

such as particle accelerators and telescopes, Nielsen says, the few scientists who have access will be cited frequently.

Cassidy Sugimoto, an informatics researcher at Indiana University Bloomington, thinks that the increasing number of collaborations can explain some of the effect. Collaborations have been steadily rising over the past century at all levels and in all fields of science². She notes that in Nielsen and Andersen's study, when authorship was divided up so that each author got a fraction of the paper, the overall inequality in citation shares remained steady. "I see it as a restructuring and reorganization of science," says Sugimoto. "It highlights that teams are nearly ubiquitous."

Nielsen and Andersen also found a decrease in the share of citations given to papers authored in the United States, and an increase in those given to papers authored in Western Europe and Australasia. The highest concentrations of 'citation elite' researchers were in the Netherlands, the United Kingdom, Switzerland and Belgium.

Vincent Larivière, a bibliometrician at the University of Montreal in Canada, is not surprised. He points out that the proportion of papers from US researchers has been dropping, as well. According to the US National Science Foundation's Science and Engineering Indicators³, the United States accounted for 29% of all papers published in 1998 but only 17% in 2018.

Larivière wonders whether excluding scientists with fewer than five publications could have affected the authors' findings. PhD students and postdocs, for instance, might publish only one or two papers before leaving academia for jobs in industry, government or the non-profit sector. If the number of such authors is increasing, this could account for some of the apparent increase in citation

concentration among senior scientists.

Andersen says that he and Nielsen had to limit their analysis to authors with multiple publications for data-quality reasons. Requiring each profile to contain multiple publications in the same field helped their algorithm to distinguish between authors with similar names; including everyone who had a single publication would have made the analysis too difficult. Still, both agree that it would be helpful to understand trends around

"There's a risk that this elite can define what research is being conducted."

'transient' authors. "If that group is growing, that makes the concentration at the top even more serious," Nielsen says.

The authors note that their data set probably includes some highly cited authors whose impact has been generated through extreme self-citation, citation 'farms' and ghost authorship.

Other inequalities

Sugimoto is not too concerned about citation inequality between established authors. She points out that 70% of the authors in Web of Science have fewer than 5 publications, meaning that the most-cited authors among the 4 million included in this study constitute "an elite of the elite", she says. "I think these inequalities are not the inequalities that matter."

Ludo Waltman, a quantitative scientist at Leiden University in the Netherlands, says that the study does not show that citation inequality leads to inequality in funding or career advancement. "In the end, that's what

really matters," he says.

He says that some institutions are moving away from using citation and publication metrics in decisions that affect junior researchers' career arcs. And he adds that some of the citation imbalance might result from elite researchers collaborating frequently with other groups and so ending up with their names on many papers.

But the presence of an elite could be a problem if it influences the direction of research in a field. "It's hard to define some kind of limit for when this is a good thing or bad thing," Andersen says. "But there's a risk that if the concentration becomes too high, this elite can define what research is being conducted and create some kind of monopoly" on which ideas are considered interesting.

Nielsen points to a 2019 paper⁴ that found that after a scientific luminary dies, new authors and new ideas begin to enter the field more easily.

Institutions can take steps to decouple funding and tenure decisions from publishing metrics, but it's unclear whether anything can be done about the citation elite, at least until its effects are better understood. Nielsen and Andersen are now looking at whether members of scientific elites preferentially cite each other, and whether transient scientists who work as students or technicians help to build the reputation of the elite authors who employ them.

1. Nielsen, M. W. & Andersen, J. P. *Proc. Natl. Acad. Sci. USA* **118**, e2012208118 (2021).
2. Larivière, V., Gingras, Y., Sugimoto, C. R. & Tsou, A. *J. Assoc. Inf. Sci. Technol.* **66**, 1323–1332 (2015).
3. National Science Board. *Publications Output: U.S. Trends and International Comparisons* (National Science Foundation, 2019); available at <https://go.nature.com/2ozy7xd>
4. Azoulay, P., Fons-Rosen, C. & Graff Zivin, J. S. *Am. Econ. Rev.* **109**, 2889–2920 (2019).

BREAKING THE BINARY AS A TRANS SCIENTIST

Institutions need experts in racial justice and queer liberation to advocate for scientists from under-represented groups. **By Robin Aguilar**

As my intro slide transitioned into view before the audience, I felt distant. My footsteps creaked as I walked to the podium to introduce myself at my department's annual 'get to know you' and networking retreat.

"Hey, some of you might remember me as Liz, but I'm transitioning. My name is Robin! I'm from East Los Angeles and go by 'they/

them' pronouns. Nice to meet you all."

As I handed the microphone back, my words lingered in the air like static. After a roll of applause, I felt my world settle.

Coming out as queer and non-binary at the start of my PhD programme at the University of Washington, Seattle, in 2018 brought me closer to feeling that my identities would be seen and validated in my professional world

as a computational biologist doing research in genomics. I have no regrets, but the decision came with compromises. In social settings and classrooms, despite having spent hours poring through coursework, I have felt spoken over while presenting my ideas. My experiences with untoward biases were dismissed when I brought them up, and it often seemed like my peers ignored me in hallways and at social gatherings.

At one social event, I was told that I should tolerate sexism and keep my experiences with microaggressions silent if I wanted a successful scientific career. Imagining a future for myself in genomics was difficult because of the lack of role models who shared my experiences and thrived as scientists.

Being a trans person in science – on top of my intersecting identities – can feel emotionally exhausting because of the inaccurate assumption that my experiences have made me more of an authority on inclusion and justice in science, technology, engineering and mathematics (STEM) than on science itself.

Challenging this assumption made me reflect on my upbringing in a neighborhood surrounded by other Latin American immigrant families. Here, my family sustained connections to our communities and culture, such as the *pueblos* (small towns) many of us originate from in Colombia and Mexico. Being a first-generation queer and trans student from a low-income background affected my ability to find a voice as a scientist, but I was able to do so through the support of close friends and mentors who supported my personal and scientific journeys.

In being asked to stay silent about my experiences, I couldn't help but feel that the experiences of my communities were also silenced. Internships and professional-development programmes supporting marginalized scientists readied me for a PhD programme and financed it, but it felt like the field itself was not ready for me.

Making strides

To help others to have a better experience in STEM, I share my story by writing articles and creating art, and I build community spaces for other trainees. In 2019, I founded the Genome Sciences Association for the Inclusion of Marginalized Students with a team of student leaders and with financial support from our PhD programme. Our group remains trainee-led and aims to support members' scientific and personal aspirations by offering community, mentorship and visibility through social events and professional-development workshops in the Department of Genome Sciences. We host events featuring diverse speakers and perform outreach at conferences such as the National Diversity Conference organized by the Society for Advancement of Chicanos/Hispanics and Native Americans in Science, as well as the Annual Biomedical Research Conference for Minority Students, to connect with outside trainees and mentors.

For queer and trans scientists, self-advocacy without supportive communities can be exhausting and can come at the expense of professional opportunities. Those of us who do speak up when we wish to see tangible change risk being seen as trouble, a nuisance or ungrateful for the opportunities we have earned.



Robin Aguilar is a PhD candidate in genomic sciences.

Instead of relying on those of us who are willing to speak up, institutions should hire experts in racial justice and queer liberation to shift the burden of self-advocacy and emotional labour from Black, Indigenous and Latinx scientists with intersecting LGBTQ2IA+ identities (LGBTQ2IA+ is defined as lesbian, gay, bisexual, transgender, queer, questioning, two-spirit, intersex, asexual and other identities that fall outside of cisgender and heterosexual paradigms). We are often called on

“Your experiences deserve to be valued because queer and trans futures are beautiful.”

to lead discussions on anti-racism, inclusion and justice because we simply exist in STEM. With experts leading these conversations, better practices can be implemented at the institutional level without burdening researchers who are most impacted by discrimination and harassment.

How you can help

There are many routes institutions can take to champion change for trans and gender-nonconforming scientists. Cultivating spaces to share pronouns can be life changing for LGBTQ2IA+ scientists. The support I received after revealing my pronouns to supportive peers and mentors allowed me to thrive in science and continues to do so.

Providing opportunities for trainees to add their preferred name on classroom documents can uplift and reaffirm individuals

who are navigating legal name changes. And advocating for gender-affirming health care and gender-neutral restrooms can further improve the well-being and safety of trans and gender-nonconforming trainees.

Also, creating travel stipends for STEM conferences to uplift trainees with diverse and intersecting identities can help them to identify mentors and communities beyond their academic institutions. Finally, developing tools for reporting incidents of harassment can provide trainees with opportunities to work with institutions to identify community advocates and resolutions when trainees experience discrimination.

Ultimately, accountability, justice and representation must be incorporated into STEM leadership and pedagogy. Coursework led by experts who can contextualize and unpack the historical inequities in STEM higher education should be offered to trainees throughout their graduate careers.

For readers who are queer and trans scientists, I have some advice: pursue goals that motivate you and provide you with space to practice self care. It's crucial to prioritize your needs and invest in relationships, projects and hobbies that make you embrace your whole self as a scientist. Regardless of where you are in navigating your identities and their intersections, know that you are not alone. Your experiences deserve to be valued because queer and trans futures are beautiful.

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