thinking, and environmental monitoring that naturally extend to topics like pollutant dispersion and its impact on climate. For instance, projects developed under these standards may involve real-time monitoring of PM<sub>2.5</sub> levels or experiments that explore the chemistry of atmospheric pollutants—activities that mirror those found in progressive European curricula<sup>4</sup>.

In real-world terms, the importance of integrating air quality into climate change education is underscored by contemporary events. Urban areas like Los Angeles, New Delhi, and Beijing, which routinely record high levels of air pollution, provide excellent case studies. These cities serve as living laboratories where students can explore the impact of industrial activity and vehicular emissions on both local air quality and global climate trends. The evidence is clear: sustained exposure to poor air quality not only triggers public health crises, such as respiratory and cardiovascular diseases, but also exacerbates climate anomalies through mechanisms like the urban heat island effect. These tangible examples highlight why a robust focus on air quality is essential for any comprehensive climate change curriculum.

By incorporating air quality into national curricula, education systems worldwide are taking a stand for practical environmental literacy. Students are not only learning the scientific principles behind pollutant measurement and modelling but are also gaining the technical skills necessary to become active contributors to community action and policy advocacy. Such integrative educational approaches foster a generation that is more scientifically literate, socially responsible, and motivated to partake in environmental stewardship. This model of education, reinforced by cross-national initiatives and comprehensive curriculum reforms, ultimately aims to inspire a proactive attitude among learners—transforming them into tomorrow’s environmental leaders.

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<sup>3</sup> Rushtona, E. A. C., & Walshe, N. (2025). Curriculum Making and Climate Change and Sustainability Education: A Case Study from England. *Environmental Education Research*, 31(5), 1083–1097.

<sup>4</sup> UNFCCC. (n.d.). Including Climate Change in National Curricula. Retrieved from [<https://unfccc.int/topics/education-youth/good-practices/education-and-training/including-climate-change-in-national-curricula>]

This holistic approach transforms the educational experience by linking empirical data collection with broader societal challenges. It encourages a culture of responsibility and active participation; students are not merely observers but become key agents of change. They learn that every measurement contributes to a larger narrative about our collective future. The convergence of real-time data, interdisciplinary learning, and international collaboration fosters an environment where climate change education is both dynamic and deeply personal. In a world facing unprecedented ecological challenges, understanding the science of air quality is not just about learning the technicalities of sensors and data logging—it is about inspiring a generation to become stewards of our planet.

By placing air quality at the center of climate change education, we provide learners with a framework to explore the environmental crises of our time through a lens that is both scientific and humane. This curriculum module invites students to appreciate the complexities of the Earth's atmosphere, encouraging critical inquiry, innovative experimentation, and proactive learning. In doing so, it lays the groundwork for informed citizenry and future leaders who are prepared to tackle the pressing issues of environmental sustainability and global climate change.

## 2. The Significance of Air Quality in a Changing Climate

Air quality is emerging as one of the most critical indicators of environmental health in our era of rapid climate change. As nations and educational institutions worldwide recalibrate their curricula to address sustainability, it becomes vital to understand that air quality is not merely a measure of the air we breathe—it is a composite reflection of our socioecological systems. Today, air quality issues are intimately tied to human health, ecosystem integrity, and economic stability, making it a cornerstone topic in climate change education.

At its core, air quality pertains to the presence—or absence—of pollutants, such as particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>), nitrogen oxides (NO<sub>x</sub>), volatile organic compounds (VOCs), and other hazardous substances. These airborne pollutants result from both natural processes and anthropogenic activities, including industrial emissions, vehicular exhaust, and biomass burning. Poor air quality has been consistently linked to respiratory and cardiovascular diseases, neurological disorders, and other chronic health conditions. For example, research highlighted in a chapter from SpringerLink emphasizes that the prevalence of particulate matter not only exacerbates respiratory issues but also plays a direct role in accelerating climate change by influencing atmospheric heating and cloud formation .

Climate change and air quality share a bidirectional relationship. On one hand, rising global temperatures and changing meteorological patterns can worsen air pollution episodes. Heatwaves, for instance, increase the production of ground-level ozone—a powerful respiratory irritant—and intensify the urban heat island effect, further degrading the local air quality. On the other hand, many air pollutants, including black carbon and certain VOCs, act as short-lived climate forcers, contributing directly to global warming. This complex interplay creates a feedback loop where poor air quality intensifies climate change, and a warming climate, in turn, leads to further deterioration in air quality. An in-depth study published by MDPI underscores how these intertwined issues not only jeopardize

human health but also disrupt natural ecosystems and economic stability by increasing the frequency of extreme weather events.

The significance of air quality is also acutely felt in national policy and educational strategies. Many countries now include air quality monitoring and data analysis within their national science and sustainability curricula. For instance, the United Kingdom's revised curriculum integrates real-time environmental monitoring projects, enabling students to experience firsthand the challenges of measuring local air pollutants and connecting these observations with broader global climate trends. Similarly, the US Next Generation Science Standards advocate for system-level thinking that naturally encompasses topics like air pollutant dispersion and climatology. These educational frameworks emphasize that understanding air quality helps learners develop critical skills in data collection, analysis, and modelling, thereby preparing them to tackle real-world challenges in public health and environmental management.

Furthermore, the broader socioeconomic impact of poor air quality extends to marginalized communities that are disproportionately affected. The Fifth National Climate Assessment stresses that disadvantaged populations—often residing in urban areas with limited green space—are at higher risk of adverse health outcomes due to chronic exposure to polluted air. These insights not only underscore the need for equitable environmental policy but also highlight the role of education in fostering community awareness and action. Integrating air quality into climate change education thus serves as a powerful tool for bridging the gap between scientific research and practical policy-making, ultimately inspiring students to become proactive advocates for sustainable change.

In summary, air quality is a multifaceted subject that sits at the nexus of human health, environmental sustainability, and climate resilience. By focusing on air quality within climate change education, we empower learners to critically assess the interplay between industrial development, urban planning, and natural ecosystem services. Through hands-on experiments, sensor-based monitoring projects, and interdisciplinary learning, students are equipped not only with technical proficiency but also with the ethical framework needed to champion environmental justice. Emphasizing air quality in educational programs helps cultivate a generation of informed citizens and future leaders ready to address the formidable challenges posed by our rapidly changing climate.

These international educational initiatives underscore the critical importance of integrating air quality monitoring within the broader framework of climate change education. By combining hands-on data collection, sensor technologies, and collaborative international methodologies, these projects demonstrate that the challenges of air pollution and climate change are not isolated to one region but are interconnected global issues. Incorporating such examples into national curricula not only enhances technical proficiency but also equips students with the mindset and skills required to become proactive environmental stewards. They learn that through rigorous scientific investigation and community engagement, every measurement has the potential to contribute to a larger narrative—one that can inform policy, spark innovation, and drive global sustainability efforts.

### 3. Scientific Background: Air Pollutants and Their Impacts

A clear understanding of the science behind air quality is crucial to appreciating how environmental and human health are intertwined. This section delves into the nature of air pollutants, their sources, and the wide-ranging effects they have on our ecosystems and communities.

#### Types of Pollutants

##### **Gaseous Pollutants:**

Gaseous pollutants include nitrogen dioxide ( $\text{NO}_2$ ), sulfur dioxide ( $\text{SO}_2$ ), ground-level ozone ( $\text{O}_3$ ), and volatile organic compounds (VOCs).

- **Nitrogen Dioxide ( $\text{NO}_2$ ):** Primarily emitted from vehicle exhaust and industrial combustion,  $\text{NO}_2$  contributes to respiratory issues and secondary formation of particulate matter.
- **Sulfur Dioxide ( $\text{SO}_2$ ):** Predominantly produced by burning fossil fuels, particularly coal and oil,  $\text{SO}_2$  is a precursor to acid rain and can damage both human tissue and vegetation.
- **Ozone ( $\text{O}_3$ ):** While ozone high in the stratosphere protects us from ultraviolet radiation, ground-level ozone is created by chemical reactions between  $\text{NO}_2$  and VOCs under sunlight, leading to respiratory irritation and exacerbating lung diseases.
- **Volatile Organic Compounds (VOCs):** These organic chemicals originate from both industrial solvents and everyday products such as paints and cleaners, playing a crucial role in ozone formation and smog development.

##### **Particulate Matter ( $\text{PM}_{2.5}$ and $\text{PM}_{10}$ ):**

Particulate matter consists of tiny particles suspended in the air and can be broadly classified by size.  $\text{PM}_{10}$  refers to particles with diameters of 10 micrometers or less, while  $\text{PM}_{2.5}$  comprises even finer particles that can penetrate deep into the lungs. These particles originate from a variety of sources, including combustion engines, industrial processes, and even natural phenomena like dust storms. Their small size allows them to infiltrate the human respiratory system, leading to inflammation, exacerbation of asthma, and chronic lung conditions. Cities such as Beijing and New Delhi often report elevated PM levels, demonstrating how rapid urbanization and heavy traffic can dramatically degrade air quality.

##### **Heavy Metals:**

Heavy metals such as lead (Pb), mercury (Hg), cadmium (Cd), and arsenic (As) are toxic pollutants that can be emitted into the atmosphere through industrial activities, waste incineration, and mining operations. These metals can attach to particulate matter and enter the human body through inhalation or ingestion. Prolonged exposure can lead to severe health issues, including neurological

damage, kidney dysfunction, and developmental delays in children. Because they persist in the environment and accumulate in living organisms, heavy metals pose a long-term risk to both ecosystems and human health.

## Sources of Pollution

Air pollutants arise from both natural and anthropogenic (human-produced) sources. Human activities are the predominant contributors:

- **Automobiles:** Exhaust emissions from vehicles release a mix of pollutants, including PM<sub>2.5</sub>, NO<sub>2</sub>, and VOCs. Urban centers often see a correlation between traffic congestion and localized reductions in air quality.
- **Industrial Activities:** Factories and power plants frequently burn fossil fuels for energy, releasing significant amounts of SO<sub>2</sub>, NO<sub>2</sub>, and particulate matter. Industrial clusters can create localized “hotspots” of pollution, affecting surrounding communities.
- **Biomass Burning:** Agricultural practices, forest fires, and even controlled burns release a mix of particulates and gases. In regions prone to wildfires, such as parts of California or Australia, the episodic release of vast amounts of smoke and particulate matter poses both immediate and long-term health risks.

In addition to these anthropogenic sources, natural phenomena like volcanic eruptions, dust storms, and biogenic emissions from vegetation can also contribute to air pollution—though typically on a more sporadic or regional basis.

## Health and Environmental Impacts

Long-term exposure to air pollutants has pronounced and multifaceted impacts on health and the environment:

- **Human Health:** Continuous exposure to high levels of PM, NO<sub>2</sub>, SO<sub>2</sub>, and ozone can lead to chronic respiratory diseases, cardiovascular problems, and even premature death. Research consistently links increased hospital admissions and adverse health outcomes to high pollution days, explaining why cities with poor air quality face higher rates of asthma and COPD.
- **Environmental Effects:** Pollutants not only threaten human health but also disrupt ecological balance. Acid rain formed from SO<sub>2</sub> and NO<sub>2</sub> reacts with water vapor to lower the pH of soil and water bodies, leading to decreased biodiversity and altered ecosystem dynamics. Moreover, particulate matter and ozone can impair plant photosynthesis, hindering crop yields and impacting food security.
- **Climate Change:** Some pollutants, like black carbon (a component of PM<sub>2.5</sub>), are short-lived climate forcers. They absorb sunlight and contribute to atmospheric warming and the melting of glaciers, thereby linking air quality degradation with broader climate change impacts.

## Resources and Links

### Educational Resources and Definitions from Air\_Sun+Climate:

The Air\_Sun+Climate project developed a dedicated **presentation on air quality** as part of its educational module using SenseBox technology. The presentation introduces key pollutants such as O<sub>3</sub>, NO<sub>x</sub>, SO<sub>x</sub>, NMVOCs, PM<sub>2.5</sub>/PM<sub>10</sub>, CO, NH<sub>3</sub>, and Pb, explaining their sources and impacts in an accessible way for students. It emphasizes that while some pollutants have clear definitions and measurable thresholds (e.g., ozone or lead), others—like particulate matter—can be more complex to define and assess. To complement this, national agencies such as the **German Federal Environment Agency** and the **Hessian State Agency for Nature and Environment** offer public resources, indices, and real-time data to monitor air quality. These platforms help bridge scientific understanding with everyday awareness, supporting schools in connecting local measurements with global environmental goals.

### Presentation

“Air quality and climate change Project based introduction to the Sensebox technology.

<https://www.kreis-bergstrasse.de/themen-projekte/bildung/erasmus/air-sun-climate/download/2024-air-quality-course-v0003.pdf?cid=35ca>

### Links to National weather and environmental agencies

#### GERMANY

Deutscher Wetterdienst

[https://www.dwd.de/DE/derdwd/messnetz/messnetz\\_node.html](https://www.dwd.de/DE/derdwd/messnetz/messnetz_node.html)

#### GERMANY/Hessia

Hessian State Agency for nature, environment etc.

<https://www.hlnug.de/themen/luft/>

#### GERMANY

German Federal Environment Agency

<https://www.umweltbundesamt.de/themen/luft>

#### AUSTRALIA

NSW Government

<https://www.health.nsw.gov.au/environment/air/Pages/common-air-pollutants.aspx>

#### AUSTRIA

Stadt Wien

<https://www.wien.gv.at/umwelt/luft/>

#### CANADA

Government of Canada

<https://www.canada.ca/en/services/environment/weather.html>

## 4. Educational Tools and Visualization

To truly grasp these complex interactions, interactive diagrams and case studies prove invaluable. Visual tools can illustrate how pollutants disperse differently in urban versus rural settings due to variations in topography and meteorological conditions. For example, simulation software might demonstrate how a high-pressure system traps pollutants over a city, resulting in smog, or how wind patterns disperse emissions outward in open rural areas. Such resources empower students to visualize concepts like dilution, accumulation, and regional transport of pollutants, bridging theoretical knowledge and real-world phenomena.

Below are several Creative Commons–friendly resources that offer interactive diagrams, case studies, and visual tools—all of which can enhance classroom learning about air quality and climate change. These resources are ideal for integrating into curricula, facilitating hands-on exploration, and sparking class discussion.

### 1. Climate Visuals

Link: [Climate Visuals](<https://www.climatevisuals.org/climate-visuals/>)

Description: Climate Visuals is a comprehensive image library dedicated to climate change. It hosts over 1,500 images that have been made available under Creative Commons–compatible licenses. These high-impact visuals are designed to tell environmentally compelling stories and include interactive elements and case studies. They work well for educators needing diagrams or photo narratives on air quality, weather extremes, or the human impacts of climate change.

### 2. NASA Interactives – Climate Change: Vital Signs of the Planet

Link: [Interactives – Climate Change](<https://climate.nasa.gov/explore/interactives/>)

Description: NASA's "Vital Signs of the Planet" offers an immersive suite of interactive visualizations that track key climate indicators. Educators and students can explore real-time and historical data on global temperature, ice mass, sea level, and more. These tools often include visualizations related to air quality and aerosols which are essential for understanding the interplay between pollutants and climate change. NASA's materials are developed for educational purposes, and many of their visuals are available with open licensing for non-commercial and educational use.

### 3. 5 Interactive Climate Change Education Tools

Link: [5 Interactive Climate Change Education Tools to Wow Your Students](<https://altc.alt.ac.uk/blog/2023/02/5-interactive-climate-change-education-tools-to-wow-your-students/>)

Description: This resource from ALTC showcases a curated list of interactive tools that are designed to make climate change accessible and engaging for students. It includes examples of digital simulations, diagrams, and web-based activities that help explain key phenomena—



from the impacts of greenhouse gases to air pollutant dispersion. These tools can serve as excellent supplementary case studies in lessons, illustrating real-world examples of air quality issues within the broader climate context.

#### 4. Air Quality and Climate Change | Center for Science Education

Link: [Air Quality and Climate Change](https://scied.ucar.edu/learning-zone/air-quality/air-quality-and-climate-change)

Description: Provided by the Center for Science Education (operated by UCAR), this educational resource integrates interactive diagrams, animations, and case studies that explain the science behind air pollution and its effects on the climate. It features content on the behavior of different pollutants in various environmental settings, making it especially useful for demonstrating how local air quality issues are linked to global climate trends. The materials are designed for easy incorporation into lesson plans.

### Additional Tips for Use

#### Integration in Lesson Plans:

Combine these interactive tools with in-class discussions and hands-on projects (e.g., constructing simple air quality monitoring stations) to provide a holistic understanding. For instance, after exploring NASA's interactive data, students could simulate how varying levels of PM<sub>2.5</sub> influence local temperatures or photosynthesis rates in nearby plants.

#### Case Study Exploration:

Utilize the case studies presented on these platforms—such as the impact of urban traffic on NO<sub>2</sub> levels or biomass burning and its link to particulate pollution—to prompt student research projects or presentations.

#### Licensing Check:

Although these resources are geared toward educational and non-commercial use, it's good practice to check the licensing terms on each platform (most Creative Commons materials require appropriate attribution) to ensure compliance when refurbishing and sharing the content.

### Conclusion

A comprehensive scientific background on air pollutants and their impacts provides not only the bedrock for climate change education but also informs public policy and personal responsibility. By understanding the types of pollutants, their sources, and their health and environmental repercussions, learners are better equipped to engage in innovative problem solving and advocate for cleaner air. The integration of hands-on studies, data visualization, and case studies in educational curricula makes it possible to transform abstract data into actionable insights that fuel sustainable community practices.

## 5. Measurement Technologies: Sensors and Their Principles

Modern air quality monitoring relies on a host of sensors and instruments, including:

- Optical and Laser Sensors: For measuring particulate concentration via light scattering.
- Electrochemical Sensors: To detect gases like NO<sub>2</sub> or CO.
- Environmental Sensors: For monitoring temperature, humidity, and UV radiation as factors that influence pollutant behavior.

Students will learn the underlying physics and chemistry that govern sensor operation and data acquisition. This section outlines sensor types, their calibration methods, and the importance of maintaining data accuracy.

Links to Germany's National Meteorological Service and Hessian State Agency for nature, environment etc. including information on applied measurement technology.

**GERMANY:** Deutscher Wetterdienst

[https://www.dwd.de/DE/derdwd/messnetz/messnetz\\_node.html](https://www.dwd.de/DE/derdwd/messnetz/messnetz_node.html)

**GERMANY/Hessia:** Hessian State Agency for nature, environment etc.

<https://www.hlnug.de/themen/luft/>

## 6. Integrating Microcontrollers & Data Acquisition

In this module, the focus shifts to the digital backbone that makes real-time environmental monitoring possible. At the heart of the approach lies the integration of microcontroller-based platforms—most notably, the SenseBox system—which serves as a versatile gateway between physical sensors and digital data analysis. The SenseBox has been extensively developed and refined over the years, offering educators and students a robust toolkit for gathering, processing, and transmitting environmental data.

One of the key strengths of the SenseBox system is its seamless integration into Opensensemap. Opensensemap allows for real-time visualization of data collected from distributed sensor networks, empowering users to share their findings with a wider audience. This integration not only facilitates collaborative projects across schools and communities but also transforms raw data into valuable insights on urban air quality, climate trends, and other environmental parameters. Whether it is tracking fine particulate matter (PM<sub>2.5</sub>/PM<sub>10</sub>) or monitoring levels of gaseous pollutants like NO<sub>2</sub> and O<sub>3</sub>, the SenseBox offers an excellent platform for hands-on learning.

However, despite its technological maturity, the current deployment of the SenseBox system in educational contexts faces certain challenges. One notable issue is the lack of a permanent mounting

solution and a standardized setup for classroom presentations. In many schools or community centers, the SenseBox is often used in temporary or ad hoc installations, which may limit its long-term educational impact. A more permanent integration—such as dedicated displays in school science corridors or fixed installations in public learning spaces—could greatly enhance the visibility and continuous learning potential of the system. This would not only serve as a constant demonstration tool for new students but also as a lasting resource for ongoing community projects.

The module covers several key topics:

- **Microcontrollers in Environmental Sensing:** An in-depth look at platforms like SenseBox and Arduino. Students learn how these devices serve as the brains of sensor networks, collecting analog and digital signals, and converting them into data that can be analyzed further.
- **Data Acquisition Systems:** Here, the focus is on understanding how microcontrollers interface with a diverse array of sensors. This includes outlining the data flow—from sensor measurement, through analog-to-digital conversion, to storage and transmission. Practical sessions get students to experience firsthand how variables such as sensor positioning and calibration can affect data accuracy.
- **Calibration and Testing:** A critical element of any measurement system is ensuring that sensor data is both reliable and valid. Educators guide students to set up standard references, follow systematic calibration procedures, and apply error checking routines. This hands-on aspect reinforces scientific rigor and develops troubleshooting skills essential for experimental research.

Students gain practical experience coding microcontroller units (MCUs) to collect, process, and transmit environmental data. They also learn how to integrate software tools—often available open source—to visualize this data in real time via platforms like Opensensemap. This dual emphasis on hardware (sensor assembly and microcontroller programming) and software (data analysis and visualization) equips learners with a holistic understanding of modern environmental monitoring techniques.

In summary, the "Integrating Microcontrollers & Data Acquisition" module serves as the pivot between abstract theory and practical, real-world impact. By leveraging the advanced capabilities of the SenseBox system and its integration in the Opensensemap ecosystem, students are empowered to become citizen scientists who can monitor air quality, analyze trends, and even influence local policy through data-driven insights. Addressing the current gaps—such as establishing permanent mounting and presentation solutions—will further enhance this innovative educational framework, ensuring that technology becomes an enduring part of the learning environment.

## Permanent Installations in School Settings

### The Rationale for Permanent Installations

Permanent installations of environmental sensor systems, such as the SenseBox, offer schools a unique opportunity to transition from short-term projects to a continuous, real-world monitoring system. By embedding a SenseBox system within a permanent display or dedicated learning area, schools can provide students, staff, and even community members with ongoing access to live air quality data. This approach not only reinforces classroom lessons but also transforms the school environment into a living laboratory, encouraging curiosity and long-term engagement with environmental issues.

### Advantages and Implementation Strategies

1. **Continuous Data Collection and Analysis:** A permanently mounted SenseBox can collect data over extended periods, allowing students to analyze trends, identify seasonal variations, and even correlate local events (e.g., traffic patterns or nearby construction) with changes in air quality. This continuous flow of information can be displayed on digital dashboards or interactive screens in common areas such as halls or science labs.
2. **Community Engagement:** Long-term installations foster community involvement. In projects like “Schule als lokaler Klimaakteur im Kiez” (School as a Local Climate Actor), SenseBox units have been integrated into school settings in Berlin to serve not only as educational tools but also as platforms for citizen science. These projects invite local residents to explore the same data, thereby enhancing public awareness and engagement in environmental stewardship.
3. **Technical Considerations:** To ensure a successful permanent installation, several technical aspects must be addressed:
  - a. **Robust Mounting Solutions:** Unlike temporary setups, permanent installations require secure mounting hardware that can withstand weather extremes if installed outdoors. This might involve custom-built enclosures or weatherproof cabinets.
  - b. **Power and Connectivity:** Ensure consistent power supply—often through either a direct electrical connection or solar panels—and stable WiFi connectivity, so that sensor data is reliably transmitted to platforms like openSenseMap.
  - c. **Maintenance and Accessibility:** The installation should be placed where it is both secure and easily accessible for routine maintenance, sensor recalibrations, or data troubleshooting.

For example, a school in Berlin has successfully installed an outdoor SenseBox measurement station at a designated “Klima-Corner.” The system is integrated with a digital dashboard that displays real-time data on air quality and is frequently used by both teachers and local community leaders to discuss urban climate challenges [8].

### Further Resources on Permanent Installations:

- **SenseBox – Messstation für Schulen und lokale Akteurinnen im Kiez:** Visit SenseBox Installation Project This project offers detailed examples and guidelines for schools aiming to use SenseBox as a permanent environmental sensing station<sup>5</sup>.
- **SenseBox Documentation:** Read the SenseBox Docs The documentation provides technical guidelines and installation tips, including information on mounting options for various use cases<sup>6</sup>.

### Air\_Sun + Climate: A Benchmark in Permanent Environmental Monitoring Stations

The Air\_Sun + Climate project stands out as one of the best-developed permanent environmental monitoring stations. As part of the Erasmus+ KA210 initiative coordinated by Kreis Bergstraße and digi\_space, this project has set a high standard for integrating advanced sensor technology into a sustainable, long-term educational framework. Notably, the permanent station is entirely based on the SenseBox system—a robust, open-source sensor platform specifically designed for environmental monitoring.



At the heart of the project is the SenseBox system, which has been extensively developed and tailored for educational applications. This system is adept at measuring key parameters such as particulate matter (PM<sub>2.5</sub>/PM<sub>10</sub>), UV radiation, and various meteorological data. By basing its infrastructure on SenseBox, the project benefits from its proven reliability, ease of integration, and seamless connection to openSenseMap. This integration provides users with real-time visualizations of environmental data,

<sup>5</sup> <https://climate-change.center/toolbox/sensebox-messstation-fuer-schulen-und-lokale-akteurinnen-im-kiez/>

<sup>6</sup> <https://edu.books.sensebox.de/en/>

allowing students, educators, and community members to track changes and analyze long-term trends interactively.

The permanent installation methodology developed within the Air\_Sun + Climate project ensures that sensors are securely mounted in strategic locations. These stations remain operational over extended periods, delivering continuous data streams that are essential for longitudinal studies on air quality and climate interactions. For example, sensor installations have been successfully set up at various key venues such as the Landratsamt Heppenheim, local observatories, and community centers in partner cities like Istanbul and Granada. These fixed installations serve not only as hands-on learning tools but also as enduring public resources that highlight the connection between human activity, air quality, and climate change.

The project's comprehensive approach extends beyond just installation. It rigorously addresses technical challenges such as ensuring a stable power supply, maintaining efficient data connectivity, and implementing regular sensor calibration protocols to reduce measurement drift. The emphasis on these technical details guarantees the high quality and reliability of the data, which is essential both for scientific research and for supporting local environmental policies.

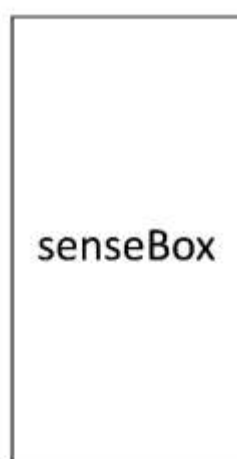
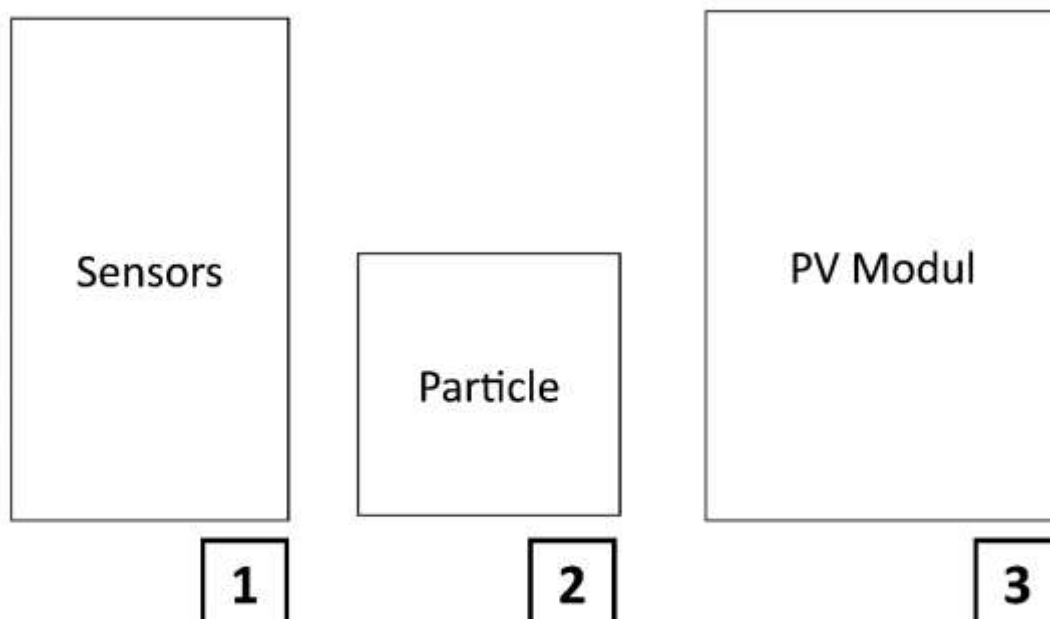
Educationally, the impact of Air\_Sun + Climate is profound. Students actively engage in every stage—from sensor setup and microcontroller programming to calibration and data analysis—thereby gaining the practical skills needed to manage real-world environmental monitoring systems. The project not only builds technical proficiency but also nurtures critical thinking, collaborative problem-solving, and a deep understanding of how sustainable practices can mitigate environmental challenges.

This permanent station, by virtue of its foundation on the SenseBox system, demonstrates an exemplary model for integrating digital environmental monitoring into everyday educational settings. It provides a template for schools and community centers worldwide to adopt similar setups, ensuring that environmental education remains engaging, data-driven, and responsive to the challenges posed by climate change.

## Resources and Links

2. Air\_Sun + Climate | Kreis Bergstraße. Retrieved from [Kreis Bergstraße Website](<https://www.kreis-bergstrasse.de/themen-projekte/bildung/erasmus/air-sun-climate/>)

3. „Air\_Sun+Climate“ – digi\_space Projekt. Retrieved from [dblt.de](<https://dblt.de/index.php/gesellschaft/umwelt/5170-air-sun-climate-digi-space-projekt.html>)



## Environmental monitoring

**4**

1. Temperature, humidity, air-pressure
2. Particle (PM 2.5 and PM 10)
3. PV-Module
4. Light and UV-Index, MC-Unit

The station is linked to [www.opensensemap.org](http://www.opensensemap.org) and can be found with the search string: airsunclimate



This environmental monitoring station is part of the Erasmus+ Project „Air\_Sun + Climate“.



Erasmus+  
Enriching lives, opening minds.

digl\_space  
die Informations

senseBox



nnn Lorsch



Co-funded by  
the European Union

[sensebox-board.jpg \(4724×7087\)](#)

Download of MS-Publisher data are available on the website: [Air\\_Sun + Climate](#) | [Kreis Bergstrasse](#)

## 7. Hands-On Session: Building an Air Quality Monitoring Station

The students, aged 14-17, who could be visiting the sensebox workshop are likely to be curious, tech-savvy, and interested in learning about environmental monitoring. These young individuals may have a passion for technology and innovation, and are eager to get hands-on experience in building and programming their own sensing devices. They may be environmentally-conscious and motivated to make a positive impact on the world around them. These students are likely to be creative problem-solvers who enjoy working collaboratively with their peers to tackle real-world issues related to climate change and air quality. Overall, the students visiting the sensebox workshop are likely to be enthusiastic and driven to learn and explore the possibilities of sensor technology.

### Resources:

- Presentation on atmosphere, climate and air quality
- SenseBox system (edu and components to build your own IoT-System, SenseBox board)
- Laptops, Internet access
- Flash cards (e.g. <https://sensebox.de/de/lernkarten-mcu> )

### Day 1: Introduction to Air Quality

#### Objectives:

- Understand the basics of air quality and its importance
- Introduce the SenseBox system and its capabilities
- Learn about different air pollutants and their sources

#### Activities:

- Introduction to the workshop and overview of the week's activities
- Presentation on air quality and its impact on health and the environment
- Demonstration of the SenseBox system and its components
- Group discussion on different types of air pollutants and where they come from

#### Learning Outcomes:

- Students will have a basic understanding of air quality and its importance
- Students will be familiar with the SenseBox system and its capabilities
- Students will be able to identify different air pollutants and their sources

### Day 2: Monitoring Air Quality with SenseBox

#### Objectives:

- Learn how to set up and calibrate the SenseBox system
- Understand how to collect and analyze air quality data
- Explore different types of sensors and their functions

#### Activities:

- Hands-on workshop on setting up and calibrating the SenseBox system

- Data collection exercise in different locations to observe variations in air quality
- Instruction on data analysis using the SenseBox software
- Experimentation with different sensors to measure various air pollutants

#### Learning Outcomes:

- Students will be able to confidently set up and calibrate the SenseBox system
- Students will know how to collect and analyze air quality data
- Students will have hands-on experience with different sensors and their functions

### Day 3: Field Trip – Air Quality Measurement in the Community

#### Objectives:

- Apply knowledge and skills learned in the workshop in a real-world setting
- Collaborate with peers to collect and analyze air quality data
- Gain a practical understanding of air quality issues in the local community

#### Activities:

- Field trip to different locations in the community to measure air quality
- Data collection and analysis in groups using the SenseBox system
- Group presentation on findings and recommendations for improving air quality in the community
- Reflection and discussion on the importance of citizen science in monitoring air quality

#### Learning Outcomes:

- Students will apply their knowledge and skills in measuring air quality in the community
- Students will collaborate effectively with their peers to collect and analyze data
- Students will understand the importance of community involvement in monitoring air quality

### Day 4: Data Interpretation and Visualization

#### Objectives:

- Learn how to interpret and visualize air quality data
- Understand the significance of trends and patterns in the data
- Practice communicating findings and recommendations effectively

#### Activities:

- Workshop on interpreting and visualizing air quality data using the SenseBox software
- Data visualization exercises to identify trends and patterns
- Group discussion on the significance of the data and its implications for air quality
- Presentation practice on communicating findings and recommendations to a wider audience

#### Learning Outcomes:

- Students will be able to interpret and visualize air quality data effectively
- Students will understand the significance of trends and patterns in the data
- Students will practice communicating their findings and recommendations clearly and effectively

### Day 5: Wrap-Up and Reflection

#### Objectives:

- Reflect on the week's activities and learning outcomes



- Discuss the impact of air quality measurements on health and the environment
- Identify ways to continue monitoring and improving air quality in the community

#### Activities:

- Group reflection on the workshop experience and key takeaways
- Discussion on the impact of air quality measurements on health and the environment
- Action planning session to identify ways to continue monitoring and improving air quality in the community
- Closing ceremony and certificate distribution

#### Learning Outcomes:

- Students will reflect on their learning and experiences from the workshop
- Students will understand the importance of air quality measurements in protecting health and the environment
- Students will develop a plan for continued monitoring and improvement of air quality in the community

### Cross-Curricular Integration and Future Approaches

The air quality module is designed not only to fit into science or technology classes but also to complement other subjects:

- Mathematics: Data statistics, error analysis, and modelling techniques.
- Geography: Mapping pollutant dispersion and understanding the impact of local topography.
- Art & Media: Creative visualization of air quality data—turning graphs and charts into data art installations that make environmental issues accessible to a wider audience.
- Civics and Economics: Discussion on policy-making, public health, and sustainable economic models based on environmental data.

### Conclusion

By the end of the workshop week, students will have gained a comprehensive understanding of air quality, measurement techniques using the SenseBox system, data analysis and interpretation skills, and the importance of citizen science in monitoring and improving air quality. The curriculum is designed to be engaging, hands-on, and interactive, providing students with a well-rounded educational experience.

## 8. Resources, References, and Further Reading

This chapter compiles an extensive range of resources designed to support a curriculum focused on air quality measurements and climate change education. The resources span digital platforms, peer-reviewed literature, technical documentation, and institutional guidelines. These materials are intended to provide both breadth and depth of knowledge, enabling students and educators to engage with the scientific, technical, and policy-related aspects of air quality and environmental monitoring.

### Online Platforms and Digital Archives for the Sensebox system

Objective:

To introduce the Sensebox platform and that facilitate data sharing, simulation, and interactive analysis.

#### OpenSenseMap

A collaborative data platform that aggregates and visualizes real-time air quality measurements from sensor networks. OpenSenseMap functions as both a repository for public data and an analytical tool for examining spatial and temporal trends in environmental monitoring.

Link: [OpenSenseMap](<https://opensensemap.org/>)

#### SenseBox

SenseBox is a modular, open-source sensor platform designed to measure various environmental parameters, including particulate matter, UV radiation, temperature, and humidity. Widely utilized in citizen science projects and educational settings, SenseBox supports hands-on learning by empowering users to build, program, and deploy their own air quality measurement stations. It plays a key role in initiatives such as the Erasmus+ project. For in-depth product information, documentation, and further learning resources, visit the official website at

Link: [senseBox.de](<https://sensebox.de/>).

Link: [senseBox.de] (<https://edu.books.sensebox.de/en/>).

#### digi\_space (Official Website)

digi\_space is an innovative digital laboratory providing extensive resources for exploring and applying digital technologies in education—from robotics to sensor-based environmental monitoring. It acts as a hub for both structured workshops and open-ended projects, bridging theoretical content with practical experimentation.



Link: [digi\_space | Kreis Bergstrasse](<https://www.kreis-bergstrasse.de/themen-projekte/digitalisierung/digi-space/>)

digi\_space Erasmus+ Programme Sub Website – Air\_Sun + Climate

Serving as the dedicated portal for the Erasmus+ KA210 project "Air\_Sun + Climate," this sub website offers detailed insights into the project's objectives, methodologies, and resources. The initiative focuses on developing interactive, hands-on workshops that integrate air quality measurements with broader themes of renewable energy and climate adaptation. This resource is essential for educators and students interested in participating in transnational collaborations and learning modules aimed at building practical skills in environmental monitoring.

Link: [Air\_Sun + Climate | Kreis Bergstrasse](<https://www.kreis-bergstrasse.de/themen-projekte/bildung/erasmus/air-sun-climate/>)

SenseBox – Messstation für Schulen und lokale Akteurinnen im Kiez:

Visit SenseBox Installation Project This project offers detailed examples and guidelines for schools aiming to use SenseBox as a permanent environmental sensing station.

Link: [Climate Change Center | Berlin](<https://climate-change.center/toolbox/sensebox-messstation-fuer-schulen-und-lokale-akteurinnen-im-kiez/>).

## Scientific Journals and Peer-Reviewed Publications

Objective:

To provide access to rigorously evaluated research that covers sensor technology, environmental science, and data analytics.

Key Journal Articles:

Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and Health Impacts of Air Pollution: A Review. *Frontiers in Public Health*, 8, 14.

Link: [DOI: 10.3389/fpubh.2020.00014](<https://doi.org/10.3389/fpubh.2020.00014>)

Zhong, Q., & Shen, H. (2022). Air Quality in a Changing World. *Climate*, 10(12), 188.

Link: [MDPI](<https://www.mdpi.com/2225-1154/10/12/188>).

Gautam, S., Sagar Gautam, A., Awasthi, A., & Ramsundram, N. (2024). The Significance of Air Quality. In *SpringerBriefs in Geography*.

Link: [Springer Link]([https://link.springer.com/chapter/10.1007/978-3-031-77057-9\\_2](https://link.springer.com/chapter/10.1007/978-3-031-77057-9_2)).



More articles see references of

U.S. Global Change Research Program. (2023). Fifth National Climate Assessment: Chapter 14 – Air Quality. Retrieved from

Link: [NCA2023](<https://nca2023.globalchange.gov/chapter/14/>).

## Research Studies and Case Reports

U.S. Global Change Research Program. (2023). Fifth National Climate Assessment: Chapter 14 – Air Quality. Retrieved from [NCA2023](<https://nca2023.globalchange.gov/chapter/14/>).

UNESCO. (2024). School-Family-Community Collaboration for Climate Change Education project. Retrieved from [<https://www.uil.unesco.org/en/articles/school-family-community-collaboration-climate-change-education-project>](<https://www.uil.unesco.org/en/articles/school-family-community-collaboration-climate-change-education-project>).

Global Partnership for Education. (2025). Building Climate Smart Education Systems. Retrieved from [<https://www.globalpartnership.org/what-we-do/building-climate-smart-education-systems>](<https://www.globalpartnership.org/what-we-do/building-climate-smart-education-systems>).

Mar, K. A., & Unger, C. (2023). International Initiatives on Air Quality and Climate Change. In Handbook of Air Quality and Climate Change. Springer. Retrieved from [[https://link.springer.com/rwe/10.1007/978-981-15-2760-9\\_47](https://link.springer.com/rwe/10.1007/978-981-15-2760-9_47)]([https://link.springer.com/rwe/10.1007/978-981-15-2760-9\\_47](https://link.springer.com/rwe/10.1007/978-981-15-2760-9_47)).

Rushtona, E. A. C., & Walshe, N. (2025). Curriculum Making and Climate Change and Sustainability Education: A Case Study from England. Environmental Education Research, 31(5), 1083–1097.

UNFCCC. (n.d.). Including Climate Change in National Curricula. Retrieved from [<https://unfccc.int/topics/education-youth/good-practices/education-and-training/including-climate-change-in-national-curricula>]

## Technical Documentation, Manuals, and Education tools

Objective:

To facilitate the detailed understanding of sensor technologies, circuit integration, and climate modelling.

## Technical documentation

[Opensensemap](<https://opensensemap.org/>): A collaborative platform where sensor data is shared and visualized, making it a powerful tool for community-based projects.

[SenseBox Learning Cards](<https://sensebox.de/de/lernkarten-mcu>): A series of flash cards and guides on the basics of microcontroller programming and sensor usage.

[Arduino Official Website](<https://www.arduino.cc/>): An excellent resource for learning about microcontroller coding and project ideas, which can complement the SenseBox system.

[Creative Commons Educational Resources for IoT and Environmental Monitoring](<https://creativecommons.org/>): Explore tools and case studies available under Creative Commons licenses.

## Educational tools:

"Air Quality and Climate Change | Center for Science Education." Retrieved from [<https://scied.ucar.edu/learning-zone/air-quality/air-quality-and-climate-change>](<https://scied.ucar.edu/learning-zone/air-quality/air-quality-and-climate-change>).

"About Climate Visuals - Climate Outreach." Climate Visuals. Retrieved from [<https://www.climatevisuals.org/climate-visuals/>](<https://www.climatevisuals.org/climate-visuals/>).

"5 Interactive Climate Change Education Tools to Wow Your Students." ALTC Blog, February 2023. Retrieved from [<https://altc.alt.ac.uk/blog/2023/02/5-interactive-climate-change-education-tools-to-wow-your-students/>](<https://altc.alt.ac.uk/blog/2023/02/5-interactive-climate-change-education-tools-to-wow-your-students/>).

"Interactives – Climate Change: Vital Signs of the Planet." NASA, retrieved from [<https://climate.nasa.gov/explore/interactives/>](<https://climate.nasa.gov/explore/interactives/>).

## Institutional and Governmental Agencies

### Objective:

To access authoritative data and policy documentation from national and international organizations that monitor air quality and support climate research.

### Germany:

#### Deutscher Wetterdienst (DWD):

Link: [DWD Measurement Network]([https://www.dwd.de/DE/derdwd/messnetz/messnetz\\_node.html](https://www.dwd.de/DE/derdwd/messnetz/messnetz_node.html))

#### Hessian State Agency for Nature and the Environment:



Link: [Hessian Luftdaten](<https://www.hlnug.de/themen/luft/>)

German Federal Environment Agency (UBA):

Link: [UBA Air Quality](<https://www.umweltbundesamt.de/themen/luft>)

Australia:

NSW Government – Air Quality Information:

Link: [NSW Air Pollutants](<https://www.health.nsw.gov.au/environment/air/Pages/common-air-pollutants.aspx>)

Austria:

City of Vienna Environmental Office:

Link: [City of Vienna](<https://www.wien.gv.at/umwelt/luft/>)

Canada:

Government of Canada – Environment and Weather Services:

Link: [Canadian Environment](<https://www.canada.ca/en/services/environment/weather.html>)

Global Initiatives:

World Health Organization (2018): Global Air Quality Guidelines. These guidelines offer scientifically backed thresholds and recommendations for pollutant measurements.

Link: [WHO Global Air Quality Guidelines](<https://www.who.int/publications/i/item/9789240034228>)

UNFCCC: Guidelines and best practices for integrating climate change into national curricula.

Link: [UNFCCC Education Initiatives](<https://unfccc.int/topics/education-youth/good-practices/education-and-training/including-climate-change-in-national-curricula>)

Global Partnership for Education (2025): Initiatives for building climate-smart education systems.

Link: [Global Partnership](<https://www.globalpartnership.org/what-we-do/building-climate-smart-education-systems>)