CITIZEN SCIENCE COMES OF AGE

Efforts to engage the public in research are bigger and more diverse than ever. But how much more room is there to grow?

BY AISLING IRWIN

Filip Meysman knew he had made his mark on Antwerp when he overheard commuters discussing his research project on the train. Then, just a few days later, he saw an advertisement about his work on television. There it was, he says, "in between the toothpaste and George Clooney's Nespresso".

As a biogeochemist at the University of Antwerp in Belgium, Meysman wasn't used to drawing so much attention. But that was before he adopted the citizens of northern Belgium as research partners. With the help of the Flemish environmental protection agency and a regional newspaper, Meysman and a team of non-academics attracted more than 50,000 people to CurieuzeNeuzen, an effort to assess the region's air quality (the name is a play on Antwerp dialect for 'nosy' people).

The project ultimately distributed air-pollution samplers to 20,000 participants, who took readings for a month (see 'Street science'). More than 99% of the sensors were returned to Meysman's laboratory for analysis, yielding a bounty of 17,800 data points. They provided Meysman and his colleagues with information about nitrogen dioxide concentrations at 'nose height' — a level of the atmosphere that can't be discerned by satellite and would be prohibitively expensive for scientists to measure on their own. "It has given us a data set which it is not possible to get by other means," says Meysman, who models air quality.

Citizen science — active public involvement in scientific research — is growing bigger, more ambitious and more networked. Beyond monitoring pollution and snapping millions of pictures of flora and fauna, people are building Geiger counters to assess radiation levels, photographing stagnant water to help document the spread of mosquito-borne disease, and taking videos of water flow to calibrate flood models. And an increasing number are donating thinking time to help speed up meta-analyses or assess images in ways that algorithms cannot yet match.

Japanese priest Sadamaru Okano stands beneath a Geiger counter (top left) that sends radiation readings to the Safecast project. BEHROUZ MEHRI/AFP/GETTY

The movement is surfing wider societal forces, including a thirst for data; the rise of connectedness and low-cost sensor technologies; and a push to improve the transparency and accessibility of science. Increasingly, government institutions and international organizations are getting in on the action. The US and Scottish environmental protection agencies, for example, have incorporated citizen science in their routine work. The United Nations Environment Programme is exploring ways of using citizen science to both monitor the environment and stoke environmental concern. And the European Commission has made a range of funding opportunities available for citizen science within its €80-billion

(US$92-billion) Horizon 2020 research and innovation programme.

At the same time, citizen-science proponents have grand visions for the future of the field. They hope that such efforts will become a major source of high-quality data and analysis in areas relevant to policymakers as well as scientists. In December, multiple citizen-science organizations banded together to form a worldwide group — the Citizen Science Global Partnership. One of its first tasks is to explore how citizen science can help to monitor progress towards the UN's Sustainable Development Goals, which aim to address global challenges ranging from hunger to environmental degradation by 2030.

To gain legitimacy, many expect that the field will have to overcome lingering concerns about the reliability of its measurements and its usefulness in research. "There needs to be some type of acceptance and institutionalization of citizen science," says Steffen Fritz, a specialist in Earth observation and citizen science at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria. "It needs to be not just bottom-up — it needs also to be accepted as some kind of official data stream."

COUNTERS AND ENCOUNTERS

The origins of citizen science go back at least a couple of millennia. In ancient China, migratory locusts frequently destroyed harvests, and residents have helped to track outbreaks for some 2,000 years. The modern form of such research arose after science became a professional activity, creating a cohort of interested outsiders in the process. The phrase 'citizen science' itself was coined in the mid-1990s. Alan Irwin, a sociologist now based at the Copenhagen Business School, defined it both as "science which assists the needs and concerns of citizens" and as "a form of science developed and enacted by the citizens themselves".

Some of the earliest modern citizen-science projects, starting with bird counts in the early twentieth century, involved concentrated outdoor campaigns to record animal sightings. Since then, public involvement has grown to encompass a range of roles. Muki Haklay, a geographer at University College London, has outlined a taxonomy of involvement, from 'crowdsourced' citizen science, in which lay people contribute data or volunteer computing power, to 'co-created' and 'collegial' research, in which members of the public actively engage in most aspects of a project, or even conduct research on their own.

In areas such as biodiversity, where citizen science first thrived, projects are breaking boundaries through the sheer volume of participants and data. The Global Biodiversity Information Facility, the world's largest such repository, says that it gets half of its billions of data points from lay sources. The group estimates that it has supplied data for more than 2,500 peer-reviewed papers in the past ten years.

At iNaturalist, a social network to which anyone can submit a photograph of their encounters with flora and fauna, co-director Scott Loarie has presided over a doubling of submitted images every year since it was launched in 2008. He tries to trace scientists' use of iNaturalist data and has counted 150 papers so far — but he thinks that the actual number is much higher because many of the papers don't cite the organization.

Other researchers have enlisted the public in more-involved projects to enhance research activities, including checking data derived from other sources. When a team published a paper[1] in 2011 suggesting that there could be enough marginal land to grow biofuel sufficient to meet half the world's liquid-fuel needs, Fritz recruited an army of citizen analysers to participate in the IIASA's Geo-Wiki project to study the claim. After working through thousands of images from Google Earth, they generated estimates of land use that were hundreds of millions of hectares lower than those of the original paper[2]. "We downgraded the initial estimates drastically," says Fritz.

Fritz thinks that some people are attracted to his projects because they want to contribute to science, whereas those who become most involved are drawn to the prospect of co-authorship on papers. Some simply like the offer of Amazon vouchers, he says, or a few euros.

Other projects can draw participants for political and social reasons. Within days of Japan's Fukushima Daiichi nuclear disaster in 2011, a small group mobilized to distribute Geiger counters (and ultimately DIY assembly kits) to anyone who wanted to measure radiation levels themselves. At times, local and central governments were hostile to the effort, says Azby Brown, an architect and a leader of the group, now called Safecast. But the findings proved useful, exposing inaccuracies in government readings: high counts where people had been told it was safe to go, and low counts in places that had been deemed unsafe. There is still scepticism about these citizen-generated data, Brown says, although the International Atomic Energy Agency has invited him to speak at several meetings over the past few years.

But it's not just lay people with concerns or scientists with a bright idea who trigger projects: governments and their funding arms are also getting involved. With the support of the European Commission, for example, a project called Ground Truth 2.0 has set up six pilot 'citizen observatories' in Africa and Europe. Each is designed to encourage a three-way conversation between laypeople, scientists (or those who process the data) and those who could benefit from the data, such as policymakers or local authorities. Ground Truth 2.0's leader, Uta Wehn, a researcher at the IHE Delft Institute for Water Education in the Netherlands, says that earlier citizen observatories funded by the European Union included the public as an afterthought. But here, scientists don't dictate the project; they choose the location and let interest groups decide what issue they want to explore and how to do it. "We're putting the people before the sensors," she says.

One observatory, which is examining deteriorating water quality in the Mälaren region of Sweden, found out through early discussions that the existing data on water quality are dispersed, and that local people who do the monitoring had no connection with the decision-makers.

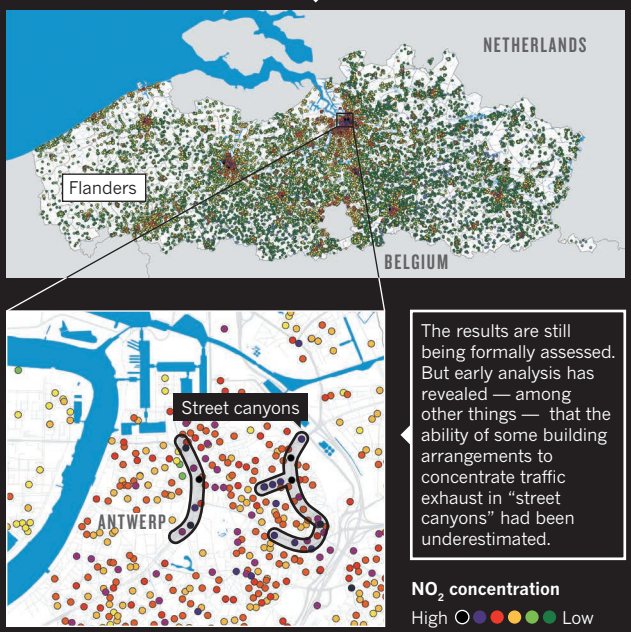
SOURCE: CURIEUZENEUZEN

STREET SCIENCE

In May, a collaboration that included the Flanders Environment Agency in Belgium ran a month-long citizen-science campaign to help test a computer model of air quality in the region.

Participants installed nitrogen dioxide samplers on first-floor, street-facing windows inside V-shaped signs to create a standard measurement set-up.

All told, some 20,000 people participated in the project across the Flanders region. Each paid €10 (US$11.5) to join the experiment.



The results are still being formally assessed. But early analysis has revealed — among other things — that the ability of some building arrangements to concentrate traffic exhaust in "street canyons" had been underestimated.

CATIE RAFFERTY/MEDIASANCTUARY.ORG

Youth-programme participants Donovan Wooten and Maya Sanders record observations with iNaturalist.

Two years in, Wehn says it is too early to say whether such projects are changing policy. But participants laud the relationships that have been built between various stakeholders, she says.

Some research leaders are looking to citizen science to foster more inquisitiveness in the 'post-truth' era, in which emotional appeals often seem to win out against fact-based arguments. François Taddei, co-founder of the Center for Research and Interdisciplinarity in Paris, thinks that citizen science can revive critical thinking. Children exposed to such projects are "much less prone to fake news and all these problems that we are facing in the information age", he says.

GROWING PAINS

Yet, even as its aspirations become grander in scale, citizen science faces a number of challenges, including data quality and recruitment — in terms of both persuading more scientists to work on such projects and enlisting enough citizens to participate in them.

Papers published in the past few years have identified flaws in citizen-sourced data, including deviations from standard protocols and biases in recording or in the choice of sampling sites[3,4]. Graham Smith, a wildlife ecologist who analyses sightings made by members of the public for the London-based Mammal Society, a British conservation charity, says that Sunday ramblers will ignore yet another rabbit bounding across their path but unfailingly note a more spectacular sighting such as an otter, which is "the most recorded mammal in Britain for its population size".

Smith, who works for the UK Department for Environment, Food and Rural Affairs, has explored statistical approaches to combat this bias. New apps that track a citizen's route and time in the field are also enriching the data, he says. Meanwhile, simple techniques exist for testing the quality of online analysis, says Fritz. His group inserts occasional control submissions that test a contributor's conclusion against a predetermined professional one (those who regularly fail — about 5%, estimates Fritz — are dropped, whereas those who do well can progress to become co-authors of papers). Scent, a project that uses a gaming app to encourage citizens to photograph land use, has humans and algorithms check one another for errors, says Daniele Miorandi, a communications engineer for the project.

Some academics fear that the public is getting fatigued by all the options, and note that participation in some projects, such as the United Kingdom's long-running Big Garden Birdwatch project, has declined. In an unpublished paper, Haklay has estimated that the number of people globally who could be drawn into regular data collection is about 1.7 million. "You can get a lot of people for a short time investment, or very few people for a deep and intensive engagement, but you can't get everyone doing it all the time," he says.

Researchers and participants are also encountering challenges with ethics, data use and privacy. In Kenya, for example, one of Wehn's citizen observatories is a mapping project that enables people to note poaching incidents, wildlife encounters and fencing, which can be harmful to animals. But the data gathered could be used for nefarious purposes. "Sightings by the tourists might be perfect for the poachers," says Wehn. She says the team is in careful discussion with authorities about what data can be disclosed.

These issues are likely to grow, particularly with the rise of health-monitoring apps. Philip Mirowski, a historian at the University of Notre Dame in Indiana, has raised concerns about the fate of citizen data. He points to projects, such as PatientsLikeMe, that ask people to upload medical information. At least in the United States, he says, "the people who generate the data really don't have any say in what's done with it".

Meanwhile, leaders in the field are pushing for more professionalization, by attempting to systematize the available research and agree on common methodologies. The Open Geospatial Consortium, an international alliance of businesses, research institutes and government groups, has launched a taskforce to get citizen data streams to talk to one another. And the US-based organization SciStarter, an affiliate of Arizona State University in Tempe, has made tools and other resources available for avoiding pitfalls in rolling out projects.

Some are sceptical of efforts to manage citizen science from the top down. Michiel van Oudheusden, a sociologist at the Catholic University of Leuven in Belgium who has studied the example of Fukushima Daiichi, says that citizen science can be especially valuable when it is unaligned with the establishment. "Subversiveness can be very productive," van Oudheusden says.

But Martin Brocklehurst, an environmental consultant and citizen-science advocate, believes that the benefits of bringing order to the field outweigh those of being an outsider. "Too much of citizen science is like a fireworks display: it's great science, but it's short-lived," Brocklehurst says. "We need to start embedding it into the routine way that we do science to support the policy-making process."

Perhaps that is what CurieuzeNeuzen has achieved. The group thinks it reached a world record in the density of air-quality measurements. Now the people of Flanders are mulling over the findings. Among other things, the results revealed that the centres of rural villages, which were thought to have pure air, in fact have high levels of traffic-related air pollution.

The project has opened political doors that more-subdued announcements by the scientific community might never have done. Air quality became a theme in local Flemish elections, which were held in mid-October. Meysman says that he has received many invitations to present his data. And the European Environment Agency says that it aims to apply the approach more widely.

Still, Meysman says, citizen science isn't always feasible. Less-established scientists, under pressure to publish, could not afford the time he has devoted to the CurieuzeNeuzen project, he says. Personally, he has loved watching the effort unfold — the communications campaign, the wave of public interest, the valuable new data — and the chance to put the results to practical and political use. "If I had collected the data myself, I would have had much less impact." ■

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1. Cai, X., Zhang, X. & Wang, D. *Environ. Sci. Technol.* **45**, 334–339 (2011).
2. Fritz, S. *et al. Environ. Sci. Technol.* **47**, 1688–1694 (2013).
3. Tiago, P., Ceia-Hasse, A., Marques, T. A., Capinha, C. & Pereira, H. M. *Sci. Rep.* **7**, 12832 (2017).
4. Kallimanis, A. S., Panitsa, M. & Dimopoulos, P. *Sci. Rep.* **7**, 8873 (2017).