Experiments outside the lab come with new responsibilities

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St. Ives is an idyllic seaside town on the southwest tip of England. It is a magnet for holidaymakers and artists. In early 2023, its residents were surprised to find that their beloved bay had become the location for an experiment. A technology start-up called Planetary Technologies had gained permission from the local water company to add magnesium hydroxide to a wastewater outlet pipe and pump it a mile offshore. Some within the community were outraged to find out from a national newspaper not only about the planned release of the chemicals, but that a small test had already happened the previous September. That April 2023, more than 300 protesters gathered on the beach, some with slogans on their surfboards. Most of them were concerned about the risks to their ecosystem and its crabs, seals, and lobsters. On finding out more about the company and its ambitions, some of the protesters started to see the experiment in a new light.

One campaigner wrote about her realization that "there was a wider global conversation around geoengineering and the climate crisis as well as the specific issues relating to testing in St. Ives Bay." The company's plan was to evaluate a geoengineering idea called "ocean alkalinity enhancement," raising the pH of the sea to draw carbon dioxide from the atmosphere. An independent risk assessment was commissioned. The report classified the trial as "low-risk." The seals, it seemed, would be safe for now. But this didn't answer all of the public's questions. Some wondered who would do the long-term monitoring required to understand the full range of environmental impacts. Some were suspicious that the company had already sold carbon credits on the promise that its interventions would work. The residents included some passionate climate campaigners, who felt patronized by the company's insistence that the climate crisis necessitated interventions such as alkalinity enhancement. Since the protest, the company has consulted the community and vowed that their next test won't involve selling carbon credits. But the company now seems to have gone quiet. Some of the locals suspect they have retreated and are looking for new places to run their tests in peace.

Scientists used to experimenting under laboratory conditions and tech companies developing software models are often taken by surprise when they take their activities outside. Experiments in vitro or in silico are a world away from in vivo or in situ tests with real people. This doesn't just apply to environmental R&D. When self-driving cars are tested on city streets, generative artificial intelligence (AI) models are unveiled, or genetically modified mosquitoes are released as a strategy to combat malaria, society becomes a laboratory and the public become part of the apparatus. The rules and ethical procedures that normally govern laboratories aren't sufficient to take care of real-world experiments.

In the case of geoengineering, public concerns have gone beyond the direct effects of experiments; we have also seen people taking issue with what the experiments are for. Very

few scientists regard geoengineering as an unalloyed good idea. Even those who think it might be an unfortunate necessity in our climate toolkit recognize the uncertainties involved in playing with ecosystems. And they acknowledge the political risk of dangling the possibility of a technological fix in front of the policy-makers who are negotiating steps to mitigate climate change, many of whom are hungry for excuses to delay or water down their commitments. People concerned about geoengineering worry that experiments might set precedents, reinforce enthusiasm for the technology, and make deployment of geoengineering schemes more likely.

One of the hopes behind a recent Solar Geoengineering Non-Use Agreement, of which I was an early signatory, is that enthusiastic innovators who stumble upon geoengineering might be made aware of the gravity of geoengineering debates. People from rich countries may, for example, have not considered the views of those in the Global South when they start exploring technologies that are, by definition, planetary. An admirable new framework from the American Geophysical Union helps scientists understand the ethical debates involved not just in the possible uses of geoengineering, but in research that points toward its development.

Back in 2011, I was involved with a proposal for the first field test of a geoengineering technology in the UK. The Stratospheric Particle Injection for Climate Engineering (SPICE) project planned to launch a balloon to test the feasibility of spraying mist into the atmosphere as a form of solar radiation management (SRM)—reducing the amount of sunlight that reaches the planet's surface. As I described in my book, *Experiment Earth*, the team of researchers from a range of scientific disciplines initially regarded this as a low-stakes engineering test. After the project received media coverage and some negative attention from environmental interest groups, it became clear that the social context for the experiment was far more complicated. In the end, the researchers decided to call off the test.

Following SPICE, a number of other real-world geoengineering experiments have subsequently been proposed or conducted, with varying degrees of scientific credibility. In 2012, an entrepreneur, with the backing of some Indigenous community leaders, dumped 100 tonnes of iron sulfate from a ship off the coast of Canada. The hope behind this attempt at "ocean iron fertilization" was that plankton would grow, help attract salmon back to the waters, and draw some carbon dioxide from the atmosphere. The science behind it was dubious, and the absence of any real rules prompted the London Convention, which regulates pollution at sea, to prohibit such releases unless they were deemed "legitimate scientific research." A number of teams have begun exploring a different set of experiments at sea, testing the idea of "cloud brightening" using sprays from ships. This summer, a team from the University of Washington were stopped from running tests in the San Francisco Bay. They had kept a previous experiment secret because of controversies about geoengineering. The Biden administration felt the need to clarify that "The U.S. government is not involved in the Solar Radiation Modification (SRM) experiment taking place in Alameda, CA, or anywhere else."

Some geoengineering researchers have recognized the need to include others in deliberations about their outdoor experiments. A team of researchers from Harvard

University wanted to run an outdoor SRM experiment in a way they regarded as open, inclusive, and honest. Their project tried to create a framework for legitimate experimentation, but the weight of the issues proved too much. After several false starts in Arizona and then in Sweden, they finally gave up in March 2024. One company, Stardust, has asked for outside help in thinking through the implications of their SRM plans.

Even when such experiments don't get off the ground, they offer useful lessons. However, some would-be disruptors seem to have concluded that transparency only causes more problems. With little care for what others might think, a startup called Make Sunsets has begun releasing balloons filled with the material for "reflective, biodegradable, high-altitude clouds." The company is already selling what it calls "cooling credits" to help clear the conscience of those wishing to offset their carbon dioxide emissions. Their claims are scientifically spurious, but the media attention they have garnered and the money they claim to have raised suggest that irresponsibility can have its rewards. In many cases, outdoor experiments are best seen as public displays. One of the St. Ives protesters told me that she suspected the company had come to Cornwall for the photo opportunity rather than the marine ecology. The company seemed to be seeking attention rather than knowledge.

The biologist François Jacob once called experiments "machines for making the future." This is especially true when experiments are attempts at public persuasion. Innovators may try to claim, as they have with self-driving cars, that their devices are still prototypes and they are merely running tests, but "experiments" have a habit of becoming the new normal. With software and online platforms, we have become used to a state of perpetual experimentation—being, as one company's strapline puts it, "always in beta."

When scientists go outside, it becomes harder for them to control not just the variables of an experiment, but also the social context of an experiment. But we wouldn't want them to retreat to their labs. If they are to succeed, technologies need to be tested in the real world. As the head of Planetary Technologies told a journalist, "There really is no substitute for real-world work." If scientists choose to conduct their tests in secret, or let experiments be run by those who care little for either scientific research or public concerns, then public trust will be damaged. Responsible researchers should want a clear dividing line between their activities and those of the start-ups looking for attention and investment. So what models for responsible experimentation should we be looking to develop?

We can learn important lessons from one area of innovation where the stakes are high, experimentation in the real world is vital, and public trust is paramount. New medicines have to pass a set of clinical trials, scaling up the experiments to monitor risks and benefits . We know that drugs need to be tested on real people, at scale, but we don't let pharmaceutical companies mark their own homework. Some philosophers have proposed that we do the same for self-driving cars. This would probably be more trustworthy than the current approach, but it would go against the grain of Silicon Valley's innovative freedom. In health care, researchers and clinicians are starting to realize that new AI tools might need clinical trials just as new medicines do. But the number of robust trials of AI use in clinical practice that have been carried out is tiny. A recent review found only 86 worldwide.

Experiments are ultimately about learning. It's up to policy-makers to ensure that the lessons are widely shared. Experiments in the real world provide data that speak well beyond the researchers' hypotheses. And yet scientists who take their experiments outside seem to struggle to learn from others' missteps. Perhaps they presume that their research is new, so old lessons don't apply. This is a mistake. The experiences of geoengineering researchers offer important guidance for other technologies. Reckless experiments don't just dent the reputations of one company or one research team. They undermine the case for whole fields of innovation. With the newest cutting-edge AI models, companies have released them into the wild with little consideration of what is at stake. As we start to understand the benefits and the risks, AI companies need to start taking more responsibility for their experiments.