Engaging primary students with the issue of air pollution through citizen science: lessons to be learnt

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Abstract

This paper shares insights from an air quality research project that involved 258 primary school children aged between 5 and 11. The children attended a dedicated session led by scientists explaining the nature of air pollution. They then wore specially designed backpacks with built-in air quality sensors during their commute to school for one week to measure air pollution. The generated data were used by scientists to determine children's exposure to air pollution in and around their schools. To examine the children's understanding of both air pollution and ways to reduce exposure, participating children completed surveys (pre- and post- the monitoring week). Interviews with ten teachers were conducted to help contextualise the survey findings. Our findings indicate that contributory citizen science projects constitute a valuable approach to engaging children in environmental education. We also note the importance of ensuring the active participation of teachers, particularly so that misconceptions are rapidly identified and thereafter addressed.

Keywords: Air pollution, primary science, citizen science

Introduction

Air pollution – a complex mix of gases and particles – has been associated with a variety of health problems, from breathing difficulties to heart disease. Children are particularly susceptible due to their immature and developing immune and respiratory systems, relatively high inhalation rates and lower body weights. Air pollution can also adversely affect children's cognitive development (Gehring *et al,* 2013; Sunyer *et al,* 2015). In this paper, we reflect on the findings of a study designed to document children's exposure to air pollution, through a citizen science approach to data generation with the aim of giving the children themselves a prominent role. Specifically, we discuss the impact of participation on children's understanding of, and ideas about, air pollution and highlight key lessons learned with a view to informing further citizen science initiatives that involve primary schools.

The Breathe London Wearables Study

During March to July 2019, The Breathe London Wearables Study (BLWS) provided participating primary school children (n=258, from five London schools) with a backpack incorporating a small air pollution sensor[1] and a GPS tracker. By wearing the backpacks on their daily school commute over the course of a week, the children collected air quality data, including nitrogen dioxide and particulate matter exposure levels. Participating children also kept a travel diary, which included the mode of transport used to travel to and from school.
The involvement of children in this study is in keeping with a contributory citizen science approach to data generation (Bonney *et al*, 2009).

[1.] The N609 sensor unit used in the backpacks was developed by Dyson. The unit captures data on particulate matter ($PM_{2.5}$) nitrogen dioxide, humidity and temperature. Unfortunately, the Dyson unit is not currently commercially available, however there are other ways of measuring air pollution whilst also involving children in the research process, for example see (EEA) European Environmental Agency, (2019); and Morgan and Shallcross (2021).

At the outset of the study, air quality scientists gave a presentation to schoolchildren and staff to share the research aims and to highlight the causes of and dangers posed by air pollution. Scientists also returned to the participating schools at the end of the project to present the findings generated from the data collected by the children and to provide advice and information on how to reduce exposure to air pollution. The findings showed that children were most exposed to air pollution during the morning commute and that children who walked, cycled or scooted to school via residential streets were less exposed than those who walked on the main roads or travelled by car or bus (full findings are reported elsewhere, paper currently under review).

The BLWS provided an opportunity to better understand the impact of participating in an air quality-focused citizen science project. Children across school years 1–6 (ages 6-11) completed short surveys before and after wearing the backpacks, which examined their understanding of the causes and the health effects of air pollution, and potential strategies to reduce and avoid exposure. These surveys were completed at home. The second survey (completed at school two weeks after the results of the study were presented) additionally asked children to share changes made in their own behaviour to reduce exposure to harmful pollutants and to draw a picture for other children explaining the dangers of air pollution. 220 children (85% of those who wore the backpacks) completed the first survey, and 180 children (70%) completed the second survey (see Table 1).

Semi-structured interviews with ten teachers provided further contextualisation to the children's responses. Informed parental/carer consent and institutional ethical approval were obtained prior to the study.

Analysis of students' survey responses

The pre-surveys from each school were read by the research team to gain a sense of the children's understanding of air pollution. Unsurprisingly, this varied greatly, but most children initially had a limited understanding of invisible pollutants such as those caused by traffic, and did not consider their own schools to be particularly adversely affected.

Next, we read through the post-surveys and sorted them according to whether the children's subsequent responses and drawings indicated a relatively 'clear' conception of the risks associated with air pollution or, by contrast, a more 'ambiguous' or less clear conception of air pollution. Incorrect conceptions and incomplete surveys were also counted. In conducting this analysis, we acknowledge that there is a continuum between a clear or stable conception, through to a more ambiguous or mixed conception and, at the other end of the continuum, an incorrect conception. Further, we note that children (like all learners) may hold multiple conceptions at once (Taber, 2000).

Finally, we note that some children – especially the younger ones – may have misunderstood the directions on the survey, ticked several responses without distinguishing their particular views, or sought to please the scientists by guessing what they thought would be preferred responses. (Moreover, we acknowledge that we did not ascertain reading ability, or English language proficiency of individual respondents.) In this way, we do not claim that our findings outlined below indicate the complete extent of children's understanding. Rather, we highlight ambiguities in understanding to draw attention to common and potentially persistent misunderstandings that may impede behaviour change and limit air pollution amelioration.

Table 1. Numbers of children per age group completing pre- and post-surveys.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Pre-survey	18	27	47	52	53	23	220
Post-survey	5	27	38	42	49	19	180

Findings

The post-surveys demonstrated a range of views and misconceptions, even though the children had attended an initial presentation explaining the nature of pollution and had engaged in collecting data during their commute to and from school. The scientists' presentations of the data analyses (via a written report, and an assembly) explicitly referred to the importance of travelling away from busy roads to reduce exposure to harmful pollutants and of the benefits of active travel (cycling, walking, scooting). Across all five schools, the number of clear conceptions outnumbered mixed or incorrect conceptions. However, in three schools, between a third and a half of children demonstrated some degree of confusion in their understanding. The ambiguous or incorrect responses were not dependent on year group (see Table 2).

Examples of clear conceptions on the part of students

The majority of the children expressed a clear understanding of the effects of traffic-related air pollution. When asked what they were doing to reduce their exposure (*What are you doing right now to make sure the air you breathe is clean?*), children offered the following types of responses:

'I am walking to school, telling my parents to turn off the engine when there (sic) stopping' (Child aged 9/10, School A).

'I walk to school on not so busy roads' (Child aged 9/10, School A).

'I cycle to school more regularly now' (Child aged 10/11, School C).

Figure 1. Clear conception of how best to reduce exposure to air pollution.

When asked what they thought could be done in the future, responses included:

'We can make rules to ban stuff that makes air polution (sic) and you could make filters to stop air pollution' (Child aged 7/8, School E).
'People could walk, cycle or scoot to school and people shouldn't use a car so much as cars produce pollution and it affects our breathe (sic)*'* (Child aged 8/9, School D).

We also noted that several children displayed nuanced reasoning in their responses. They had clearly considered the issues and come to their own conclusions about best practices. For example, one child expressed a view that might be shared with many adults faced with the issue of transporting their children to school:

'I don't think you should ban the dropping off by car/picking up because people live far from the school. I think they should just turn off the engine when they've stopped' (Child aged 9/10, School A).

Table 2. Clear and ambiguous conceptions of air pollution per school.

School	No of post surveys completed	Clear conceptions about traffic pollution	Mixed and/or ambiguous conception	Incorrect conceptions	Incomplete surveys	% of surveys indicating mixed or incorrect conceptions
A	38	30	6	0	2	16
B	49	22	22	0	5	45
C	19	13	2	0	4	11
D	30	14	12	3	1	50
E	44	23	15	0	6	34

Examples of mixed and/or ambiguous conceptions

Surveys categorised as mixed and/or ambiguous did not necessarily display misunderstandings about air pollution. Rather, they demonstrated that children held a number of conceptions and, in some instances, appeared to be fusing such conceptions with other ideas related to health and the environment. For example, when asked about what they were doing now to ensure that air is clean, a child aged 9/10 from School D responded *'do not smoke or make pollution. And walk to school'.* However, when asked about the impacts of air pollution, the same child wrote that *'it kills sea animals because they can eat the rubbish'* and, when asked to draw a picture about the air pollution, the child drew a large cigarette and a 'skull and crossbones' symbol.

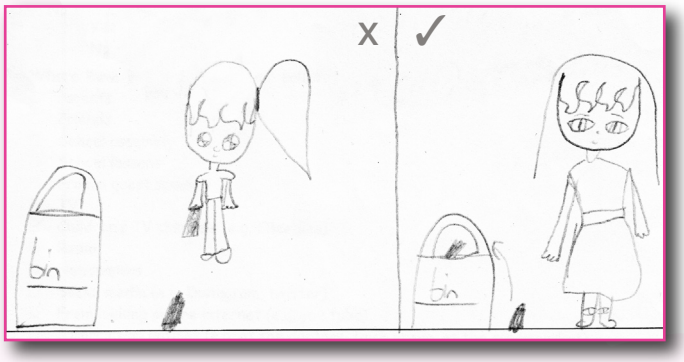
A child aged 7/8 (School A) expressed a variety of environmental messages. When asked what could be done to improve air quality, they wrote *'Don't litter. Plant more trees. Recycle more'.* Their drawing, however, depicted someone coughing in a cloud of fumes.

Another 7/8 year-old (School E) displayed an amalgam of health messages in their conceptualisation. They wrote about the need to walk to school, drew a detailed picture of lungs and particulate matter but, when asked what to do to make air quality better in the future, wrote *'eat healthier food'.* Similarly, a child aged 8/9 (School B) appeared to conflate air pollution messages with other health recommendations: *'Persuade my parents to use the car less. Buy an electric car. Keep exercising'.*

Examples of misconceptions

Fortunately, examples of incorrect understandings or misconceptions were few and far between. One child simply referred to the need to put rubbish in the bin throughout their survey and, made no mention of traffic pollution or steps to avoid it. When one child aged 9/10 (School B) was asked how to ensure that they breathed cleaner air, they said *'not breathe that much, and brush your teeth'.* In categorising these instances as examples of misconceptions, we are aware that the confusion may have resulted from the wording of the question in the survey. Furthermore, we accept

Figure 2. Example of incomplete or misconception relating to causes of air pollution.



that individual children may not have associated the survey questions with their earlier experience of taking part in the air pollution monitoring study. Such explanations notwithstanding, we think that it is important to highlight these examples to showcase the types of confusion that children may experience.

Teacher interviews

The data gathered from the teacher interviews offer insights into the varied responses of the children. The conflation with other environmental issues such as recycling and ocean plastics may be due to children having engaged with such topics previously as part of their standard curriculum, as a teacher at School B explains:

'The air pollution topic is new, there would usually be more things like plastic and deforestation which affects animals. With plastic, children can see: when you see it in the ocean and you know it is killing animals. Children often love animals and they are horrified that some actions are affecting animals, whereas I suppose with air pollution being quite invisible perhaps, it hasn't been such a big thing' (Teacher 1, School B).

The week-long nature of the air pollution research project, meanwhile, may not have afforded enough time for either the teachers or the children to situate the new ideas and content amidst other learning and to make sense accordingly, as the teacher at School E makes clear:

'Children didn't talk about the results very much, they didn't really understand. Timing is also an issue because towards the end of the term they have lots on and it is hard to remember' (Teacher 2, School E).

The complexity of the topic was noted by several teachers. Teacher 1 from School B highlighted that the technology used in the air pollution sensors in the backpacks should have been better explained, as the children had many questions about how the data were collected. One or two teachers appeared to struggle themselves in understanding the results. Teacher 2 (School E), however, clearly recognised the implication of the data and recommended that parents should be invited to join the sessions led by the scientists as this would encourage whole families to change their behaviours.

In terms of teaching practices regarding air pollution, some teachers shared their perception that the topic might only be addressed by colleagues with a specific interest and/or concern, as air pollution is not part of the science curriculum at Key Stages 1 and 2 (primary years) in England. When asked how they themselves might introduce the topic, most were inclined to immediately link it to recycling, highlighting that teachers, like children, tend to group environmental topics together.

Implications for teaching about air pollution

From the analyses above, it is apparent that the majority of the children who participated in the study have a clear understanding of causes, risks and ameliorative measures associated with air pollution. However, some children appear to have experienced some confusion. We acknowledge that this may be due to the survey design, or children misconstruing instructions. However, we assert that the relatively high numbers of ambiguities in the responses may also reflect worryingly high levels of misconceptions in primary pupils' understanding of air pollution.

Misconceptions are common (Allen, 2014). Indeed, identifying and addressing typical or frequent misconceptions in the domain of science has long been the aim of science educators (Hewson & Hewson, 2003; Wandersee *et al*, 1994). However, misconceptions in the domain of environmental education are arguably more problematic. As Palmer (1995) has noted, incomplete knowledge or even stereotypical thinking will constrain environmental understanding, which may in turn impede behavioural change.

And yet, misconceptions may be inevitable. This study clearly demonstrates that the learning – and teaching – of complex (multi-factor) environmental issues is not straightforward. Firstly, it is clear that messages that have been promulgated for longer – for example, anti-smoking, healthy eating, recycling campaigns – appear to be prominently fixed in the minds of children. Any new messages concerned with aspects of health may then be assimilated or conflated with existing ideas resulting in muddled or ambiguous conceptions.

Secondly, full comprehension of the issue of air pollution and its primary causes may be affected by children's conscious or unconscious notions of control. For example, air pollution caused by fumes from vehicles and smoke from big factories are essentially invisible. Cigarette smoke, on the other hand, is something that children can often see and smell at home, at the school gates, and at the bus stop. Moreover, smoking is seen as something that individuals do, and that individuals can stop (or be persuaded to stop). Previous researchers have noted that abstract nouns and agentless processes can be difficult to understand (see Rickinson, 2001). Children cannot make decisions about car driving or cycling, but they can pester and persuade their parents not to smoke.

The wider research team continues to monitor air pollution and identify safer routes to school and collect data. Future studies are planned for Birmingham in early summer 2021, and other studies are ongoing in various African countries, including Ghana, Malawi, Nigeria, South Africa, Tanzania, Uganda and Zimbabwe. However, we also recognise that more is needed in our work with schools to ensure that messages take hold, are not misconstrued, and prompt meaningful lasting change. To reduce confusion, we recommend the following:

1. Ensure active inclusion/participation of the teacher. In our analysis of teacher interview data, we noted that most teachers described their role as gatekeepers and facilitators. They were not cast as active participants in the research, nor were they necessarily equipped with greater content knowledge. It is important that adults – teachers, classroom assistants, parents – also participate in a study to help embed the message.

2. Be alert to and thereafter actively address common misconceptions. We have known for a long time that there is confusion in distinguishing between environment-related phenomena. Dimitriou and Christidou (2007) documented that environmental concerns, including ozone depletion, global warming, air pollution and acid rain, are confused and conflated. Indeed, Boyes and Stannistreet (1996, p.194) noted that the word 'pollution' is problematic and that *'children need to be made more aware of the specific pollutants and the different problems that they cause'.*

3. Design initiatives that promote the trinity of environmental education: learning *about*, *in* and *for* the environment (Lucas, 1972). That is, we recommend that:

- Children learn *about* air quality and the effects of air pollution;
- Children conduct research *in* air quality by collecting and analysing data. This may involve backpack monitors, but could be as simple as counting cars and traffic flow at different times of the day; and
- Children act *for* air quality by taking active steps to reduce pollution (e.g. lobbying for reduced car use) in their environment.

Given the findings reported above, we note that learning *'about'* needs more work if we are to unpick the confusion surrounding ideas about air quality and broader ideas around health. Fortunately, resources such as those produced by the Primary Science Teaching Trust are available (see https://pstt.org.uk/resources/curriculum-materials/citizen-science-air-pollution).

For engagement *in* issues of air quality research, we would point to the benefits that citizen science projects confer. Moreover, we note that the children in our study found gathering data by wearing the backpack to be the most exciting and rewarding aspect. Finally, and with respect to action *for* improved air quality, we would argue that, whilst citizen science projects offer considerable opportunity for developing active participation, the greatest benefits will ensue when teachers, and parents, are also actively involved in the research process.

Figure 3. A child's powerful illustration about the dangers of air pollution.

Figure 4. A child's commentary on air pollution amelioration.

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