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Effective communication of scientific data in a citizen science project, the EduCITY

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Abstract Air pollution, although decreasing, remains a significant risk in European cities and continues to have serious health effects on the population. This issue is well covered in the media but is still misunderstood and raising public awareness remains a challenge. EduCITY is an educational project that uses mobile game-based learning, augmented reality, and low-cost air quality sensors to promote education for sustainability. The project develops interdisciplinary educational games on different sustainability topics. Games related to air pollution can be played using environmental sensors. However, the public often cannot interpret raw scientific data because they do not have the necessary knowledge. Therefore, an air quality index needs to be developed to enable a correct interpretation of the data. This work aims to develop an air quality index that translates quantitative data into qualitative information that can be understood by school-aged population. To this end, a literature review of work on communicating air pollution data and related health effects to the public is presented. The review is conducted using Google search engine (for websites and grey literature) on the following topics: “citizen science”, “communication of scientific data”, and “air quality index”. The result is a framework of current good practices for pollution indices and their communication to the public. Currently, most indices are based on legal values and traffic light-like color scales and are not applicable in the context of citizen science. The newly proposed indices must consider the shorter signal acquisition time of the EduCITY sensors, which differs from the design of most common indices. Based on these results, an air quality index is proposed to inform a school-aged audience in an understandable way about the level of pollution detected by the sensors and their potential health effects.

Keywords: Air Quality Index, Citizen Science, Communication of Scientific Data, Environmental Awareness

Introduction

The world’s population is growing rapidly, and it is estimated to have reached 8 billion in 2022 and will reach 10 billion by 2059 (Gaigbe-Togbe et al., 2022). *Although cities cover only 2% of the Earth's surface, they are home to 56% of the world’s population, and this is expected to rise to 68% by 2050* (Neil et al., 2022). *The combination of these two factors leads to a greater concentration of anthropogenic activities in*

the urban areas. As these activities generate negative externalities that resolt in the deterioration of the urban environment, with an increase in problems such as air pollution.

Estimates show that air pollution is the fourth largest risk to human health, surpassed only by high blood pressure, poor dietary habits, and smoking (Juginović et al., 2021). *Although air pollution has decreased in most developed countries, it remains a significant problem. According to the World Health Organization (WHO) air quality guidelines, it is estimated that 95% of Europe's urban population is exposed to concentrations of ozone (O_3) above the limit values, 96% for particulate matter 2.5 microns or less in diameter (PM2.5), and 89% for nitrogen dioxide (NO_2)* (European Environment Agency (EEA), 2020).

Smart cities address these and other sustainability issues (Addas, 2023). Broadly speaking, the concept refers to cities that use information and communication technologies to improve their services and infrastructure, thereby increasing the overall efficiency of the city. The aim is to create a more livable city, characterized by a clean environment, a sustainable economy, and an improved quality of life (Alawadhi te al., 2012; Sharif & Pokharel, 2022). *Environmental sensors are one of the tools used to implement urban pollution reduction strategies.*

To develop an action plan to combat environmental pollution, it is necessary to have comprehensive knowledge of the problem to solve (sources, causes, effects, etc.). This is done through environmental monitoring. Only then is it possible to develop a strategy on how to reduce pollution in the most efficient way. Traditional environmental monitoring is carried out using reference methods, which are expensive due to the cost of the equipment and the need for specialized staff to operate it. This high cost limits the ability to carry out environmental monitoring activities and results in monitoring being sparsely distributed in time or space. Air pollution has high temporal and spatial variability, which means that traditional monitoring methods are not sufficient to fully understand them (Gelb & Apparicio, 2020; Hassani et al., 2023).

Over the last decade, advances in low-cost sensing capabilities have enabled a paradigm shift in environmental monitoring, with good sensor performance results (Borrego et al., 2016; Picaut et al., 2020). *The ability to carry out sensing activities at low-cost opens new opportunities: an increase in sensing capabilities allowing for higher temporal and special resolution, the ability of citizens or communities to take measurements in collaboration with scientific institutions or for personal use, and the ability to use sensors for educational purposes in a wider range of contexts* (Picaut et al., 2020).

Now more than ever we are exposed to news about environmental problems, especially air quality. In addition, the effects of air pollution are clear and well documented by scientific research. Yet, public awareness of these issues is far from where it should be, with the public often ignoring their personal exposure, either by denying the negative effects or by neglecting their exposure. In most cases, air pollution is not perceptible to the human eye. Perception of risk is highly dependent on sensory awareness and experience of the effects of such exposure. If pollution cannot be perceived visually, olfactorily, or aurally, its risks are usually not perceived by the public (Marquart et al., 2022). *Public awareness is crucial for several reasons, for example, road traffic is the main source of air pollution in cities, so public engagement in the adoption of softer means of mobility is essential to improve environmental quality. A false perception of pollution is an obstacle to the implementation of good practices because of a lack of understanding of the urgency of doing so. The risk of air pollution cannot be fully perceived by the layman, hence the importance of good environmental education on these issues.*

The EduCITY project

This work is part of the EduCITY project, an environmental education project funded by FCT- Fundação para a Ciência e Tecnologia (PTDC/CED-EDG/0197/2021). EduCITY uses game-based learning to promote education for sustainability. This project aims to empower participants, including school-age children, to make informed, sustainable decisions by playing games on sustainable development. The games are structured as a quiz with multiple-choice questions. After each question, the user receives immediate feedback, as to whether the question is correct or incorrect. The games are played in urban pathways with questions posed at different points of interest where the user needs to be to answer them. Throughout the game, the user is invited to interact with different resources such as augmented reality, images, and videos. These are used as learning tools, as the resources may contain the answers to the questions. In games related to air quality, there is an option to pair the app with environmental sensors. The sensors will then accompany the users during the game, allowing them to measure two parameters of the environmental quality of their surroundings.

The EduCITY sensors are the Plantower PMS5003, which measures the concentration of particulate matter $PM_{2.5}$ and PM_{10} in $\mu g/m^3$. The sensors are connected to an ESP32 microcontroller, which provides Bluetooth connectivity, displays the sensor's readings, and is coupled to a battery that provides approximately 5 hours of remote use. This equipment is mounted in sensor boxes as shown in Figure .

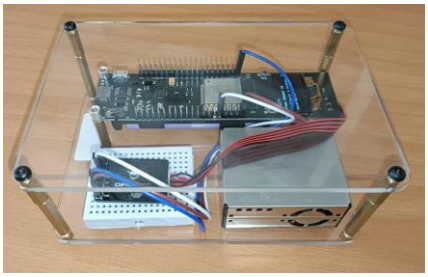

Figure 1- Example of the EduCITY PM Sensor Box

Using the sensors together with the EduCITY app and the educational games allows users to explore their curiosity by observing in the real world what they are learning.

However, the public often lacks the knowledge to interpret raw scientific data (Gupta & Eden, 2022). A concentration of pollutants only means something if you understand it as high, low, or harmful to human health, otherwise, it is just a number. It is therefore necessary to translate the quantitative data into qualitative information, which describes the severity of the pollution and can convey potential health effects. Air quality indices (AQI) are used to estimate the level of risk associated with a given concentration of pollutants. This is usually done using words such as "good" or "moderate" along with traffic light-like color codes (Gupta & Eden, 2022; Sowlat et al., 2011).

Currently, most AQIs are designed based on regulatory values, considering hourly averages. This is not compatible with the EduCITY app and sensors. Games are designed to last approximately one hour, and players are constantly moving between points of interest and sensors that have signal acquisition periods shorter than one hour.

In this sense, this work aims to develop an AQI that enables the interpretation of low-cost sensors data in the EduCITY app.

Methodology

The literature review is developed to summarize current practices in public communication on air quality data via AQI. To this end, a grey literature review is conducted to understand how different projects, governmental agencies or civil society use environmental data to promote public awareness. This search is made in English and Portuguese.

The research question that this study aims to answer is: "What are the current practices in the communication of scientific data to the public from air pollution sensors via indices?".

The search was conducted in December 2023, entering separately the following search equations on Google Search Engine:

a) "air quality index" OR "air pollution index",

b) "índice de qualidade do ar" OR "índice de poluição atmosférica".

The review method used is the integrative review adapting the methodology proposed by Tavares De Souza et al. (2010). This methodology was chosen because it enables a creative approach to data collection that enables the generation of new knowledge. This type of review critically looks at existing literature en-

abling the formation of new frameworks or perspectives (Renner et al., 2022) while enabling the combination of different types of studies (Tavares De Souzaet al., 2010). For the literature search, the used methodology is adapted from Katelyn Godin et al. (2015).

Searching in platforms like Google Search Engine can be overwhelming due to the number of search results, so it is essential to limit the admitted results by relying on Google to rank results, presenting the most relevant at the top of the list. Due to Google's lack of ability to combine all search terms in one search, there is the need for conducting various searches, making it essential to reduce the number of accepted results in each search. (Godin et al., 2015). This research will be limited to the first 25 results of each entered prompt. The results will be selected according to the criteria presented in Table 1.

Table 1 – Inclusion and exclusion criteria for search results in Google Search Engine.

Inclusion criteria	*Exclusion criteria*
It concerns the use of at least an index	*It does not cover the use of at least an index*
It concerns outdoor pollution	*Concerning indoor pollution*
It concerns the urban environment	*It does not cover the urban environment*
It concerns the use of environmental data to improve public awareness	*It does not concern the use of environmental data to improve public awareness*
It presents the most updated version of the information	*It presents an outdated version of the information*

Results

The search equations a) and b) resulted, after selection according to the exclusion criteria and exclusion of duplicates, in 16 websites related to air quality. The results of this search are summarized in Tables 2 and 3. These tables summarize the AQI used in each website with a focus on $PM_{2.5}$ and PM_{10} because these are the pollutants of interest for the EduCITY project.

Table 2. Summary of the results of the search in English related to air quality.

Website	*Index*					*Method*
	Description	*Concentration interval [μg/m³]*		*Recommended Actions/ Health Advice/ *PM specific recommendations.*		
		$PM_{2.5}$	PM_{10}	*At-risk individuals*	*General population*	
(World's Air Pollution: Real-Time Air Quality Index, n.d.) The used index is the US EPA (United States Environmental Protection Agency) Air Quality Index						
(IQAir, n.d.) The used index is the USA EPA Air Quality Index						
US EPA - Air Quality Index (AQI) Basics (U.S. EPA, n.d.)	*Good*	*0-12*	*0-54*	**None*		*The average period considered for the index depends on the variability of the air quality. More variability means shorter average. Index is calculated considering the worst pollutant.*
	Moderate	*12.1-35.4*	*55-154*	**"Should consider reducing prolonged or heavy exertion"*	-	
	Unhealthy for sensitive groups	*35.5-55.4*	*155-254*	**"Should reduce prolonged or heavy exertion."*	-	
	Unhealthy	*55.5-150.4*	*255-354*	**"Should avoid prolonged or heavy exertion."*	**"Should reduce prolonged or heavy exertion."*	
	Very Unhealthy	*150.5-250.4*	*355-424*	**"Should avoid all physical activity outdoors"*	**"Should avoid prolonged or heavy exertion."*	
	Hazardous	*250.5-500.4*	*425-604*	**"Should remain indoors and keep activity levels low."*	**"Avoid all physical activity outdoors."*	
	Good	*0-10*	*0-20*	*"The air quality is good."*		

"European Air Quality Index: current air quality information at your fingertips" (European Environmental Agency, n.d.)	Fair		10-20	20-40	"Enjoy your usual outdoor activities."	PM2.5 bands of concentration are based on WHO short-term risks. PM10 bands of concentration are defined by a 1:2 ratio [PM2.5: PM10]. Overall index corresponds to the worst score. A 24h-mean is used to calculate the index for for PM.
	Moderate		20-25	40-50	"Consider reducing intense outdoor activities if you experience symptoms." / "Enjoy your usual outdoor activities."	
	Poor		25-50	50-100	"Consider reducing physical activities, particularly outdoors, especially if you experience symptoms." / "Consider reducing intense activities outdoors, if you experience symptoms such as sore eyes, a cough, or sore throat"	
	Very Poor		50-75	100-150	"Reduce physical activities, particularly outdoors, especially if you experience symptoms." / "Consider reducing intense activities outdoors, if you experience symptoms"	
	Extremely Poor		75-800	150-1200	"Avoid physical activities outdoors." / "Reduce physical activities outdoors."	
AQI (AIQ, n.d.)	Good		See the USA EPA Air Quality Index		"The air is fresh and free from toxins. People are not exposed to any health risk"	-
	Moderate				"Mild threat to sensitive individuals" / "Acceptable air quality for healthy adults"	
	Poor				"Inhaling such air can cause slight discomfort and difficulty in breathing."	
	Unhealthy				Problematic for at-risk individuals / -	
	Severe				"Exposure to air can cause chronic morbidities or even organ impairment."	
	Hazardous				"Beware! Your life is in danger. Prolonged exposure can lead to premature death."	
What is the Daily Air Quality Index? (UK Department for Environment Food & Rural Affairs, n.d.)	Low	1	0-11	0-16	"Enjoy your usual outdoor activities." / "Enjoy your usual outdoor activities."	The concentration of each pollutant is compared to the respective interval (based on recommendation by the Committee on Medical Effects of Air Pollutants). The overall index corresponds to the worst score. AQI is calculated using a 24-hour running mean for PM2.4 and PM 10.
		2	13-23	17-33		
		3	24-35	34-50		
	Moderate	4	36-41	51-58	"People who experience symptoms should reduce strenuous physical activity, particularly outdoors." / "Enjoy your usual outdoor activities."	
		5	42-47	59-66		
		6	48-53	67-75		
	High	7	54-58	76-83	"Reduce strenuous physical exertion, particularly outdoors (...). People with asthma may (...) use their inhaler more often." / "Anyone experiencing discomfort such as sore eyes, cough or sore throat should reduce activity, particularly outdoors."	
		8	59-64	84-91		
		9	65-70	92-100		
	Very High	10	71+	101+	"Should avoid strenuous physical activity." / "Reduce physical exertion, particularly outdoors, especially if you experience symptoms"	
Spare the air - San Francisco Bay Area Air Quality Status (Bay Area Air Quality Management District, n.d.) The used index is the USA EPA Air Quality Index						
Air quality index - Air Quality Index for Western Australia	Good		0-25	0-50	*"No change needed to your normal outdoor activities"	AQI for PM10 and PM2.5 is based on clock hour aver-
	Fair		25-50	50-100	*"Reduce outdoor physical activity if you develop symptoms (...). Follow the treatment plan recommended by your doctor." / *"No change needed to your normal outdoor activities"	

(Government of Western Australia Department of Water and Environmental Regulation, 2023)	Poor	50-100	100-200	*"Avoid outdoor physical activity if you develop symptoms (...). When indoors, close windows and doors (...). Follow your treatment plan (...)."	*"Reduce outdoor physical activity if you develop symptoms like cough or shortness of breath."	ages. AQIs represent the concentration of the gaseous pollutants based on National Environment Protection (Ambient Air Quality) Standard reached for each gas pollutant and Health advice on one-hour averaged particle concentrations.
	Very Poor	100-300	200-600	*"Stay indoors as much as possible with windows and doors closed (...). If you feel (...) uncomfortable, consider going to a place with cleaner air (air-conditioned building) (...). Actively monitor symptoms and follow the treatment plan (...)."	*"Avoid outdoor physical activity if you develop symptoms (...)." "When indoors, close windows and doors until outdoor air quality is better."	
	Extremely Poor	300+	600+	*"Stay indoors as much as possible (...). If you feel (...) uncomfortable, consider going to a place with cleaner air (air-conditioned building) (...). Actively monitor symptoms and follow any treatment plan (...)."	*"Stay indoors as much as possible (...). If you feel that the air in your home is uncomfortable, consider going to a place with cleaner air (air-conditioned building) (...)."	
Air Quality Index (Finnish Meteorological Institute, n.d.)	Good	0-10	0-20	"No known impacts."		"Is an hourly index which describes the air quality today (...). (...) the highest sub-index determines the overall index (...)."
	Satisfactory	10-25	20-50	"Very unlikely"		
	Fair	25-50	50-	"Unlikely"		
	Poor	50-75	100-200	"Sensitive individuals may experience adverse effects"		
	Very poor	75+	200+	"Sensitive population may experience adverse effects"		
British Columbia - Air Quality Health Index	Low Risk	1	0-5	0-10	Enjoy your usual outdoor activities.		"Reports on the health risks posed by a mixture of pollutants, including PM2.5 Ground-level"
		2	15-5	10-20			
		3					
	Moderate Risk	4	15-25	20-30	Consider reducing or rescheduling strenuous activities outdoors if you are experiencing symptoms.	No need to modify your usual outdoor activities unless you experience symptoms.	
		5	25-40	30-40			
		6	40-60	40-50			
	High Risk	7	60-80	50-150	Reduce or reschedule strenuous activities outdoors. Children and the elderly should also take it easy.	Consider reducing or rescheduling strenuous activities outdoors if you experience symptoms such as coughing and throat irritation.	
		8	60-80				
		9	80-100				
		10	250-500				
	Very High	+	500+	150+	Avoid strenuous activities outdoors. Children and the elderly should also avoid outdoor physical exertion.	Reduce or reschedule strenuous activities outdoors, especially if you experience symptoms.	

Table 2. Summary of the results of the search in Portuguese related to air quality.

Website	Index					
	Description	Concentration interval [$\mu g/m^3$]		Recommended Actions/ Health Advice/ *PM specific recommendations.		Method
		$PM_{2.5}$	PM_{10}	At-risk individuals	General population	
	Very Good	0-10	0-20	None		The concentration of each pollutant

Relatório do Estado do Ambiente- Índice de Qualidade do Ar (APA, 2023)	*Good*	*11-20*	*21-35*	*None*		*is compared to the respective intervals. The overall index corresponds to the worst classification. Based on European legislation (2001 to 2010) and revised according to new WHO recommendations on pollutants concentration.*
	Average	*21-25*	*36-50*	*Very sensitive people, with respiratory diseases, should limit outdoor activities.*	*None*	
	Weak	*26-50*	*51-100*	*Should avoid intense outdoor physical activity. Respiratory and cardiovascular patients should follow the treatment and seek extra care in the case of symptoms.*	*Should avoid other risk factors.*	
	Bad	*51-8000*	*101-1200*	*Should stay at home with the windows closed.*	*Avoid outdoor physical exertion.*	
QualAr - Informação sobre qualidade do ar (APA, n.d.) The used index is the Relatório do Estado do Ambiente- Índice de Qualidade do Ar						
Relatório do estado do ambiente dos Açores (Direção Regional do Ambiente e Alterações Climáticas, n.d.) The used index is the Relatório do Estado do Ambiente- Índice de Qualidade do Ar						
Índice de Qualidade do Ar – IQAr (Instituto Estadual De Meio Ambiente E Recursos Hídricos (Iema), 2023)	*Good*	*0-25*	*0-50*	*May present symptoms (dry cough, tiredness).*	*No effects.*	*The concentration of each pollutant is compared to the index intervals. The overall index corresponds to the worst classification obtained. Health effects of air quality as established in the law decree Decreto Estadual Nº 3463-R/2013.*
	Moderate	*25-50*	*50-100*	*Extremely sensitive groups may experience symptoms and should avoid prolonged or strenuous outdoor activities.*		
	Bad	*50-75*	*100-150*	*May present more serious health effects and should avoid prolonged or strenuous outdoor activities.*	*May present symptoms such as dry cough and tiredness.*	
	Very Bad	*75-125*	*150-250*	*May present more serious health effects and should avoid prolonged or strenuous outdoor activities.*	*May present worsening of symptoms (burning in the eyes nose and throat and shortness of breath). Should reduce outdoor activities.*	
	Terrible	*125+*	*250+*	*Increase in premature death. Should avoid outdoor activities.*	*Increase in the risk of cardiovascular and respiratory diseases. Should avoid outdoor activities.*	
Qualidade do Ar Atual (Accuweather, n.d.)	*Excellent*	*0-5*	*0-15*	*“No risk”*		*The overall index corresponds to the worst classification obtained considering all measured pollutants. Health thresholds and limit values from WHO guidelines, legislation, and EPA guidelines from multiple*
	Fair	*5-15*	*15-45*	*"Risk in case of chronic exposure. (...) Minor to moderate symptoms from long-term exposure."*	*"The air quality is generally acceptable"*	
	Poor	*15-30*	*45-80*	*"(...) unhealthy for sensitive groups.*	*"Reduce time spent outside if you are feeling symptoms(...)"*	
	Unhealth	*30-60*	*80-160*	*"Health effects can be immediately felt by sensitive groups."*	*"May experience difficulty breathing and throat irritation with prolonged exposure. Limit outdoor activity"*	

	Very unhealthy	60-150	160-400	"Health effects will be immediately felt by sensitive groups and should avoid outdoor activity."	"May experience difficulty breathing and throat irritation. consider staying indoor (...)."	countries and scientific studies.
	Dangerous	150+	400+	"Any exposure to the air, even for a few minutes, can lead to serious health effects on everybody. Avoid outdoor activities."		
IQAr - Índice de Qualidade do Ar (Secretaria do Meio Ambiente e Infraestrutura Governo de Rio Grande do Sul, n.d.)	Good	0-25	0-50	Negligible effects.		Index intervals are based on Brazilian National Patterns of Air Quality. The overall index corresponds to the worst classification obtained. The index is based on 24-hour averages.
	Regular	26-60	51-120	May present symptoms like chest pain, dry cough, and tiredness.	-	
	Inappropriate	61-124	121-249	Symptoms are worsened. Should reduce outdoor strenuous activities.	May present symptoms. Should reduce outdoor strenuous activities.	
	Bad	125-209	250-419	Avoid areas with high intensity of traffic if symptoms are worsened. Should avoid outdoor strenuous activities without due precautions in proximity of industrial areas.		
	Terrible	210-249	420-499	Risk of premature death. Should avoid outdoor strenuous activities without due precautions and avoid areas with high intensity of traffic or in proximity of industrial areas.	Significative increase of symptoms. Should avoid outdoor strenuous activities without due precautions and avoid areas with high intensity of traffic or in proximity of industrial areas.	
	Critical	250+	500+	Increased risk of premature death. Should be especially careful.	Serious risk of manifestation of respiratory disease. Should avoid outdoor strenuous activities without due precautions and avoid areas with high intensity of traffic or in proximity of industrial areas.	

The search allowed the identification of 16 results that use AQI to communicate air quality data to the general population. These indices differed by the colors used, the concentration intervals considered, the health advice, and the number of intervals. Some of the indices opt to divide the index only by categories while others also attribute number scales to convey the severity (from 0 to 10; or from 0 to 500).

The number of intervals per index varies from four to six. The two indices that have four intervals (low, moderate, high, and very high) further subdivide them into subindices that are identified by a different color and a number scale (from 1 to 10). The four indexes that have five intervals divide one of the previously mentioned intervals. Five indexes have six categories, they divide two of the categories. The division of intervals enables health advice that is better suited to the potential health effects of the pollutant. In low concentration intervals, the minimal threshold that may cause harm is better defined, and in higher concentration intervals the severity of different concentrations of pollutants may be better communicated. Some indexes have specific health advice for specific pollutants, like particulate matter. In general, the colors chosen to illustrate the risk vary from lighter colors (like green, yellow, and orange) to darker colors (like red, purple, brown, and black). There is great variability in the colors used. In some cases, blue substitutes green at low concentration intervals, and bright colors, like pink, might be used to illustrate high concentrations of pollutants.

The indices are based on WHO guidelines regarding health consequences of air pollution, US EPA, EEA, or other environmental protection agencies guidelines, and legislation. These guidelines and the indexes that are based upon them consider the health effects of at least 1 hour exposure to air pollutants, meaning the described health effects of at least one hour exposure to air pollution. Each index considers different time averages, and some indices alternate between shorter-term averages when the air quality is more variable and longer-term averages when air quality is more constant. The indices are developed for periods equal

to or greater than 1 hour. When using low-cost sensors under the conditions of the EDUCITY project, measurements are made for periods of minutes. Therefore, it is necessary to consider the risk level information they communicate as indicative of short-term exposure.

Most indices divide health advice for the general population and for sensitive groups. Despite several differences between the different health recommendations, it can be summed up in some groups. The health advice for the first concentration interval (very good/ good) is usually regarded as having no or very little health impacts and good for outdoor activities. In the next interval (regular/ moderate) sensitive population might experience light symptoms and are advised to limit strenuous outdoor activities with no advice for the general population. In the next level, (bad/ weak) sensitive group symptoms are worsened and should be observed, reduction of strenuous outdoor activities is recommended, and heavily polluted areas and other risk factors should be avoided, general population may have symptoms and, in that case, are advised to limit extraneous outdoor activities. In the next level (bad/ very bad) sensitive group symptoms are worsened and there is an increase in premature death, sensitive groups should limit all strenuous activities, observe symptoms, follow prescribed medical treatments, and stay indoors as much as possible. In the general population symptoms are worsened should avoid strenuous activities, limit outdoor time, avoid other risk factors, and when indoor close the doors and windows until air quality is better for sensitive groups. In some cases, there is an additional category (dangerous/ very critical) for cases in which even a few minutes of exposure can have health effects and increase the risk of premature death. This is more common in indexes designed for heavily polluted regions. Some indices have heath advice specific for certain pollutants like PM describing the health effects of exposure to such pollutants.

All the indices consider several pollutants for its calculation, but the considered overall index corresponds to the worst classification of all pollutants. The US EPA AQI is the most used index (6 of the 16 results), being used with some adaptations or integrally.

Discussion

An AQI is designed to communicate air quality forecasts and measurements to the population. When designing it there is the need to understand the target audience. In a heavily polluted environment, an index that uses concentration intervals designed for a low pollution environment may be ineffective. In this case, the reported index would be critical/ very bad most of the time, and the audience would have been advised to take extreme precautions. This may result in a disregard of the index because of its impracticability. At the same time, the index must reflect the health impacts of pollution exposure. An AQI is designed based on scientific knowledge, but the execution needs to consider its effectiveness in communicating with the audience. For these reasons, there is great variability between several AQI worldwide.

When designing an AQI several factors are usually taken into consideration: current knowledge of the health impacts of the exposure to air pollution, legislation regarding air quality guidelines, air pollution patterns of the area of interest, and the target audience of the index.

EduCITY AQI will be used in Aveiro, a medium size city in the center of Portugal, by school-aged children. The index must consider the WHO air quality related health guidelines, European air quality guidelines, Portuguese references regarding AQI, the age of the audience (school-aged children), the measured pollutants, and the characteristics of the EduCITY sensors.

The concentration intervals will be developed by harmonizing the EEA AQI, which observes WHO latest recommendations and European guidelines, with the Portuguese EPA AQI in other to reduce the differences between the user experience with EduCITY AQI and the Portuguese official index. The health advice will be developed considering these two indices, US EPA and Department of Water and Environmental Regulation of the Government of Western Australia PM specific health advice. Health advice/ recommended actions will be developed for the target audience. Finally, the health advice needs to reflect the exposure time that they are referring to and the difference to the data that is being used to calculate the index.

The AQI proposed for the EduCITY app is illustrated in Table 4.

Table 4. Air quality index proposal for the EduCITY app

Description	*Concentration interval [μg/m³]*		*Recommended Actions/ Health Advice*
	$PM_{2.5}$	*PM_{10}*	
Very Good	*0-10*	*0-20*	*Air quality is very good. No health risks.*
Good	*11-21*	*21-40*	*Enjoy your day as usual.*
Moderate	*21-25*	*41-50*	*Sensitive people (ex. respiratory diseases) may experience symptoms in prolonged exposure (>1h). Reduce intense outdoor activities if experiencing symptoms.*
Poor	*26-50*	*51-100*	*Prolonged exposure (>1h) may worsen symptoms. Risk groups (ex. respiratory diseases) should avoid outdoor physical activities. General population should avoid other risks and reduce outdoor physical activities.*
Bad	*50-75*	*101-150*	*Risk groups and others, experiencing symptoms, should stay indoors as much as possible. Outdoor physical activities should be avoided.*
Very Bad	*75-800*	*151-1200*	*Dangerous for risk groups (avoid physical activity). Stay indoor as much as possible with windows closed especially if experiencing symptoms.*

Conclusion

Air pollution continues to be one of the greatest health risks to the urban population, but it remains misunderstood despite its impacts. Smart cities with environmental monitoring capabilities may play a crucial role in identifying such problems and developing efficient solutions. Current air quality monitoring systems are expensive, limiting monitoring capabilities. The results of these monitoring activities are slow and inefficient in raising public awareness in the population. Citizen science and low-cost sensors have demonstrated great potential for improving monitoring capabilities and raising population awareness.

The EduCITY project uses GBL to promote education for sustainability. The EduCITY app can be connected to low-cost environmental sensors, combining GBL with citizen science. When presented with scientific data, citizens may not have the necessary knowledge to interpret it. Therefore, it is essential to convey the results of the low-cost sensors in an understandable way. AQI represents a way of translating the sensors' quantitative information into a qualitative description that relates it in an understandable way to health risks and recommendations.

A grey literature search was conducted to understand the current practices in the communication of results from air quality sensors using indices. The search resulted in 16 indices that varied in the number of intervals, the subdivision of intervals, the colors used to illustrate the risk scale, the health effects/advice, and the description of air quality. Most of the indices are based on WHO air pollution guidelines and local air quality guidelines, legislation, and patterns. These parameters are based on evidence of the effects of at least one hour of exposure to pollutants which is not compatible with results from low-cost sensors, that typically have shorter acquisition periods. This search resulted in a set of guidelines that were followed to develop an AQI adjusted to the needs of the EduCITY project.

In future work a scientific literature search should be made to complement this work, the index should be evaluated for its efficacy in the communication of scientific data and for its potential in environmental education.

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