

Environmental Education for Air Quality: A Comparative Pedagogical and Methodological Study Between the International Context and Medellín, Colombia

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HOW TO CITE:

John Mauricio Castaño-Orozco ,
Carlos Augusto Álvarez-Arboleda
y Leyla Yamile Jaramillo-Zapata
(2026). Environmental Education
for Air Quality: A Comparative
Pedagogical and Methodological
Study Between the International
Context and Medellín, Colombia.
International Journal of Special
Education, 41(17s), 873-882

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ABSTRACT:

[Introduction]: Air pollution is a complex socio-environmental problem in contemporary cities and demands responses that integrate regulation, social participation, and civic education. In this context, environmental education has emerged as a strategic field for promoting critical understanding of the problem, social appropriation of knowledge, and changes in citizen behavior. [Objective]: This article comparatively analyzes the pedagogical and methodological approaches of international environmental education programs for air conservation and local programs implemented in Medellín, identifying convergences, divergences, and gaps in terms of citizen participation, critical thinking, data use, territorial contextualization, and evaluative monitoring. [Methodology]: The study adopted a qualitative-interpretive approach, using comparative documentary analysis. This included, on the one hand, scientific and review articles located in ScienceDirect and Scopus on international programs; and on the other hand, official documents and sources on local programs, organized into bibliographic records and analysis matrices. [Results]: The results show that, internationally, citizen science and low-emission zone programs tend to integrate community participation, intensive data use, technological mediation, and monitoring strategies that strengthen social ownership of the issue. Locally, programs like SIATA and PROCEDA exhibit higher levels of critical participation and pedagogical territorialization, while PIGECA, PEEU, and PPCA demonstrate strengths in cross-cutting themes, governance, and interdisciplinarity, although with less participatory depth and common weaknesses in systematic evaluation. [Conclusions]: The most robust programs are those that combine critical pedagogies, contextualized methodologies, substantive citizen participation, and ongoing evaluation and feedback mechanisms.

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Keywords: Environmental education; air pollution; civic behavior; citizen science; Medellín

Introduction

Air pollution is recognized as one of the greatest threats to public health and urban sustainability, due to its effects on respiratory diseases, quality of life, and social and economic development processes (World Health Organization, 2021; Hoffmann et al., 2022). That is why many countries have taken regulatory measures (Farzadfar et al., 2022; Jayaraj et al., 2017). The United States, for example, has defined control criteria for air pollutants, which are regulated at maximum levels, according to the conditions of the territory (Kuklinska et al., 2015). In addition, the European Commission proposed revising air quality guidelines, seeking to align the European Union's standards with the recommendations of the World Health Organization (Beloconi & Vounatsou, 2023).

Latin America, one of the most urbanized regions on the planet, faces significant challenges, with about 80% of its population living in large cities, which exerts significant pressure on the environment; countries such as Mexico, Brazil, Chile, Peru, Ecuador, Argentina, and Colombia, exceed the maximum levels of air pollutants allowed by the WHO, causing a large number of deaths in the region (Guidos-Fogelbach et al., 2020).

In Colombia, major cities such as Bogotá, Bucaramanga, Cali, Medellín, among others, experience a considerable increase in air pollution levels (Institute of Hydrology, Meteorology and Environmental Studies [IDEAM], 2020). The Metropolitan Area of the Aburrá Valley (AMVA), a region made up of the city of Medellín and its nine surrounding municipalities, characterized by being geographically narrow, with few winds and high population density, also suffers from the problem of air pollution, due to the large vehicle fleet and the industrial sector, as major contributors, especially PM_{2.5} and PM₁₀ particulate matter, worsening in recent years and exceeding the limits established by the World

Health Organization (Bush et al., 2017; Grisales-Romero et al., 2021).

Faced with this reality, environmental education has been promoted as a strategy aimed at strengthening public understanding of the problem, fostering a sense of belonging to the territory and promoting transformations in citizen practices. In this sense, environmental education programs for air conservation involve citizens in the understanding and solution of local problems, fostering citizen responsibility towards the environment and promoting their active participation in the territory (Ibañez, 2024). There is a tension between initiatives focused on information awareness and others that move towards more critical, participatory and data-driven approaches. On an international scale, programs such as citizen science (CI) provide citizens with active participation in scientific research, collecting large-scale data to reduce the impact on human health (Hooyberghs et al., 2022); on the other hand, the Low Emission Zones (LEZ) program, an environmental strategy, a policy measure implemented in several cities in the European Union, to improve air pollution in urban centers, where there are marked areas where the entry of vehicles with high emissions is completely prohibited (Pestel & Wozny, 2021).

In most European and American cities, where air pollution is still a problem, these programs are emerging as a commitment to air pollution, appearing as an alternative solution (Bruyneel et al., 2025; Schaefer et al., 2020).

At the local level, the AMVA has configured a programmatic ecosystem in which institutional, community, university and technological initiatives converge. That is why, since 2017, important advances have been made in environmental policies at the metropolitan and municipal level, through the implementation of various environmental education programs focused on air pollution such as PIGECA, SIATA, PROCEDE, PEEU and PPCA, each

with differentiated pedagogical and methodological features (Metropolitan Area of the Aburrá Valley [AMVA], 2023). However, the mere existence of programs does not guarantee cultural changes or sustained behavioral impacts, especially when these programs have weaknesses in their pedagogical articulation, in their territorial contextualization, or in their evaluation and monitoring mechanisms.

Despite this type of program, an analytical gap persists: there are still few studies that compare, in the same interpretative framework, the pedagogical and methodological approaches of international and local environmental education programs for air conservation. This article seeks to respond to this gap through a comparative analysis that allows identifying patterns, convergences, differences, and challenges for the strengthening of environmental education policies and practices in urban contexts. Consequently, the objective of the study was to comparatively analyze the pedagogical and methodological approaches of international and local environmental education programs for air conservation, with emphasis on their contributions to citizen participation, the appropriation of knowledge, and the transformation of environmental behavior.

Methodology

The study was developed from a qualitative-interpretative approach, through comparative documentary analysis of two previously constructed bodies of information. The first corpus corresponded to international programs and was based on the review of scientific and review articles published in English, located in the ScienceDirect and Scopus databases, in the period 01-10, using keywords related to air pollution, environmental education and environmental education programs. The second corpus was made up of local programs implemented in Medellín, identified from official sources and documentary bases such as Ambientalex Info, the Ministry of Environment in Colombia, the Mayor's Office of Medellín and the Metropolitan Area of the Aburrá Valley. In both cases, the information was organized

through bibliographic files and analytical matrices in Excel, with the purpose of unifying comparison categories and enabling the cross-reading of the programs. The central categories of analysis were: pedagogical approach, understood as the set of theories, principles and orientations that underpin teaching and learning; methodological or didactic approach, understood as the methods, resources and concrete strategies of educational mediation; citizen participation; use of technology and data; monitoring and evaluation; and declared impact on citizen behavior.

The comparison was made using an interpretative analysis logic aimed at identifying convergences, divergences, gradients and gaps between programs. Rather than establishing mechanical equivalences between different experiences, the interest consisted in understanding how each program configures its pedagogical and methodological rationality, what type of environmental citizenship it promotes and to what extent it integrates processes of feedback and social appropriation of knowledge. This procedure made it possible to construct a comparative reading useful for academic discussion and for the formulation of guidelines applicable to the local context.

Results

International Programs: Citizen Science and Low Emission Zones

The analysis of the international corpus made it possible to identify two main types of programmes: citizen science (CC) and low emission zones (LEZ). As shown in **Figure 1**, both programs share the intention of intervening in the problem of air pollution through environmental education processes aimed at citizens, but they differ in the way they articulate participation, regulation, knowledge, and behavior change.

In citizen science, the pedagogical component is oriented towards the active construction of knowledge and towards the direct involvement of citizens in processes of observation, measurement, analysis and interpretation of environmental data. This programme approaches

a participatory and cognitive pedagogy, in which the citizen ceases to be a passive receiver of information to become a subject who investigates, interprets and acts on his environment with the support of sensors, digital platforms and open science frameworks. Methodologically, it privileges problem-based and data-based learning, collaborative work, situated experimentation and the generation of shared evidence to understand air quality and its effects on daily life.

Low-emission areas, on the other hand, have a more hybrid configuration between urban

regulation, citizen awareness and civic education on mobility and public health. Its pedagogical approach incorporates cognitivist and behavioral elements, insofar as it seeks to inform, persuade, and modify behaviors related to automobile use and urban mobility practices. From a methodological point of view, they combine communication campaigns, workshops, community actions, collective awareness strategies and continuous monitoring and evaluation systems, in order to socially reinforce the legitimacy of restrictions and to show their impact on reducing emissions.

Figure 1. Comparative pedagogical and methodological approach to CC and LEZ programmes

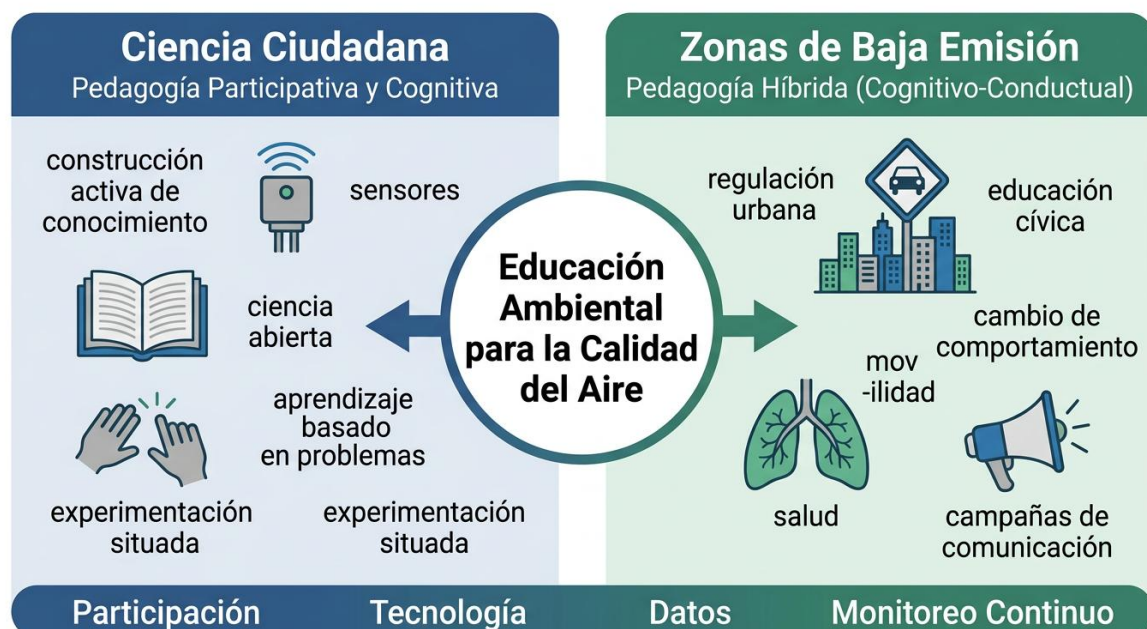


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Taken together, the international programs analyzed show a tendency to integrate community participation, technology, data, and continuous monitoring as central elements of environmental education for air conservation. This feature gives them an important strength: they do not limit themselves to informing about the problem, but create devices for citizens to observe it, interpret it and relate to it from concrete decisions on mobility, environmental monitoring and collective action.

Local programs in Medellín

In the local case, the analysis identified a set of programs with heterogeneous pedagogical and methodological configurations: PIGECA, SIATA, PROCEDE, PEEU and PPCA, all linked in different ways to environmental education for air conservation. Although they share a general orientation towards the social appropriation of knowledge and the construction of environmental awareness, they differ markedly in their levels of criticality, community participation, territorialization and evaluative monitoring (See **Figure 2**).

SIATA and PROCEDA stand out as the programmes with the most robust pedagogical approaches from a critical-participatory perspective. At SIATA, the articulation between citizen science, territory and the use of sensors transforms the urban space into a pedagogical laboratory where citizens can relate data, health and the environment, strengthening their capacity for critical reading of the problem. In PROCEDA, the incorporation of local, community and ancestral knowledge, together with processes of empowerment and resolution of environmental conflicts, configures a pedagogy that not only informs, but also seeks to train subjects capable of intervening critically in the transformation of the territory.

PIGECA occupies an intermediate position. Its strength lies in its transversality, curricular integration, educational participation and the appropriation of knowledge, but it presents a

more moderate criticality. This suggests a pedagogical model oriented towards awareness-raising, normative co-responsibility and institutional articulation, rather than the explicit confrontation of social or economic structures associated with air pollution.

PEEU and PPCA, in turn, show strengths in interdisciplinarity, training for environmental management and multisectoral governance, but less intensity in deep community participation. In PEEU, a reflexive-academic approach predominates that links scientific knowledge and territorial actors, although with greater institutional weight. In PPCA, environmental education is integrated into campaigns, public policies and citizen culture actions, prioritizing practical results, organizational changes and verifiable responses to pollution episodes, rather than extensive pedagogical processes of critical participation.

Figure 2. Comparative pedagogical and methodological approach to local programs

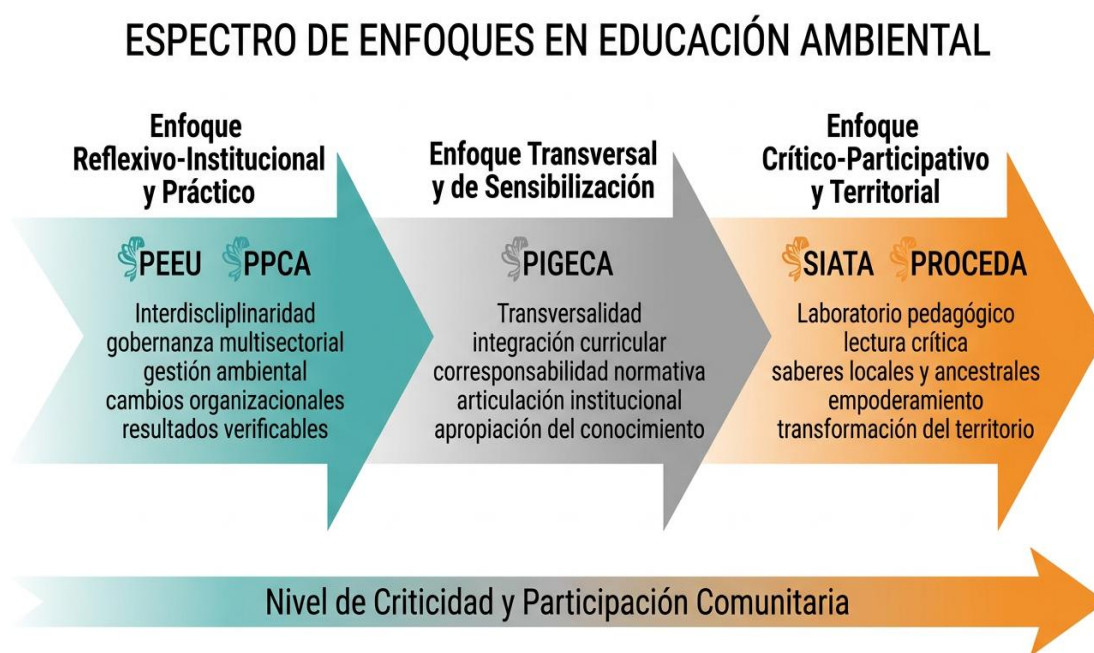


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Comparative pedagogical and methodological approaches

The integrated comparison shows that international and local programs converge in recognizing that environmental education for air

conservation cannot be reduced to the transmission of information, but requires mediations capable of linking knowledge, experience and citizen action. However, the way in which this articulation is resolved differs between the two programmatic sets (see **Figure 3**).

In pedagogical terms, citizen science, SIATA and PROCEDA, share a participatory and critical orientation, characterized by high social appropriation of knowledge, direct relationship with the territory and citizen protagonism in the construction of meaning about air pollution. In contrast, low-emission zones and programmes such as PPCA are closer to a pedagogical logic of awareness-raising, co-responsibility and behavioural regulation, where citizens are called upon to modify habits within previously established regulatory frameworks.

From a methodological point of view, the differences are also significant. Citizen Science and SIATA stand out for the intensive use of data, sensors, digital platforms and problem-based learning, while PROCEDA and PEEU privilege processual, reflective and contextualized methodologies, focused on collaborative research, workshops and critical reading of the territory. PIGECA combines technological

strategies, workshops and more structured training actions, while PPCA emphasizes the orientation to practical and verifiable results, articulating campaigns, urban interventions and multisectoral training.

A particularly relevant finding is that the greatest difference between international and local experiences is not so much in the presence of pedagogical discourses, but in the systematicity of monitoring and evaluation. In LEZs, continuous monitoring and data-driven feedback appear as central components to reinforce educational messages, legitimize public decisions and adjust strategies. In the local case, on the other hand, the programs show recurrent gaps in systematic evaluation, which limits the possibility of determining more precisely their impact on citizen behavior and on the continuous improvement of their pedagogical and methodological components.

Figure 3. Comparative pedagogical and methodological approach to both types of programs

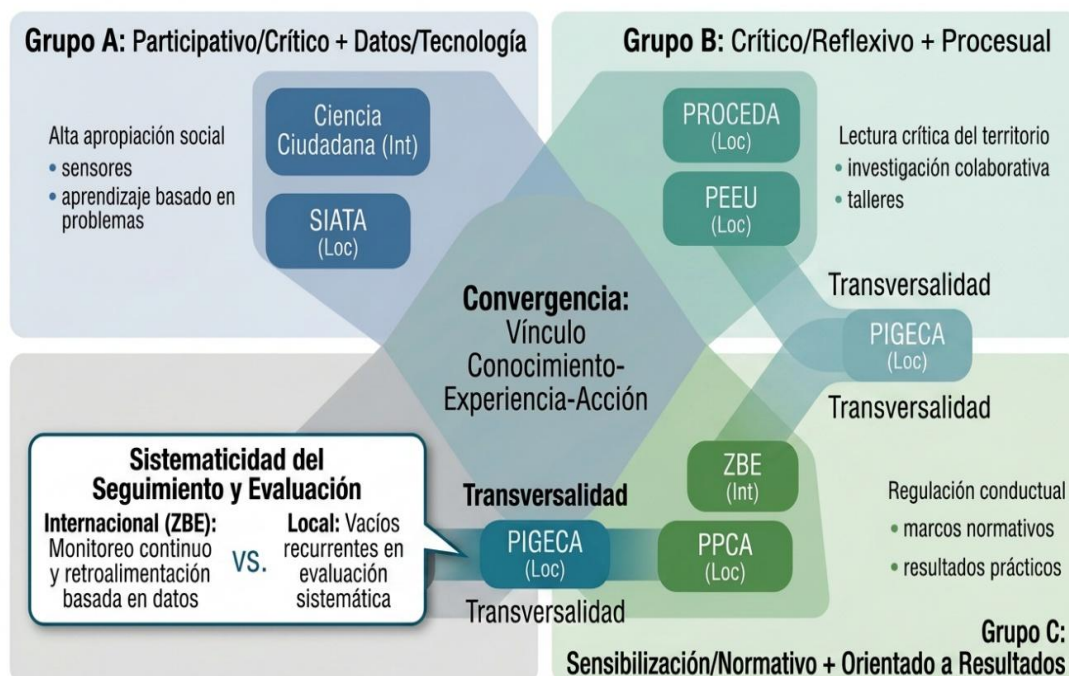


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Table 1 summarizes the comparison of international and local programs in terms of pedagogical and methodological approach

Table 1. Comparative synthesis of pedagogical and methodological approaches

Program	Predominant pedagogical approach	Predominant methodological approach	Citizen participation	Data Usage/ Technology	Monitoring and evaluation
CC	Participatory, cognitive, critical construction of knowledge	Data-driven learning, collaborative research, sensors	High	High	Moderate to Strong
LEZ	Awareness-raising, co-responsibility, behavioural regulation	Campaigns, workshops, continuous monitoring, public information	Media	High	Strong
PIGECA	Participatory and interdisciplinary with moderate criticality	Workshops, curricular integration, training platforms and strategies	Medium-high	Medium-high	Weak to moderate
SIATA	Critical-participatory and social appropriation	Interactive data, citizen sensors, territory as a laboratory	High	High	Moderate
PROCEED	Critical-participative and community	Processual, contextualized, collaborative research	High	Medium	Weak to moderate
PEEU	Reflective-academic and interdisciplinary	Processual, contextualized, territorial formation	Media	Medium	Weak
PPCA	Institutional, co-responsible, governance-oriented	Campaigns, urban interventions, results-oriented	Media	Media	Weak

Source: Authors' elaboration based on documentary analysis information

Discussion

The results allow us to affirm that environmental education for air conservation is configured today as a hybrid field, in which pedagogy, urban management, environmental data, social participation and public regulation converge. This hybridization explains why the most robust programs are not necessarily those that offer more information about the problem, but those that manage to articulate knowledge, situated experience, possibility of action, and feedback mechanisms (Santos, 2018).

First, the comparison shows that the most promising pedagogical approaches are those that move citizens from the place of audience to the place of epistemic and political actor. Citizen science, SIATA, and PROCEDURE stand out precisely because they turn territorial experience, data reading, and collective action into constitutive components of the educational process, strengthening the social appropriation of knowledge and environmental agency (Sandoval-Dueñas et al., 2021). From this perspective, environmental education does not operate only as awareness-raising, but as a mediation for critical understanding of the territory and for informed participation in air management (Ocampo, 2008).

Secondly, the findings show that the programmes closer to institutional governance logics, such as LEZ, PIGECA and PPCA, provide equally valuable dimensions, although with a different pedagogical rationale. Its strength lies in its ability to articulate regulation, citizen culture, public communication and intersectoral coordination, which are essential aspects when dealing with complex urban problems such as air pollution (Área Metropolitana del Valle de Aburrá, 2017; Carvalho Neto, 2026).

However, when these strategies are not accompanied by more participatory and critical pedagogical processes, they run the risk of remaining at the level of regulatory compliance or episodic awareness, with less capacity for profound transformation of habits and representations (Espinoza, 2023).

Third, the comparative discussion allows us to identify that evaluation constitutes the main breaking point between the international and local programs analyzed (Cruz, 2022).

While in LEZ continuous monitoring is integrated into the very design of the program and feeds back into its messages, its restrictions and its social legitimacy, in Medellín there is still a structural weakness in the systematic evaluation of the educational processes associated with air conservation. This limitation is not minor: without sustained evaluation, programs have less capacity to learn from themselves, adjust strategies, and demonstrate with evidence their real impact on citizen behavior (Sterling, 2010).

Finally, the findings suggest that strengthening environmental education for air conservation in Medellín does not involve copying international models, but translating their learning to local territorial conditions. In this sense, the combination of citizen science, contextualized methodologies, critical reading of the territory, inter-institutional governance, and formative assessment appears as a promising way to build more comprehensive, relevant, and sustainable programs over time (Patiño, 2025).

Conclusions

The comparative analysis made it possible to establish that international and local environmental education programs for air conservation share the aspiration of influencing public understanding of the problem and citizen behavior, but differ in the density of their pedagogical approaches, in the way they operationalize their methodologies and in the systematicity of their monitoring processes.

Among international programs, citizen science stands out for its ability to articulate collective construction of knowledge, direct participation and intensive use of technology, while low-emission zones stand out for integrating urban regulation, civic education and continuous evaluation. In the local scenario, SIATA and PROCEDURE emerge as experiences with greater critical-participatory and territorial power, while PIGECA, PEEU and PPCA show strengths in transversality, interdisciplinarity and governance,

although with less participatory depth and with more visible weaknesses in systematic evaluation.

In a cross-cutting way, the study shows that the programs with the greatest transformative potential are those that articulate four components: critical or participatory pedagogies, contextualized methodologies, social appropriation of knowledge, and permanent evaluation and feedback mechanisms. When any of these components are weakened, particularly substantive participation or evaluation, the chances of translating environmental education into lasting cultural changes in the face of air conservation are reduced.

In applied terms, the article suggests that Medellín has valuable programmatic bases to strengthen its environmental education around air quality, but it requires moving towards more integrated designs between science, citizenship, territory and evaluation. For future research, it is pertinent to delve into empirical studies on the perception of leaders, teachers, experts, and communities, as well as longitudinal evaluations of the real impact of these programs on mobility habits, environmental co-responsibility, and citizen agency.

Bibliographic references

- Metropolitan Area of the Aburrá Valley. (2017). Comprehensive air quality management plan for the Aburrá Valley (PIGECA) 2017–2030. Medellín: Metropolitan Area of the Aburrá Valley. <https://www.metropol.gov.co/ambiental/calidad-del-aire/paginas/gestion-integral/pigeca.aspx>
- Metropolitan Area of the Aburrá Valley. (2023). Environmental Education Projects. <https://www.metropol.gov.co/planeacion/Paginas/educacion-y-cultura/Proyectos-de-educacion-ambiental.aspx>
- Beloconi, A., & Vounatsou, P. (2023). Revised EU and WHO air quality thresholds: Where does Europe stand? *Atmospheric Environment*, 314, 120110. <https://doi.org/10.1016/j.atmosenv.2023.120110>
- Bruyneel, L., COX, B., Stauffer, A., Vandenthoren, L., Fierens, F., NAWROT, T., & Horemans, C. (2025). Positive impact of the introduction of low-emission zones in Antwerp and Brussels on air quality, socio-economic disparities and health: A quasi-experimental study. *En Environment international* (Vol. 199). PERGAMON-ELSEVIER SCIENCE LTD. <https://doi.org/10.1016/j.envint.2025.109515>
- Bush, S., Jordan, W., Kim, J., Le, Y., Poddar, D., & Torreon, C. (2017). Policy path to improve urban air quality in Medellín, Colombia (Capstone Project, School of International and Public Affairs, Columbia University). Columbia University. <https://sipa.columbia.edu>
- Carvalho Neto, D. D. d., Gonçalves, D. N. S., Wagner, G. M., Reis, A. C., Marujo, L. G., & D'Agosto, M. d. A. (2026). Governing Low- and Zero-Emission Zones in the Global South: An ASIF-Based Framework for Rio de Janeiro. *Urban Science*, 10(2), 93. <https://doi.org/10.3390/urbansci10020093>
- Cruz, G. (2022). Environmental Education in Basic Education Educational Institutions in Latin America: A Systematic Review. *Latin Science*, 6(3). https://doi.org/10.37811/cl_rcm.v6i3.2255
- Espinoza, A. L. (2023). The role of environmental education in the formation of conscious citizens. *Nexus Research Journal*, 2(2), 01-10. <https://doi.org/10.62943/nrj.v2n2.2023>
- Farzadfar, F., Naghavi, M., Sepanlou, S. G., Saeedi Moghaddam, S., Dangel, W. J., Davis Weaver, N., Aminorroaya, A., Azadnajafabad, S., Koolaji, S., Mohammadi, E., Rezaei, N., Abbas, J., Abbasi, B., Abbasifard, M., Abbasi-Kangevari, M., Abbasi-Kangevari, Z., Abbastabar, H., Abdoli, A., Abdollahi, M., Larijani, B. (2022). Health system performance in Iran: A systematic analysis for the Global Burden of Disease Study 2019. *The Lancet*, 399(10335), 01-10. [https://doi.org/10.1016/S01-10\(21\)001-10](https://doi.org/10.1016/S01-10(21)001-10)
- Grisales-Romero, H., Piñeros-Jiménez, J. G., Nieto, E., Porras-Cataño, S., Montealegre, N., González, D., & Ospina, D. (2021). Local attributable burden disease to PM 2.5 ambient air pollution in Medellín, Colombia, 01-10. <https://doi.org/F1000Research,%2010,%20428.%20https://doi.org/10.12688/f1000research.52025.2>
- Guidos-Fogelbach, G., Ramon, G. D., Staffeld, P., Mario, A., Sarabia, C., Sandino, C., Reyes-López, C., Duarte, P., Calderón, O., Helena, F., Romero, C., Díaz, S., Rosmary, S., De-Ramos, Piraino, P., Repka, M. S., Sisul, J., Quezada, C., Villarreal González, R., & Fernández de Córdova Aguirre, J. (2020). Air Pollution in Latin America: Health Impact and Current Regulation - Report by the Aerobiology Committee Group of the Latin American Society of Asthma, Allergy and Immunology Review Article. In *Archivos de Asmas, Alergia e Inmunología* (Vol. 4). <https://doi.org/10.5935/01-10.20200064>
- Hoffmann, C., Maglakelidze, M., von Schneidmesser, E., Witt, C., Hoffmann, P., & Butler, T. (2022). Asthma and COPD exacerbation in relation to outdoor air pollution in the metropolitan area of Berlin, Germany. *Respiratory Research*, 23(1), Article 1. <https://doi.org/10.1186/s101-10-001-10>

- Hooyberghs, H., Craemer, S. D., Lefebvre, W., Vranckx, S., Maiheu, B., Trimpeneers, E., Vanpoucke, C., Janssen, S., Meysman, F. J. R., & Fierens, F. (2022). Validation and optimization of the ATMO-Street air quality model chain by means of a large-scale citizen-science dataset. *Atmospheric Environment*, 272, 118946. <https://doi.org/10.1016/j.atmosenv.2022.118946>
- IDEAM. (2020). Report on the State of Air Quality in Colombia 2019. Bogotá, D.C., 2020. <http://documentacion.ideam.gov.co/openbiblio/bvirtual/023898/023898.pdf>
- Jayaraj, R., Rodriguez, E., Wang, Y., & Block, M. (2017). Outdoor Ambient Air Pollution and Neurodegenerative Diseases: The Neuroinflammation Hypothesis. *Current Environmental Health Reports*, 4. <https://doi.org/10.1007/s401-10-01-10>
- Kuklinska, K., Wolska, L., & Namiesnik, J. (2015). Air quality policy in the U.S. and the EU – a review. *Atmospheric Pollution Research*, 6(1), 01-10. <https://doi.org/10.5094/APR.2015.015>
- Ocampo López, Javier (2008). Paulo Freire and the pedagogy of the oppressed. *Journal of the History of Latin American Education*, no. 10, 2008, pp. 01-10. Pedagogical and Technological University of Colombia. Boyacá, Colombia. <chrome-extension://efaidnbmnnnibpcajpcgclefindmkaj/https://www.redalyc.org/pdf/869/86901005.pdf>
- Patiño Solfredy, D. (2025). The impact of environmental education on the construction of a sustainable society. *Ciencia Latina Revista Científica Multidisciplinar*, 9(3), 01-10. https://doi.org/10.37811/cl_rcm.v9i3.17553
- Pestel, N., & Wozny, F. (2021). Health effects of Low Emission Zones: Evidence from German hospitals. *Journal of Environmental Economics and Management*, 109(102512). <https://doi.org/10.1016/j.jeem.2021.102512>
- Sandoval Dueñas, A. C., Quintero Giraldo, C., Salcedo Portilla, C., Rincón, J., Villa Velasco, C. C., Ramírez Acosta, D. del P., Sarmiento Cruz, G. L., Pineda Rincón, I. A., Sánchez Zoque, L. M., & Acosta Serrano, V. I. (2021). Air Quality and Citizen Science: A Shared Exercise for Environmental Justice. In *Green Ideas* (No. 31). Heinrich Böll Foundation, Bogotá – Colombia Office. <https://co.boell.org>
- Santos, B. de S. (2018). *The end of the cognitive empire: The coming of age of epistemologies of the South*. Duke University Press
- Schaefer, T., Kieslinger, B., & Fabian, C. M. (2020). Citizen-Based Air Quality Monitoring: The Impact on Individual Citizen Scientists and How to Leverage the Benefits to Affect Whole Regions. *Citizen Science: Theory and Practice*. <https://doi.org/10.5334/cstp.245>
- Sterling, S. (2010). Transformative learning and sustainability: Sketching the conceptual ground. *Learning and Teaching in Higher Education*, (5), 17–33.
- World Health Organization. (2021). WHO global air quality guidelines: Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. <https://www.who.int/publications/i/item/9789240034228>