ELEPHANT
IN THE LAB

OPINION

Ideas as Infrastructure

Short title	Ideas as Infrastructure
Long title	Ideas: The other research Infrastructure
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Author bios	Øyvind Paasche has a long-term interest in past and present climate change and dynamics, polar regions included. During later years, he has developed a keen interest in how scientific data are handled, used and understood by actors outside academia. He is both a Senior Adviser and Senior Scientist with the Bjerknes Centre for Climate Research and NORCE Climate. Prior to his present engagement, he was the leader of the Bergen Marine Research Cluster (2011-2016). He has authored and co-authored around 30 studies in international peer-reviewed journals, co-edited the book *The New Arctic,* published in 2015 by Springer. He has also co-authored a book on how the climate system works called *What is Climate?* (in Norwegian) as well as being a contributing author to the 4th IPPC report (The Physical Science Basis). Paasche leads several ongoing projects such as *Ocean Outlook* (2016-20), *Hordaflom (2017-2020), Advanced Climate Education and Research* (2018-2021) and is also a member of *Seasonal Forecasting Engine* (2018-2021). He is part of the team running the well-known summer school *Advanced Climate Dynamics Courses* (ACDC) and is currently the Chair of the Scientific Steering Committee for the international initiative known as the *Synoptic Arctic Survey* (SAS).
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The infrastructures that natural sciences run on are many and varied. A mixed garden of tailormade instruments and laboratories designed to handle highly specific tasks. Some are placed in weather-beaten areas like the Mauna Kea Observatories on Hawaii enabling us to connect our own place in the immenseness of the Universe to superclusters like Laniakea and Virgo, whereas others are located deep below ground exploring the very fabric of light by trying to trap neutrinos. Some are costly and quite a few are ingeniously constructed. Examples are numerous.

It can be drilling equipment. Designed to retrieve pristine material from a remote ice cap or the deep-sea floor. This simple(!) form of infrastructure has facilitated research that has returned invaluable information to our societies. They include 800 000 years of global CO2 observations (1), millions of years with sea surface temperatures (2) or a unique 300-year window of net primary productivity in the North Atlantic (3). Empirical data that, as of now, cannot be produced in any other way.

Drilling equipment apart. There are other types of infrastructure that has a more immediate, vital character. Progress made the year I was born count successful imaging of a clam with the help of *nuclear magnetic resonance*, a terminology that with time decayed into *magnetic resonance imaging* or MRI if you prefer.

Paul Lauterbur, the single author behind a seminal paper published in the journal *Nature* that very year ends on an optimistic and bold note: «Zeugmatographic techniques should find many useful applications in studies of the internal structures, states, and compositions of microscopic objects.» If that was his dream, it certainly developed well. His greekifed concept for MRI – Zeugmatography – did not. Other stellar infrastructures worthwhile mentioning could include space stations, cyclotrons or the World Wide Web, but I don't think we need to exhaust the list of critical infrastructures, as the point has already been made: infrastructure is critical for science.

Many of us know of, if not about these infrastructures as they stand out like roads, tunnels and bridges in buzzing cities. They define research in the eyes and the minds of the public. Think about it. What do people associate with science? I suspect that the first image to materialize is a human being in a white lab coat. More often than before, with a pair of protective plastic glasses. In other words, science equals labs and labs equal infrastructure.

And I for one, love labs. In some sense it's where I was raised in academia. A lab is such a natural place for science to unfold; measurements are made continuously, samples are prepared, sometimes cultivated, always tested and everything is meticulously documented. A second lab, 10 000 or 1 mile away can do the same test runs, the same experiments in order to check reproducibility and/or to complement initial measurements. And by doing so, science can transcend all kinds of barriers in a pursuit of finding something out, which is the quintessence of science.

The other research infrastructure

But by focusing solely on hard infrastructure, we are missing the point – or rather – that there are other forms of infrastructure entirely. A type that we always carry with us. Safely stored inside of every scientist, and in their relations to each other, and with society. Ideas, the lifegiving building blocks of science!

Ideas are fuel for science. And then there are some ideas or concepts representing core values that science arguably depends on. The pillars that keep the roof in place. They also constitute a type of infrastructure albeit differently than laboratories, research vessels and botanical gardens. I count words like 'trust', 'openness', 'inclusiveness', 'integrity' and 'community'. There are obviously others too. Perhaps you have favorite too that define, constrain and realize the field of science that preoccupy you? Here is a justification of mine.

Trust is such an integral part of science and perhaps so obvious that it's easy to forget when discussing how we progress and make discoveries. If you have trust in your group, in your team, at your institute you have one of the most important assets in place.

If you don't trust your data, conclusions will never be reached.
If you don't trust your peers, reviews will be rendered useless.
If you don't trust your colleagues, you cannot tap into the most important resource (freely) available to you.
If you don't trust your students, how can they themselves become researchers?

If there isn't room for trust, communities will degrade and bitterness will prevail. Trust is pivotal and a cornerstone in science.

Openness has always followed and guided science from its very inception either in accounting for how your experiment initially was set up, how the codes were designed or just discussing your thoughts and observations with colleagues. In our data-driven reality, openness or transparency is of critical importance to science.

Science is, however, not only carried out by universities and research institutes obliged to share the data they generate. Private industry and national agencies carry out research on an almost unfathomable scale, but data and insights that they produce are often, and for various reasons, unavailable to the public. This can be a democratic challenge, and it deserves, in my opinion, more attention that it currently receives from media and decision-makers alike.

Inclusiveness. Science, sadly, has a poor record of inclusiveness which in effect has debilitated us from performing cutting-edge research. For the longest time science was a place for well-off white men only. This has gradually changed, and for each fence that has been torn down we have become a more diversified and richer community. In science you will always be judged and evaluated, but that should always be on your factual merits not your background, your dialect or language, sexual orientation, skin color or political preference. If research is to bring insight and

innovations to society's grand table, we need to be inclusive and we need to treat people fairly and with respect. We're all different, and diversity is one of our greatest assets. If we can be bold enough to not merely welcome it, but also defend it whenever it is challenged, I believe we've come a long way.

Integrity. What is integrity in science? It relates to the way you perform or conduct your research. Can your experiments and results be reproduced? Interpretation of data should always be as objective as possible and not be governed by secondary motives. Moreover, the scientific processes that have been involved in reaching the conclusions in question should always be transparent and intelligible. To me, integrity is also about how you treat students and peers at your workplace. In that sense, integrity and community are interlinked bridging several levels of life in science.

Community. Everyday life in science can be a lonely enterprise. The daylight hours spent in the basement, a location that house many a buzzing lab, can easily tip into something which is not entirely sustainable. Even so, there's usually others working in the same lab or someone else doing something similar somewhere else. Said differently, our identity as scientists is community-based. The loose structures that surround us are, for some reason, easy to forget during routine activities and consequently our ownership to the community we subscribe to is periodically weak. This can quickly change. Together with Henning Åkesson, presently at Stockholm University, I wrote a letter of support to US colleagues. We called it "The Nordic Letter on Climate Action and Scientific Integrity" and within a few weeks we had roughly 500 signatures, the support was overwhelming (4). It was also a manifestation of a community.

Science in society

There are good reasons to be attentive of science's position in society because it reflects back on how it is to be a scientist, and what is expected of you. In recent years, science have come under attack in many countries (which is very worrisome far beyond these brackets). In Europe, dire reports are coming from Hungary and Turkey about how science and scientists are mistreated. In the US, the Trump administrations has repeatedly demonstrated that our freedom and respected position should not be taken for granted. Standing upright when your results and conclusions and/or your intentions are not only questioned but actively sought to undermine you, your moral stamina will be put to test. Integrity is a quality most will claim to have intact but the game changes when you have to defend it.

A note on the side. I encourage engaged readers to visit the homepage of Union of Concerned Scientists every now and then, if you want to stay updated not only on how the Trump Administration actively undermine science's position, but also how one can respond as a community. The pressure on science has raised the awareness and importance of integrity and to some extent galvanized US science communities.

Having said that, the Trump Administration's withdrawal from the Paris Agreement in not just a devastating blow for international efforts to curb emissions of greenhouse gasses, but it is also an attack on climate science and climate scientists.

To me, the ideas highlighted here – trust, openness, inclusiveness, integrity and community – are my favorite stars on Science's vast firmament, words we should use for navigation and inspiration. They are perhaps the single most important infrastructure in Science.

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