https://doi.org/10.5194/egusphere-2025-3118
Preprint. Discussion started: 25 September 2025

Make the invisible visible: Reveal the Magnetic Field and Air Pollution to Foster Engagement in a Community-based Participatory Research Project

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Abstract. Citizen science is increasingly recognized as essential for engaging the public in participatory sustainability research and for addressing the complex challenges of the Anthropocene. However, fostering meaningful dialogue between science and society remains difficult, often hindered by limited opportunities for interaction and varying levels of scientific understanding. Identifying outreach formats that foster citizen engagement and initiate productive exchanges between scientists and the public is therefore a key challenge.

Here we present a hands-on science outreach workshop, based on environmental magnetism methods and conducted at schools and science fairs, that encourages citizen participation in air monitoring projects. We conducted the workshop between 2018 and 2023, reaching 850 people at 9 scientific outreach events and 195 children at 3 elementary schools. The workshop prompted more than 150 people to participate in the associated NanoEnvi community-based participatory research project, which offers to host passive biosensors in their homes or at school for a year. The workshop includes three hands-on demonstrations and experiences. It proposed to discover the magnetic phenomena, to extract airborne magnetic particles from soils, and to measure air pollution trapped on bark like a scientist. The workshop was also accompanied by lectures and an exhibition.

We observed that the workshop fostered two-way dialogue between researchers and a wide range of participants, creating opportunities for shared experimentation and knowledge co-production. We found that the positive emotions raised by experimenting and playing with magnetic phenomena during the workshop led to engagement in a participatory project on

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potential air pollution in urban surroundings. Our findings demonstrate that hands-on geoscience outreach activities have a positive impact on the science-society dialogue.

1 Introduction

Citizen sciences have emerged as a powerful tool to engage the public and bridge the gap between scientific research and society (OECD, 2020). By involving citizen in research projects related to pressing societal issues, they contribute to a better understanding of current challenges and foster inclusive knowledge production. One of the key aspects of this dynamic is the need to establish a constructive dialogue between science and society, especially to address anthropogenic problems such as air pollution (Carvallo et al. 2024; Mahajan et al., 2020; Rickenbacker et al., 2019) and climate change (Kitchen, 2023). However, this dialogue is often hindered by misunderstandings and different levels of awareness, which can lead to mistrust in science, and even defiance, particularly in relation to pollution or climate change (Oreskes, 2019).

Involving citizens—non-professional researchers—in the research process is increasingly recognized as a way to strengthen this connection (Clark and Cornes, 2023; Vohland et al., 2021). Their participation can enrich research with new perspectives, improve transparency, and support more inclusive scientific practices. But participation cannot be assumed; it must be actively encouraged (ref). To promote citizen participation in geosciences, researchers need effective and accessible approaches (Jönsson et al., 2024; Loroño-Leturiondo et al., 2019). Among these, hands-on outreach activities may offer a promising way forward. How can such experiences foster citizen engagement and initiate a productive dialogue between science and society? Here we show that our hands-on science outreach workshop, based on environmental magnetism methods and conducted at schools and science fairs, encourages citizen participation in a community-based participatory research air monitoring project. We found that the workshop fostered two-way dialogues between researchers and participants of all kinds. We found that the positive emotions raised by experimenting with magnetic phenomena during the workshop reduced the anxiety caused by the awareness of potential air pollution in urban surroundings. Our findings demonstrate that hands-on geoscience outreach activities have a positive impact on the science-society dialogue.

2 Methods

2.1 Context of the NanoEnvi project: a community-based participative research project

The NanoEnvi project is a community-based participative research project (Leite et al., 2022; Macouin et al., 2023) aimed at measuring air quality with environmental magnetism methods, inside and outside domestic homes and classrooms in the city of Toulouse. The project involved the participation of residents and classrooms hosting passive sensors for 1 year between 2018 and 2019. The passive biosensors consist of garlands composed of 5/6 ~4 cm2 squares of *Platanus* × *acerifolia* species bark pieces that are suspended from a nylon thread. The Plane tree bark used to build the bio-sensors was collected in areas far from traffic perturbations (Leite et al., 2022). Each participant or classroom received two biosensors to be placed indoors and outdoors (in the facade).

To promote participation, we set up an engaging, hands-on science workshop, which is presented in this article. This workshop illustrates the method for measuring environmental magnetism (Chaparro et al., 2023; Dawaï et al., 2021; Letaïef et al., 2023) using passive biosensors (Leite et al., 2022).

2.3 Evaluation and Ethical Considerations

We evaluate the impact of the workshop by considering the number of actual registrations in the NanoEnvi project, whenever appropriate. We evaluated the outreach events based on the total number of attendees rather than the ratio of attendees to registrations, as our objective was not to maximize participation but to share our scientific approach as broadly and inclusively as possible. Particular attention was given to the type of audience reached, including schools in priority education zones and community centers in neighborhoods with predominantly immigrant populations, with the aim of engaging groups who do not typically attend science outreach events. Our goal was to promote encounters and get our experiences out of the laboratory. Both undergraduate and graduate students participated in the events (Table 1).

We assume that the commitment and testimonies of energy and general satisfaction of all those involved - students, researchers, teachers, and visitors - must be taken into account and discussed in the results. We decided not to propose a survey to evaluate the animation device to lighten the process and promote participation and engagement. The work with teachers (see Leite et al., 2022) helps to set up the researchers' interventions in schools. The interviews covered the entire participatory project, the first part of which was the workshop presented here.

We did not collect any personal information during the animation. The two teachers who answered a semi-structured interview were provided information about the research project and the possible publication.

3 Hands-on workshop

3.1 General structure and implementation

We performed the animation in several places (Table 1) from science festivals to small neighborhood events. We also carried it out in 3 schools in Toulouse (France) and in a social center (90 children) in Senegal. The purpose of the events was generally to explain the NanoEnvi project. It was therefore sometimes accompanied by an exhibition consisting of 12 posters, a video, lectures, and a communication campaign. In some cases, we were invited to carry out this animation outside the NanoEnvi project. We also deployed the workshop during a following community-based participative project in Senegal (see online scientific blog: https://airgeo.hypotheses.org/792).

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Event name and date	Duration (h)	Type of public	Organizer	Number of participants	Number of scientists / students	Within or outside the NanoEnvi programme	Motivation of event visitors	Talk	Q&A	Draw
European Researchers's Night Oct. 2023	5	general	Toulouse Federal University	200	2 / 2	outside	visit a general scientific festival	N	N	Y
Art-Science-Citizen Residence in Senegal Jan. 2022	3	children	local NGO / Scientists	90	3 / 0	outside / other CBPR program	attend scientific workshop	N	N	Y
Quai des savoirs: May 2019	4	general	Museum/ Toulouse	40	2 / 1	outside	visit a general scientific festival on sustainable develpment	N	Y	N
National Science Day – *GET laboratory* – Oct. 2018	3	general	Science laboratory	20	3 / 0	outside	visit a general scientific exhibition	N	N	N
ESOF 2018 - July 2018	15	general	EuroScience Open Forum	100	3 / 5	within	visit a general scientific festival	N	N	N
Empalot District Summer Event - June 2018	3	specific, district	Sceintists / local NGO	20	1 / 1	within	Attend a neighborhood event with children, a children's dance show, and a summer dinner	N	Y	N
Quai des savoirs: May, 2018	7	general	Museum/ Toulouse	50	2 / 1	outside	visit a general scientific festival	N	Y	N
Forum CNRS - June 2018	3	general	CNRS	30	2 / 1	within	scientific celebration of the national research agency CNRS	Y	Y	N
Project launch: *Quai des savoirs:* Apr. 2018	12	general	Sceintists / Museum	300	5 / 4	within / launch	participate in the NanoEnvi program	Y	Y	N
Schools										
March 2022, Elementary School, Ramonville, France	4h	elementary school / deaf and hearing-impaired children	Scientists / Teachers	20	3 + Teachers / Interpreters	outside	school	Y	Y	Y
Nov. 2018, Elementary School LL Toulouse	1h30 par classroom	elementary school	Scientists / Teachers	3 Class. ≃ 75 pupils	2 /0	within	school	Y	Y	Y
June and Nov. 2018, Elementary School JJ, Toulouse	5h	elementary school	Scientists / Teachers	4 class., ≃ 100 pupils	2 / 2	within	school	Y	Y	Y

Table 1: Synthesis of the workshop implementation. "Talk" is when a seminar is given by a researcher, "Q&A" means debate and open questions, "Draw" represents a proposition to draw. Y/N means Yes and No, respectively, "CBPR": Community-based Participatory Research. All events were held in Toulouse, France, except one in Senegal.

We present here the workshop set-up that was designed for the launch of the NanoEnvi participatory program. It comprises 4 independent sequences described below. To conceive the set-up, one of us (M.M.) conducted a preliminary test during the "European researcher's night" in 2013 in Toulouse (France). The test involved bark measurements made by children using a portable susceptibility meter. The four sequences of the workshop set-up were thought to explain the method and approach, make airborne particles visible, and let the magnetic phenomenon fascinate visitors (Table 2, Fig. 1).

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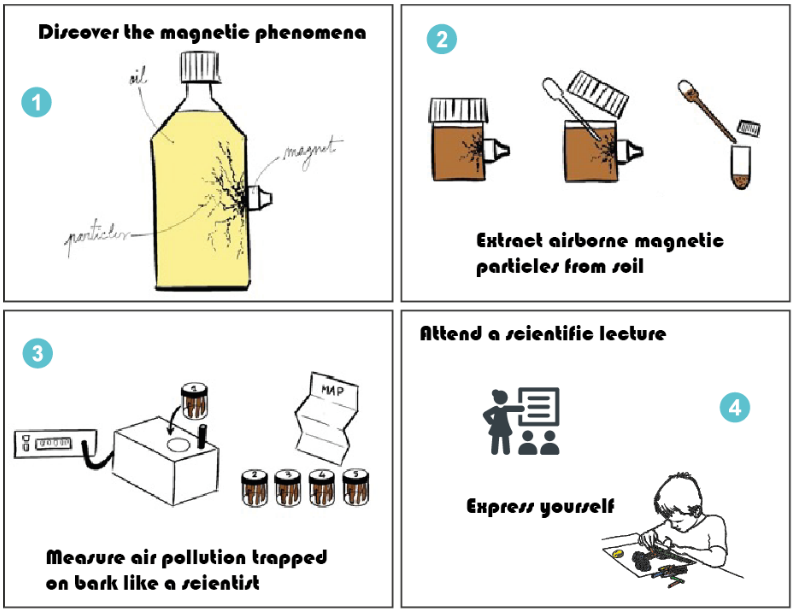

Figure 1: Schematic of the workshop presenting the 4 sequences.

The workshop was implemented in two main settings: 1- a large group (in schools) divided into four sub-groups subgroups that rotate through the 4 experiments for a given period of time, and 2- informally, without registration, at science fair stands.

Sequence	Sequence Name	question	reproductibility	interaction with public	number of attendants	easy engagement	possible context
1	Discover the magnetic phenomena	make visible the magnetic force	yes	moderate	1 to 20	high	Physics, Geosciences
2	Extract airborne magnetic particles from soil	make airborne magnetic particles visible	yes	high	1 to 8	moderate to high	General geosciences, Air pollution
3	Measure air pollution trapped on bark like a scientist	reveal the magnetic particles trapped on bark	need adaptation	high	1 to 8	moderate	Air quality / Environmental magnetism

Table 2: Characteristics of the NanoEnvi workshop sequences: *Sequence Name*, *Question:* the question it addresses, *Reproducibility:* how it is reproducible by academic or non-academic teams, *Interaction with public*: the degree of interaction it involves with participants, *Number of attendants*: the range of possible participants, *Easy engagement*: the degree to which it is easy for participants to engage, and *Possible context*: the scientific context in which the sequence might be used.

3.2 Discover the magnetic phenomena

To render the magnetic force visible, the first sequence mainly consists of demonstrations of magnetic experiments. This part is meant to be carried out by a researcher (or more generally a science communicator), with only a few manipulations by the public. First, demonstrations of attraction between magnets are presented, starting with toys containing magnets (a common

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wooden train, a familiar toy to most children) and finishing with the presentation of strong Neodymium or ferrite magnets used in the laboratory. Precautions are taken when displaying powerful magnets, which present risks when handled: a user's hand or finger may be sandwiched between the magnet, risk of swallowing, and never bring a magnet close to a person with a pacemaker. The public does not handle them. Second, to render the magnetic fields visible, transparent plastic bottles were filled with cooking oil (sunflower, rapeseed) and iron powders (Fig. 1-2). Two grain sizes of iron powder were used (coarse and fine). The demonstration consisted of shaking the bottle to disperse the iron particles and applying a magnet to the bottle's surface. The iron particles stick to the magnet in specific shapes along the field lines, while more distant particles align themselves along the field lines (Fig. 2). This experiment offers an opportunity to discuss the geometry of the Earth's magnetic field. It illustrates the differences according to latitude allowing us to discuss geomagnetism and paleomagnetism with the public. It also provides a first sensory and poetic approach to magnetic phenomena through the appearance of shapes. It is possible to have the public manipulate neodymium magnets that are not too powerful. In certain configurations (concentration of iron particles and magnet strength), the magnet sticks to the bottle's surface.

Third, the animator introduces the magnetic paste slime (*@Intelligente).* In this experiment, the leader's creativity is expressed in how he tells a story by making the magnetic paste "dance" with a magnet. Often a snake is evoked because of the elongated shape that the person has to make with the paste to make it work. The dynamics of the dough are fascinating and captivating.

These experiments are designed to build up amazement and wonder throughout the demonstrations. During events, presenters (researchers or students) are free to perform the demos in their own way with their sensibility.

Figure 2: Demo during Sequence 1 of the workshop. The bottle is filled with oil and iron particles. Magnets attract iron particles, which align along magnetic field lines. Photo credit : ASEER association -Toulouse modified for the publication by the authors.

3.3 Extract airborne magnetic particles from soil

To make airborne magnetic particles visible, we propose an experiment consisting of extracting magnetic particles from soil. The story here is that some airborne magnetic particles can fall into the ground and contaminate it, and we are on the way to

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retrieve them. We also explain that this experiment corresponds to a manipulation we often carry out in our "environmental magnetism" laboratory.

Each visitor is given a vial (30 to 120 ml) filled with soil and water. Magnetic particles (commercial magnetite powder) are added to each vial prior to the experiment to facilitate the experience. Soils contain natural and anthropogenic magnetic particles that can be easily extracted with this protocol (as we do in our laboratory), but the number of extracted particles is insufficient to be easily visible to the naked eye. For this reason, a substantial input of magnetite is made here to enable a quick and easy experiment. In addition, visitors are given a magnet, a plastic pipette (2 ml), and a small scientific tube (*Eppendorf type*) (Fig. 3). Visitors first get a hands-on experience of pipetting, where they learn to aspirate and release liquids. Next, the experiment consists in 7 steps:

1. shake the vial to disperse the soil in the water after making sure the vial is properly capped, open the vial,
2. apply the magnet to the surface of the vial slightly below the water line (with or without tape),
3. observe whether a black spot corresponding to the magnetic particles attracted by the magnet is present (if not, return to 1),
4. pipette the liquid containing the magnetic particles and simultaneously remove the magnet to allow the magnetic particles to be collected,
5. release the liquid into the tube,
6. close the tube and check with the magnet if magnetic particles are present.
7. Enjoy! Stop or return to 1.

Some people need help to pipette or remove the magnet and pipette at the same time. The latter requires coordinated actions that can be difficult regardless of the person's age and education. For example, some of us find it difficult, whereas some 7-year-olds with learning difficulties grasp it easily. As a result, this experience facilitates researcher-citizen interaction. Children are offered the possibility of taking the tube home.

3.4 Measure air pollution trapped on bark like a scientist

To reveal the magnetic particles trapped on bark, the third experiment offers the opportunity to perform real measurements of magnetic susceptibility. Magnetic susceptibility is used to quantify the amount of magnetite in a given media. Here, we propose to acquire measurements of bark (*Platanus x acerifolia*) with a laboratory instrument (Bartington MS2 magnetic susceptibility system coupled with the MS2B sensor) that could be used on the field (Fig. 4). First, we show attendees how to perform magnetic susceptibility measurements with the magnetic susceptibility meter and what it represents. A set of five bark samples in a plastic bottle (40 ml) is available. We provide a map of the city of Toulouse with the locations of the five bark samples. The participants could measure the 5 samples and write the data in a table. They could transfer the data to the map using colored stickers. A range of colors corresponding to a scale of values is displayed on the table. Once the colored stickers representing the magnetic mineral concentration values have been placed, the animator helps with interpretation. With the location of the samples on the map, participants can follow a path along the canal through the city, from a quiet urban

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environment to the dense road traffic in the city center. In this way, participants can understand that the magnetic particles present in the air and captured by the bark are emitted by the road traffic, which intensifies toward the center of the city, along with an increase in the concentration of magnetic and other airborne particles in the air we breathe.

Figure 3: Child performing the extraction in Sequence 2. Photo credit: ASEER association -Toulouse modified for the publication by the authors.

While plane bark from the city could be measured directly with the instrument we propose (as we do during our experiments in the field), we chose to enrich the samples with magnetic powder to obtain easier measurable data, with a clear difference between samples. The experiment is feasible for children from 8 years old.

3.5 Attend a scientific lecture and express yourself

Depending on the type of event, the three first sequences of the workshop are complemented by a lecture given by a researcher, a debate, and/or a proposition to draw solutions or observations.

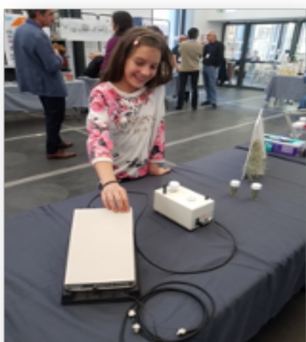

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Figure 4: Child performing measurements of bark samples in Sequence 3 with a susceptibility meter. Photo credit: Melina Macouin. Image reproduced with permission from the child's legal guardians.

This was the case for all interventions in the 3 elementary schools. First, a 20-minute talk is given by a researcher to explain the project, the scientific objectives of the project, and how the school and their class could participate. Debates (10 to 15 minutes) were proposed after the talk. In addition to the three previously described experiences (3.2, 3.3, 3,4), a fourth was proposed in which children could draw solutions for better air quality in the city or their observations about air pollution in their day-to-day activity (Fig. 5).

The presence of a live sketching artist in one of the schools gave the children examples of artistic views of the workshop (Fig. 6). It also made it easier to report on what was happening in the classroom, where photography was prohibited by the school.

4 Evaluation

The effectiveness of the protocol in engaging visitors and pupils could be assessed from the stakeholders perspectives: researchers and students, teachers, children and visitors, science fair organizers, and citizen science participants.

4.1 Researchers and Students' perspectives

Overall, researchers and students expressed their satisfaction with the protocol. Almost no adjustments were required during the project. Satisfaction was expressed with the ease with which volunteers (students and researchers) were mobilized to run the workshops. These were mainly held outside working hours. One of the researchers (M.M.) reports that although she has accompanied the extraction experiment with over 200 children, she is still moved by the stars that appear in the children's eyes when they manage to capture the magnetic particles in the tube. Another scientist (L.L.) said "What really stood out for me was the children's motivation to catch the particles, the laughter and fun, and their pride in their success". Another researcher (J.F. L.) was surprised by adults " *I was struck by the adults' determination to achieve a good result. We see coercive science education ("you have to get there and only the right result is possible"). ... No one questioned the experimental protocol...* "

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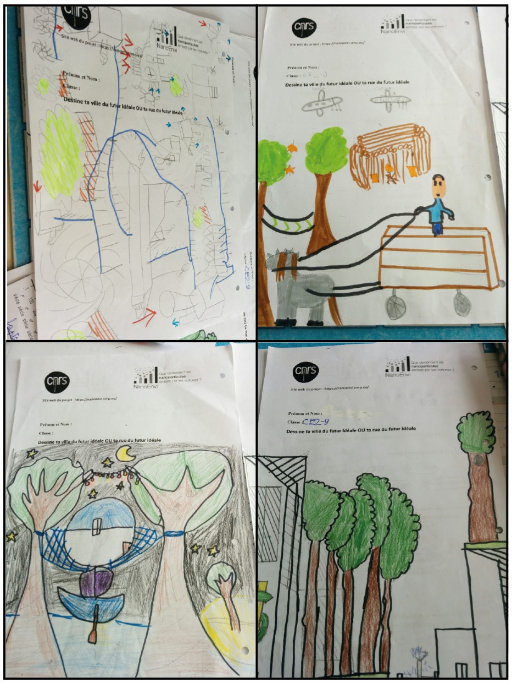

Figure 5: Drawings made by children in school during Sequence 4.

Figure 6: Painting realized during a workshop in a hearing-impaired children's classroom by the live sketching artist, Frederic Malenfer. The artist illustrated the collective work of deciding and inventing sign-language gestures for "air pollution sensor".

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4.2 Teacher's perspective

We collected the impressions of the three teachers most involved in the project. Although two of the teachers responded to a semi-directive interview, the interviews were about hosting the biosensors and managing air quality in the classroom (Leite et al., 2022). Yet, during the interview, one of the teachers expressed ~~his~~ appreciation for the protocol (Fig. 7). All teachers informally expressed their satisfaction and gratitude after the workshop. Two of them asked about the opportunity to continue the workshop in the following years.

> *"The idea was not simply to have "people come and explain something", but that there should be a bit of experimentation, a bit of manipulation, not just speeches and explanations. We have children from disadvantaged neighborhoods who need something concrete."*

Figure 7: Verbatim from a teacher in one of the participating elementary schools (children aged 9 to 12)

Another type of evaluation could be given by the example of the school principal who authorized us to intervene in the school after having informally observed the reaction of children during a workshop proposed in the neighborhood. During this workshop, three children aged around 9 left the stand with magnets after having taken part in the workshop. Half an hour later, they came back very excited, having conducted their own experiments with the soil and leaves they had found around them. The school principal was impressed by the scientific enthusiasm generated, particularly in relation to a child facing learning difficulties.

4.3 Children and visitors' perspectives

Besides the satisfaction expressed by children and visitors during the workshops, three observations can be used for evaluation purposes. First, children and visitors usually complete the experiences. Children generally bring home their map and their tubes. Some children told us in subsequent meetings that they were eager to show their families the magnetic particles in their tube with the fridge magnets. Secondly, during a recent visit by us to a school class (11-12-year-old children) specializing in learning difficulties, one student recalled the workshop we had done two years earlier in their elementary classroom. The student was eager to share the experience and could describe its objectives, much to the surprise of the current teachers. This probably illustrates the importance of hands-on experience in scientific learning as often reported (Vennix et al., 2018; Wieman, 2014). Thirdly, during the presentation of an active pumping experiment to collect air filters in the classroom, a child questioned the researcher about the pump's ecological impact (Fig. 8). This comment shows that the student understood and remembered the concept of passive biosensors that we presented during our previous intervention when we conducted the workshop. This remark moved the researcher and changed his point of view about passive/active particle collection, leading to new discussions among researchers.

- child: Did you make yourself the pump and filter system?

- scientist: Yes. I bought the equipement and made the system.

- child: You should stop make systems because it pollutes!

- scientist: I will think about it (feeling uncomforable)

Figure 8: Verbatim of a dialogue between a child and a scientist in response to the presentation of an active pumping for air filters collection by a researcher, in one of the participating elementary schools (children aged 9 to 12).

4.4 Perspectives from science fair organizers

The success of the dissemination protocol presented here could be seen in the fact that we were invited to perform it at events unrelated to our citizen science projects (see Table 1). However, it could be argued that too few researchers are proposing this type of workshop, and the communication around the citizen science project sheds light on our team.

4.5 Citizen science participants

Evaluation of the workshop protocol relies on the engagement of participants in our citizen science project NanoEnvi during workshops. The passive biosensors distribution and registration were a part of the stand. We took particular care to ensure that there was no pressure to sign up for the project during the workshops. In any case, the large number of visitors to the stand prevented any such pressure as well as the fact that we haven't generally produced enough sensors to distribute. A researcher or a PhD student was in charge of explaining the project and registration, which generally took 10 to 20 minutes. This part of the stand privileged a direct dialogue between the researcher and the participant. The participant (or his/her family) generally attended the rest of the stand beforehand. Most of the participants registered during or after these events denoting the active role of the outreach protocol.

5 Discussion

One of the challenges of citizen science in geosciences is to promote citizen participation by finding effective ways to reach and engage citizens including those who have not traditionally been encouraged to engage with science (Kirch et al., 2005; NSF, 2023). To support inclusive involvement in community-based geoscience research, we designed a hands-on workshop presented at various public events and schools. Central to the workshop is the discovery and experimentation with magnetic phenomena, which offers an alternative, tangible way to approach the issue of air quality. This interactive experience acts as a key driver of engagement: it encourages curiosity, fosters interaction between scientists and citizens, and creates space for dialogue—even for those who do not ultimately join the research project.

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5.1 Make the experimentation protocol evolve

The workshop was a success in every respect, but there were some adjustments and improvements that could be made. The "extraction" experiment (3.3) could be adjusted to offer more autonomy to people who have difficulty with fine motor skills or the simultaneity of actions required by the experience. The current set-up has the advantage of using commonly available laboratory materials. However, a larger container with a wide base could be designed and coupled with a system for simply moving the magnet closer or further away.
Another limitation is that the workshop is really well suited for explaining an air monitoring project based on environmental magnetism methods. This type of project is not common outside our specific academic fields. It is, therefore, difficult for other academics or teachers to reproduce it (Table 2). However, experiments demonstrating magnetic phenomena and the extraction of magnetic particles are easily reproducible and adaptable to different types of science educational projects, for instance, it could complement some Earth magnetic field workshop (van der Boon et al., 2022). Our team will be happy to advise on adjustments for different projects.

5.2 Foster dialogue between science and society

The workshop fostered science-society interaction through direct encounters between researchers and citizens. During a total of 9 science outreach events and workshops in 3 elementary schools, scientists interacted with 850 participants and 195 children who took part in the workshop through one or more experiments. This also led to the involvement of more than 150 citizens (not counting other people in the participating household) in the participatory science project. These face-to-face encounters opened up opportunities for two-way dialogues, enabling the scientists to convey their motivations and ethics regarding the project, and the participants to contribute their points of view, thus nurturing the evolution of the citizen science project. For example, the project opened up the possibilities for new districts to participate as asked by participants, led later to a new project in a community garden, and continued to develop passive sensors.

5.3 Facilitate inter-sciences communication

The NanoEnvi citizen project involved researchers from physics, humanities, and geosciences. We were able to witness an unexpected outcome in terms of facilitated dialogue and mutual understanding between radically different scientific fields. The need to adapt the discourse to a non-academic audience helps to find an appropriate level of language that is understandable to other disciplines. We can also report that the time spent around the workshop experience and the interactions it generated also led to new ideas for projects (some of which are currently underway) with researchers from the project and other researchers presenting at the same scientific fairs.

5.4 Adressing the eco-anxiety associated with raising difficult issues such as air pollution

The design of the citizen science and of the workshop took into account the need to go beyond denouncing the worrisome, anxiety-provoking problems of potentially degraded urban air quality without generating eco-anxiety (Watts et al., 2015; Terra Léger-Goodes et al., 2022) and solastalgia (Albrecht et al., 2007). Indeed, exposure to air pollution is one of the main environmental causes of premature death in Europe (European Environment Agency, 2021). The figure of 9 million premature deaths worldwide, including 67,000 in France, announced by WHO, was circulating in the French media in 2019 at the time of some of our interventions. The media's denunciation of the harmful health impacts of poor air quality generates negative emotions. In this context, our approach deals with air quality, but positive emotions are also generated by hands-on magnetic experiences, by touching and discovering the wonder of a physical phenomenon. We believe that these stimulating experiences, which reveal forms of art-like beauty, help to provide possible outlets and reduce environmental anxiety. To illustrate this, we can compare it with our first attempt to engage the public at a local open-air market, where we promoted the launch of the project through leaflet distribution, without the hands-on workshop component. This approach proved unsuccessful: passersby either ignored the issue altogether or reacted with high levels of anxiety when confronted with the topic of air pollution. In contrast, the interactive nature of the workshop created a more constructive and emotionally accessible entry point into the conversation. Participation and involvement in the rest of the project (Leite et al., 2022) can then be a means of empowering citizens confronted with potentially poor air quality.

6 Conclusion

This work demonstrates how a hands-on outreach activity can serve as an effective strategy to promote citizen engagement and initiate meaningful science-society interactions in the geosciences. We designed and conducted a hands-on science workshop with three experiments on magnetism and environmental magnetism. The workshop was held in three schools and at 9 science outreach events, promoting direct encounters between scientists and citizens for more than 1000 people.

Central to the workshop is the playful exploration of magnetic phenomena, offering a concrete and unconventional entry point to the topic of air quality. This hands-on approach stimulates curiosity, lowers barriers to communication, and facilitates meaningful exchanges between scientists and citizens.

Our findings show that this interactive approach encourages dialogue, and opens participation even among those initially unfamiliar or hesitant. A concrete outcome of this strategy is the involvement of over 150 households and two elementary schools in the NanoEnvi participatory research project.

For researchers and students alike, the workshop offered a dynamic and impactful model of science outreach—one that not only communicates knowledge, but also empowers. In the context of geosciences, where environmental issues like urban air quality can provoke anxiety or disengagement, this type of hands-on mediation creates accessible and constructive entry points

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into citizen science. Overall, our results highlight the potential of playful, discovery-based engagement with physical phenomena as an effective lever to foster participation in citizen science initiatives.

Author contribution

MM and SR planned the campaign; all authors performed the workshops; MM analyzed the data; MM wrote the manuscript draft; EV drew figure1, EV and MM designed figures, all authors reviewed and edited the manuscript.

Competing interests

The authors declare that they have no conflict of interest.

Ethical statement

The workshop was conducted in accordance with the ethical guidelines of the CNRS and Toulouse Museum departments, as well as general French national guidelines. We did not collect any personal information about participants during the workshop. Interventions in schools were carried out with the agreement of the Toulouse administrative department and after discussion with the teachers.

In all locations, we took into account the potential anxiety raised by the subject of air quality. We were careful to provide information that was appropriate, accessible, accurate, and balanced.

Acknowledgments

The authors sincerely thank the pedagogical teams and children of Jules Julien and Leo Lagrange schools of Toulouse, the participants of the NanoEnvi project. They also thank the children of Sebikotane (Senegal) and the Tadjabone center. The authors acknowledge the support of the city of Toulouse, Toulouse Metropole, and the "*Quai des Savoirs*". The authors thank the communication team of the CNRS-délégation Occitanie Ouest for their help along this project.

Financial support

This study was funded by the French National Research Agency ANR-grant number ANR-19-CE04-0008 through the BREATHE project and ANR-grant ANR-21-SDG1-0009 through the AIRGEO project, and has received financial support from the CNRS through the MITI interdisciplinary programs - *Osez l'interdisciplinarité*-NanoEnvi. A.L. was supported by a scholarship of the French Government and Ministry of Education.

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