A Manifesto for Rewarding and Recognising Team Infrastructure Roles

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The Scientific Reform Movement has highlighted the need for large research teams with diverse skills. This has necessitated the growth of professional team infrastructure roles (TIRs) who support research through specialised skills, but do not have primary responsibility for conceiving or leading research projects. TIRs such as Lab Technicians, Project Managers, Data Stewards, Community Managers, and Research Software Engineers all play an important role in ensuring the success of a research project, but are commonly neglected under current reward and recognition procedures, which focus on the individual academic researcher instead of the teams involved. Without meaningful identification and recognition of TIR contributions, we risk reinforcing the conceptual and practical division between academic researchers and TIRs. This situation is inequitable and detrimental to the research enterprise: the limited potential for career advancement for TIRs may cause them to leave for other occupations, ultimately leading to a loss of institutional skill, expertise, and memory. This contribution explores the evolution of specialist TIRs and the status of these positions in various settings. We provide three case study descriptions of TIR activities, so that readers may become more familiar with the breadth and depth of their work. We then propose system level changes designed to embed meaningful recognition of all contributions. Acknowledging the contributions of all research roles will help retain skill and expertise, and lead to collaborative research ecosystems that are well-positioned to address complex research challenges.

Keywords *Team Infrastructure Roles, Rewards and Recognition, Research Evaluation, Team Science, Career*

The social and technological developments of recent decades have reinforced the notion of science as a team-based enterprise. As we tackle increasingly complex scientific questions (Coles et al., **2022**), we leverage the strengths of diverse research teams, recognising that we cannot solve the significant challenges of our time through isolated endeavours. This increased diversity in practice is part and parcel of the Scientific Reform Movement, which seeks to promote the uptake of practices that improve the transparency of the research process (Penders, **2022**), as well as to provide recognition for these practises (Coles et al., **2023**). Reform of academic publication and authorship practices are one route to address such issues, but we see authorship (or contributorship, see Rennie et al. (**1997**)) as a symptom of entrenched inequity, rather than the source of it. The Scientific Reform movement should go beyond reformation of publishing and aim instead to address fundamental roots of academic inequity, such as the perceptions of what it means to be a researcher and participate in research. In this piece we will explore a broad range of factors which may lead to inequity in the academic workforce and suggest changes to research systems to improve equitable practices.

The emergence of TIRs

To illustrate the increasingly diverse and team-

based approaches to research, consider that over 5,000 named authors across the globe collaborated in the detection of the Higgs Boson at CERN (Castelvecchi, **2015**), how successful climate models require expertise in atmospheric physics, soil science, meteorology, and more (Huebner et al., **2017**), or the integration of research into artificial intelligence with moral philosophy (Jobin et al., **2019**). With increasing collaboration and growing research complexity, new specialised roles have emerged to support research processes. We call these *team infrastructure roles* (TIRs), making explicit their structural function in the research process. TIRs bring vital expertise to the process of research, but they are not well integrated in traditional academic organisational structures.

TIRs contributing to the research process include laboratory technicians, project managers, grant officers, finance managers, privacy officers, patent officers, and internal review board members (Heffner, **1979**; UKRI, **2023**). These roles are known collectively as "professional service staff" or "research professionals". Their position in between supporting roles and academic researchers has been referred to as the "third space" (Whitchurch, **2008**). While some contributions of these roles may appear to be solely bureaucratic, one cannot deny the value of a skilled project manager, finance manager or technician in handling their respective responsibilities. We provide some examples of TIRs and their diverse areas of speciality below and in **Table 1**. These examples and perspectives are primarily informed by our academic experience in the US and Europe. The challenges, case studies, and changes that we suggest may be less applicable, or necessary, in other contexts. For example, low/middle income countries may prioritise other forms of research reform rather than dedicate resources to these types of positions (Bezuidenhout & Chakauya, **2018**; Bezuidenhout et al., **2017**; Onie, **2020**).

The emergence of new TIRs has introduced unmapped complexity into the academic ecosystem, particularly in relation to recognition, reward, and development. We argue that successful integration of TIRs in the academic system will require naming, exploring, and resolving frictions associated with these new roles.

Challenges

Lack of autonomy within TIR roles

Academic researchers are afforded substantial freedom in determining their career paths. This stems from historical positioning of academic researchers as "appointees" who perform scholarship as a public duty, rather than "employees" who are a means of production for a university (Finkin & Post, **2011**). This legitimises autonomy in the management of day-to-day activities and professional development (Wolf & Jenkins, **2021**), contributing to an internally recognised credit system.

In contrast, many TIRs are employed as "technical staff", with a specific remit in their job description to perform support activities, governed by the requirements of academic researchers or the broader goals of the research institute. Consequently, pursuing projects or publications outside of this support remit can be seen as a distraction. This lack of autonomy limits the ability of TIRs to prioritise the growth of their skills alongside evolving research disciplines or methodology, constrains their opportunities for progression towards leadership roles, and ultimately squanders their ability to inform the direction of the research agenda.

Limited formalisation of career pathways

Many TIR careers lack development pathways (NCRIS, **2022**; Virágh et al., **2019**). This is in contrast to academic research careers, where the criteria for promotion up to the highest levels are well documented, clearly advertised, and often supported by formal and informal systems of mentoring. For example, the *Vitae Researcher Development Framework* (Vitae, **2014**) maps out academic researchers' expected skill development across all facets of scholarly activity. Individuals employed in Human Resources or Finance positions can also access industry-specific accreditation and qualifications to support their progression (for example, training offered through the Chartered Institute of Personnel and Development for Human Resources professionals, or the Association of Chartered Certified Accountants for accountants).

In contrast, conventional opportunities for career development, such as increasing job responsibility and resulting uplifts in remuneration (UKRI-Research England, **2022**; Virágh et

al., **2019**), are inconsistent for TIRs. Individuals in TIR positions may therefore look outside of the academy for progression, with subsequent departures leading to institutional memory loss (Bossu & Brown, **2018**; McInturff & Adenis, **2022**). A lack of professional recognition also introduces challenges in funding TIRs, especially where salaries are not competitive with similar roles outside of academia (UKRI-Research England, **2022**). The restriction of developmental opportunities, lack of established profiles and compensation, and limited funding routes leave TIRs to act as lone advocates for their own positions, a stressful and complicated task due to their unique niche within the academic organisational structures.

Prejudice against TIR activities and career choices

The growing availability of TIRs in research institutes means that academic researchers can increasingly "outsource" some of the research responsibilities that were traditionally theirs alone. Passing those tasks to professionals may be viewed by some as "a hollowing out of [...] what it means [...] to be an academic" (Macfarlane, **2011**, p. 71). By this account, whilst specialisation of roles and responsibilities may increase efficiency, it may also negatively impact traditional academic values and identity, reinforcing a working culture geared only towards maximum productivity (Beatson et al., **2021**; Limas et al., **2022**; Wellcome Trust, **2020**). Thus, the mere existence of TIRs may be viewed negatively by some within the academy.

Prejudice can also result from changes to the status of roles within an institution. Harloe and Perry (**2005**) suggest that moving to a "co-operative form of production" akin to co-creation, rather than one in which TIRs simply facilitate the work of academics, may undermine the "collegial culture" in universities. In this culture, research academics have traditionally had exclusive responsibilities in determining their university's governance and organisation through engagement with institutional decision-making systems (such as committees). TIRs may thus be viewed as yet another non-academic staff member whose increasing influence dilutes academics' autonomy and authority, and/or increases their already heavy workload. This perspective highlights current tensions in the system: TIRs may be perceived as not sufficiently qualified to exert influence in the system, despite the fact that many TIRs are highly skilled researchers with doctoral degrees and years of academic experience (Teperek et al., **2022**; UKRI-Research England, **2022**).

TIRs may also be stigmatised as "failed academics" because they do not pursue traditional academic careers (ARMA, **2020**; Gould van Praag, **2022**; Sever & Janssen, **2017**). This parallels the prejudice against "leaving academia" for industry, often viewed as a last resort for those who "couldn't hack it" (Gewin, **2022**).

These prejudices towards the activities and career choices of TIRs make it more difficult to enact changes to infrastructure and reward systems which could benefit them. It also contributes to "imposter syndrome", with the barriers to reward and progression implicitly reinforcing the message that TIRs are of lower status than academic researchers (Sims, **2021**; UKRI-Research England, **2022**). Relatedly, the prejudice can also go the other way: TIRs may believe that academics' reluctance to engage with their help is limiting the potential of an institution (Harloe & Perry, **2005**). These tensions can negatively impact attempts at institutional change.

Recognition of TIR contributions

Academic incentives are often focused on the contributions of the individual, and the image of a "lone academic genius" (Elkins-Tanton, **2021**). This is reinforced by prizes awarded to singular "outstanding" academic researchers, the common practice of naming a research group by the lead Professor (for example, the "Smith lab"), and apparent ownership of team members ("[Person X] is *my* PhD student" or "*my* postdoc"). The power to confer authorship is generally enacted by senior researcher(s) and, in many disciplines, only the first and last authors are deemed to have done the actual work. Practically, however, research builds on previous work as well as a diversity of contributions that do not always lead to authorship and are therefore not formally recognised (Coles et al., **2022**; Forscher et al., **2020**; Shirazi, **2014**; Tiokhin et al., **2021**). By focusing solely on individuals and first/last authorship positions on publications, the academic research system neglects the value of a broader set of contributors - with their own unique skills and expertise

(Baum et al., **2022**). This results in precarious positions for TIRs, as their work rarely translates directly to authorship, let alone a first or last authorship position. TIRs are therefore not fully participating in the credit economy (Zollman, **2018**), where prestige from authorship and awards can bring further rewards in the form of downstream funding success and access to high-status jobs (Huebner & Bright, **2020**).

Growth of TIRs

Some emerging TIRs have been exemplary in handling the challenges outlined above. These examples may serve to illustrate the utility of making TIR duties, performance expectations and influence more explicit, along with the merits of forming professional communities of practice. These roles have been listed in order of more established (Research Software Engineer) to relatively recent (Research Application Manager). These roles exemplify how well-resourced TIRs can bring substantial value to the academic workflow. In **Table 1** we additionally summarise career trajectories and opportunities for recognition in each role.

Example 1: Research Software Engineer

Research software engineering represents an established specialised research role: a hybrid between researcher and programmer which requires expertise in both research and programming. Similar roles have existed for decades with a variety of titles, but the specific title – Research Software Engineer (RSE) – was conceived at Collaborations Workshop in Oxford in 2012 (Hettrick, **2016**), followed by the formation of the RSE Association in 2013. The rise of RSEs demonstrates the power of naming and defining a role, providing an identity and focal point for action (Sims, **2021**). Hettrick (**2016**) summarises the first four years of actions by the RSE Association, including numerous articles, market analysis, and policy work. Today, there are RSE networks on every continent, an international council of RSE associations, and an emerging, standardised career path for RSEs. Many institutions have established RSE groups, independent of research labs, while the Netherlands eScience Centre is an example of an independent organisation which centres the role of RSEs in the research process. This is the result of sustained, organised advocacy efforts by both researchers and RSEs.

RSEs function both as individuals in embedded roles as well as consolidated groups who provide expertise on a project-by-project basis within their institutions. This "consultant" model provides access to RSE expertise for groups who do not have the budget for longer term investment.

Example 2: Research Community Manager

Research Community Managers (also known as Scientific Community Managers) foster collaboration, engagement, connection, and productivity among members of a community, where a *community* is a group of people united by a common tool, discipline, location, service, or interest. Only in recent years the coordination and management of scientific communities has become formalised, as cross-institutional and international collaborations have become more common. The *Center for Scientific Collaboration and Community Engagement* (CSCCE) was established in 2016 to provide training, support infrastructure, and advocacy for Research Community Managers, formalising it as a distinct professional role (CSCCE, **2022a**). The first Community Engagement Fellowship cohort in 2017 kick-started the conversation around the nature of scientific community management and its unique challenges and considerations compared to communities outside academia. The CSCCE provides a space where Research Community Managers can receive support, domain-specific updates, and opportunities for collaboration and professional development. The CSCCE is now developing a community manager certification (CSCCE, **2022b**), so that individuals who are expected to foster community engagement can perform their role with confidence and a thorough understanding of the technical and theoretical basis of community activities.

Example 3: Research Application Manager

Research Application Managers (RAMs; The Turing Way Community, **2022b**) bring product thinking and stakeholder engagement to research outputs. For example, RAMs at The Alan Turing Institute address the need for sustainability of research infrastructure, extend

Table 1 A summary of each of the example roles described in the main text, highlighting whether there is an established professional advocacy organisation, expected career trajectories and professional development, comparisons to roles outside of research, and how these roles can be recognised.

	Research Software Engineer (RSE)	Research Community Manager (RCM)	Research Application Manager (RAM)
Summary of Role	Creates and/or maintains software specifically intended for research purposes	Fosters collaboration and engagement among a specific scientific community	Guides research projects (including infrastructure) for sustained impact and reuse through user community engagement
Professional Organisation	National and regional RSE associations	CSCCE	None yet
Sources of Professional Development	Software development training; Software Sustainability Institute	Community management training; CSCCE	Product management training
Career Pathways	Increasing rank, management of other RSEs or RSE teams	Director of organisations, scientific organisation administration, programme/network management	None yet
Non-research Equivalents	Software development	Community/outreach manager, developer advocate	Developer relations, product manager, developer advocate
Reward/Recognition Opportunities	Conferences, software publications, software citation, awards	Conferences, informal praise, training and development opportunities, contributorship on publications, awards	Conferences, inter-institute interactions, wider uptake of projects

existing research outputs and software, and seek opportunities to reuse and reproduce these outputs in new scenarios (The Turing Way Community, **2022b**). RAMs think beyond the research project cycle, cultivate a broader understanding of a discipline's trajectory, and understand the interconnectedness of scientific research more broadly. This role is still emerging as distinct from a Product Manager in industry or an academic Innovation Officer, with little formal documentation or organised advocacy in place. RAMs represent an interesting example of a newly emerging TIR which may experience a similar trajectory as RSEs and Research Community Managers.

Pathways forward

Here we present pathways through the challenges described and towards the successes of the highlighted case studies. We identify first steps towards a vision in which all TIRs are appropriately rewarded, recognised, and integrated with the work and priorities of research academics. An appropriate next stage will be the evaluation of costs and practicality of each intervention in supporting immediate or long-term change, with iterative piloting and refinement towards the idealised vision.

Re-imagine the research system to emphasise the process, not only the outcomes

Although research is primarily viewed in terms of knowledge production, we take inspiration from the values described in the SCOPE framework (INORMS, **2022**) and recommend that individual *outputs* (such as publications, discoveries, technologies) be deprioritised in favour of elevating the *process*. More specifically, many research activities do not directly lead to outputs that are commonly measured and rewarded in academia, such as those of the TIR

case studies described previously. Additionally, efforts that improve the research process by increasing transparency, reproducibility, and cooperation may not lead to journal publications. A narrow focus on publications as a reward mechanism will necessarily draw time away from such improvements. The focus on individual outputs additionally encourages implicit or explicit "gaming" of the system, with production metrics being prioritised above all other concerns (Goodhart's law; Goodhart, **1984**).

One way to emphasise the research process is through normalising the sharing of research artefacts (such as protocols, data objects, code, preprints) produced through the process. A move to more frequent or continuous publishing will alleviate some of the pressures associated with precarious contracts, such as the lag between contribution and traditional journal authorship. Expanding *incremental publications to include research artefacts, broadly defined,* can also reduce gatekeeping around authorship—research groups may be more willing to acknowledge a named contribution where there is a clearer connection between the work and the published object. For example, a lab technician working on a protocol will have a stronger claim to be a named contributor on a published protocol than a research paper that uses that protocol. Alongside systems that are specific for one type of output (for example, arXiv for preprints or PREreview for published peer reviews), general-purpose platforms such as ResearchEquals, PubPub, and Octopus enable the creation of a timely and persistent record of broad research contributions. By affording attention and credit to a broader range of output types, the primacy of the final journal article in evaluation metrics will be reduced and each contribution will garner respect in its own right.

An expansive system for recognising contributions

We imagine a future where research is inclusive and participatory, with each contribution being valuable to the process and subsequent outcomes. This requires the acknowledgment that different individuals bring a diverse and meaningful array of skills and expertise, including those from backgrounds that lack traditional academic credentialing. Contributions can be in the form of materially-visible work (for example writing, data collection, software development), workflow improvements, ideation, and more. A thorough and accurate accounting of all contributions will require moving beyond quantifiable metrics such as datasets curated or lines of code written. As TIRs can support the research process in a myriad of ways, integrating qualitative descriptions of their contributions will be necessary to properly recognise their efforts.

The Contributor Roles Taxonomy (CRediT; (Brand et al., **2015**) is an increasingly popular framework for recognising contributions. However, even with 14 codified roles, the CRediT system does not fully address the problem of recognising diverse contributions. As previously noted, it is too common that "research" is synonymous with "peer-reviewed publication", when there are many other contributions that are impactful within the research endeavour. For example, Harris et al. (**2020**) published on the decades-long collaborative NumPy programming library project. There was a notable lack of gender diversity among the listed authors of the published report (Gallant, **2022**), despite gender diversity among the more recent code and documentation contributors (Weber Mendonça, **2020**), raising the question of how to recognise indirect contributions. If research is conducted in a version control system that tracks all changes (such as the Open Science Framework), one might assume all contributions would be observable and easily collated. But such a system will overlook efforts that are not readily recorded in said system (such as coordination and planning efforts, or offline discussions). The Turing Way's 'Record of Contributions' (The Turing Way Community, **2022a**) demonstrates one way to recognise all forms of contributions, where indirect contributions can be nominated into the tracking system: namely, using the all-contributors bot (All Contributors, **2022**). In addition, systems for tracking impact via citations will need to be much more comprehensive. For example, even with Digital Object Identifiers (DOI) emerging as a de facto standard, a DOI generated using Zenodo is only recorded as a citation if it is properly indexed, which is currently not always the case.

Furthermore, a focus on publications will neglect some TIR contributions entirely, especially for roles where the primary responsibilities do

not include research. Indeed, TIR contributions can include teaching, training, mentorship, lab supervision, and consultations provided by specialised experts in funding acquisition, outreach, project management, statistics, data analysis, or software development. These contributions rely on research content expertise yet are not easily folded into publishable research objects. Although some of these activities are performed within the remit of high-level leadership, appointment to such positions often requires evidence of a "successful research career", ignoring the expertise accumulated in TIR roles. Although it is unrealistic to expect any single system for recognising contributions to be ideal for every context, a credit framework that is customisable for different institutions and locales is an important first step towards addressing these challenges.

A system to validate research outputs

The above framework presupposes a large expansion in the types of research outputs. However, there may be resistance in recognising these outputs as "valid" because many lack formal systems for external peer review. Indeed, a system which incentivises "productivity" without an assessment of quality (no matter the output type) could lead to decreased trust in research. To ensure the quality of research outputs, and the ability for researchers to build effectively upon each other's works, systems should be established for expert review of all research outputs. Mirroring the peer review system for publications, TIRs could then participate by contributing their experience and skills to the review process.

Notwithstanding the complex debates about open peer review (Heesen & Bright, **2021**; Ross-Hellauer, **2017**), unremitted labour (Aczel et al., **2021**), and power dynamics (Huber et al., **2022**), peer review can serve a useful purpose in validating research outputs. Realising an appropriate system for peer review of diverse research outputs, however, will require large infrastructural and behavioural shifts. In the case of research software, such systems have already emerged in venues such as rOpenSci (**2022**), pyOpenSci (Holdgraf et al., **2022**), and the Journal of Open Source Software (**2022**). For other types of outputs, a peer review system would need to be designed to integrate effectively with how the outputs are used. For example, research protocols cannot be easily modified following reviewers' suggestion, so there would have to be a well-specified role or aim for reviewer feedback beyond the suggestion of changes.

Standardised roles and pathways for career development

As demonstrated in the TIR examples above, and by Jetten et al., (Jetten et al., **2021**) for the Data Stewards in the Netherlands, the trend to professionalise TIRs leads to improvements in the visibility of their work, increased opportunities for training and networking with peers, and role-specific rewards and recognition. We argue that professionalisation also improves the integration of TIRs within research organisational structures. As seen with Research Software Engineers, TIRs may operate in fully independent teams that consult with academic researchers. This structure necessitates leadership responsibility, creating the opportunity for parity in responsibility and compensation between an academic researcher managing a lab group and a TIR managing a team of research support specialists. TIR leadership will also invite a degree of autonomy to direct activities and professional development within the team, including the opportunity to contribute to larger infrastructural change through service on institutional committees. The demarcation of specific responsibilities also supports negotiations to command a salary commensurate with expertise and makes it easier for individuals to move across institutions.

Professionalisation is, however, hampered by variability in the recognition and career support available to TIRs across institutions. This variability could be addressed through the creation of a new job family and pathway which parallels the development of the distinction between "Research", "Teaching and Research", or "Teaching and Scholarship" grades found in many UK institutions (for example the University of Sussex (**2019**) and University of St. Andrews (**2015**)), and the work by the National Collaborative Research Infrastructure Strategy (NCRIS, **2022**). Promotion levels in these new job families should match academic and managerial roles, in contrast to the Technical and Operational or Facilities profiles that only go as high as a standard post-doctoral grade. We

note that these job families were legitimised in the UK following negotiation between campus trade unions (University and Colleges Union (UCU), Unite and Unison) and representatives of the employers. Such a change may therefore require engagement of Unions across the sector to advocate on behalf of all research institution employees.

The professionalisation of TIRs could be further accelerated if larger mainstream funders created TIR fellowships (see similar recommendations by Teperek et al. (**2022**) and UKRI-Research England (**2022**)). This would require a cultural change from funders to value long-term investment in individual TIRs, and infrastructural change in how funds are distributed. In our idealised future, once role profiles are professionalised and standardised, institutions may ensure the continuity of support without the need for individual fellowships, through dedicated structural funding. A recent report by the UK Science, Innovation and Technology Government committee (U. K. Science, Innovation and Technology Committee, **2023**) on Reproducibility and Research Integrity recommended that "Funders and universities should develop dedicated funding for the presence of statistical experts and software developers in research teams. In tandem, universities should work on developing formalised, aspirational career paths for these professions." showing fledgling support for this idea at the highest level (U. K. Science, Innovation and Technology Committee, **2023**).

Conclusion

Recent socio-technical advancements have brought attention to the opportunities and needs surrounding research teams with diverse expert skills. Nevertheless, there is considerable work to be done to ensure that all individuals who make significant contributions to research teams are appropriately acknowledged and rewarded. TIRs are a unique facet of this problem, as positions dedicated to support research, but existing outside the typical researcher career structure. As a result, TIRs experience a lack of autonomy, have limited opportunities for career development, and face prejudice for deviating from the traditional academic credit system.

While acknowledging that there are significant challenges faced by TIRs in the current academic model, we highlighted three cases where there have been efforts to professionalise TIR profiles, thereby creating communities, recognisable standards in training, development opportunities, and collective advocacy: Research Software Engineers, Research Community Managers, and Research Application Managers.

Drawing from the successes and learnings of these examples, we suggest four system-level changes to address issues in the systems of reward and recognition available to TIRs, and their integration with the work and priorities of research academics. A summary of each proposal is provided below:

1. Shift the focus of academic research to appropriately value the *process* of the endeavour, not only the *prestige* of the outputs. Acknowledging that no output is necessarily final, we advocate for frequent or continuous public documentation (publication) of every stage of research, allowing for recognition of various contributions at each stage.
2. Expand the system for recognising contributions, going beyond the implementation of CRediT, by acknowledging contributions that are not visible in the form of authorship.
3. Create mechanisms for validating the quality and impact of non-journal outputs akin to peer review, noting that this will require infrastructural development in the delivery of review, and agreement on review standards for different output types.
4. Standardise and professionalise roles and pathways for career development, culminating in an academic career track which is distinct from the current "researcher" versus "non-researcher" dichotomy and, importantly, not restricted in the level of influence or reward achievable.

These proposals are offered at a time of increasing focus on increasing support for the open dissemination of research outputs (Concordat Working Group, **2016**; Office of Science and Technology Policy, **2022**; UNESCO, **2021**), calls to improve the broader culture of academia (COARA, **2022**; Wellcome Trust, **2020**), improving the bureaucratic efficiency of academia (Independent Review of Research Bureaucracy, **2022**), and the existing commitments to improve TIR positions (NCRIS, **2022**;

Technician Commitment, **2020**). If we seek to actualise the reform and ambitions of motions such as the San Francisco Declaration on Research Assessment (DORA, **2012**), we must acknowledge that there is significant scope to modernise the culture and tools we use to recognise and reward contributions. Systemic changes that improve the access of TIRs to career satisfaction will impact the reward and recognition processes relevant to the entire academy, making room to acknowledge, value and celebrate more diverse contributions and contributors to research.

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- **Arielle Bennett**: Conceptualisation, Project administration, Supervision, Writing - original draft, and Writing - review & editing.
- **Daniel Garside**: Conceptualisation, Visualisation, and Writing - review & editing.
- **Cassandra Gould van Praag**: Conceptualisation, Visualisation, Writing - original draft, and Writing - review & editing.
- **Thomas J. Hostler**: Conceptualisation, Writing - original draft, and Writing - review & editing.
- **Ismael Kherroubi Garcia**: Conceptualisation, Writing - original draft, and Writing - review & editing.
- **Esther Plomp**: Conceptualisation, Project administration, Supervision, Visualisation, Writing - original draft, and Writing - review & editing.
- **Antonio Schettino**: Conceptualisation and Writing - review & editing.
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- **Hao Ye**: Conceptualisation, Project administration, Supervision, Visualisation, Writing - original draft, and Writing - review & editing.

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References

Aczel, B., Szaszi, B., & Holcombe, A. O. (2021). A billion-dollar donation: Estimating the cost of researchers' time spent on peer review. *Research Integrity and Peer Review*, *6*(1), 14. https://doi.org/10.1186/s41073-021-00118-2 (see p. 26).

All Contributors. (2022). *All contributors* (Version v2.17.0). Retrieved September 27, 2022, from https:/ / web.archive.org/ web/ 20220927025500/https://github.com/all-contributors/all-contributors (see p. 25).

ARMA. (2020). The ARMA survey on research culture. https://arma.ac.uk/wp-content/uploads/2021/03/ARMA-Research-Culture-Survey-2020.pdf (see p. 22).

Baum, M. A., Braun, M. N., Hart, A., Huffer, V. I., Meßmer, J. A., Weigl, M., & Wennerhold, L. (2022). The first author takes it all? Solutions for crediting authors more visibly, transparently, and free of bias. *British Journal of Social Psychology*. https://doi.org/10.1111/bjso.12569 (see p. 23).

Beatson, N. J., Tharapos, M., O'Connell, B. T., Lange, P., Carr, S., & Copeland, S. (2021). The gradual retreat from academic citizenship. *Higher Education Quarterly*. https://doi.org/10.1111/hequ.12341 (see p. 22).

Bezuidenhout, L. M., & Chakauya, E. (2018). Hidden concerns of sharing research data by low/middle-income country scientists. *Global Bioethics*, *29*(1), 39–54. https://doi.org/10.1080/11287462.2018.1441780 (see p. 21).

Bezuidenhout, L. M., Leonelli, S., Kelly, A. H., & Rappert, B. (2017). Beyond the digital divide: Towards a situated approach to open data. *Science and Public Policy*, *44*(4), 464–475. https://doi.org/10.1093/scipol/scw036 (see p. 21).

Bossu, C., & Brown, N. (Eds.). (2018). *Professional and support staff in higher education*. Springer Singapore. https://doi.org/10.1007/978-981-10-1607-3 (see p. 22).

Brand, A., Allen, L., Altman, M., Hlava, M., & Scott, J. (2015). Beyond authorship: Attribution, contribution, collaboration, and credit. *Learned Publishing*, *28*(2), 151–155. https://doi.org/10.1087/20150211 (see p. 25).

Castelvecchi, D. (2015). Physics paper sets record with more than 5,000 authors. *Nature*, nature.2015.17567. https://doi.org/10.1038/nature.2015.17567 (see p. 21).

COARA. (2022). *The agreement on reforming research assessment*. Retrieved September 30, 2022, from https://web.archive.org/web/20220930124600/https://coara.eu/agreement/the-agreement-full-text/ (see p. 27).

Coles, N. A., DeBruine, L. M., Azevedo, F., Baumgartner, H. A., & Frank, M. C. (2023). Big team' science challenges us to reconsider authorship. *Nature Human Behaviour*, *7*(5), 665–667. https://doi.org/10.1038/s41562-023-01572-2 (see p. 20).

Coles, N. A., Hamlin, J. K., Sullivan, L. L., Parker, T. H., & Altschul, D. (2022). Build up big-team science. *Nature*, *601*(7894), 505–507. https://doi.org/10.1038/d41586-022-00150-2 (see pp. 20, 22).

Concordat Working Group. (2016). *Concordat on open research data*. UK Research and Innovation. Retrieved September 1, 2022, from https://www.ukri.org/wp-content/uploads/2020/10/UKRI-020920-ConcordatonOpenResearchData.pdf (see p. 27).

CSCCE. (2022a). *About the center* [CSCCE]. Retrieved April 27, 2022, from https://web.archive.org/web/20220427165526/https://www.cscce.org/about/ (see p. 23).

CSCCE. (2022b). *CSCCE community manager certification program* [CSCCE]. Retrieved May 29, 2022, from https://web.archive.org/web/20220729002352/https://www.cscce.org/trainings/cscce-community-manager-certification-program/ (see p. 23).

DORA. (2012). *San Francisco declaration on research assessment* [DORA]. Retrieved September 3, 2022, from https://web.archive.org/web/20220903151339/https://sfdora.org/read/ (see p. 28).

Elkins-Tanton, L. (2021). Time to say goodbye to our heroes? *Issues in Science and Technology*, *37*(4), 34–40. Retrieved September 10, 2022, from https://web.archive.org/web/20220910202704/https://issues.org/say-goodbye-hero-model-science-elkins-tanton/ (see p. 22).

Finkin, M. W., & Post, R. C. (2011). *For the common good: Principles of American academic freedom*. Yale University Press. (See p. 21).

Forscher, P. S., Wagenmakers, E.-J., Coles, N. A., Silan, M. A. A., Dutra, N. B., Basnight-Brown, D., & IJzerman, H. (2020, May 20). *The benefits, barriers, and risks of big team science* (preprint). PsyArXiv. https://doi.org/10.31234/osf.io/2mdxh (see p. 22).

Gallant, L. (2022, September 16). *A team of 26 authors and there appears to be 0 gender diversity... that is an active choice and [tweet by @lissgallant]* [Twitter]. https://web.archive.org/web/20200916222153/https://twitter.com/lisgallant/status/1306357619712577537 (see p. 25).

Gewin, V. (2022). Has the 'great resignation' hit academia? *Nature*, *606*(7912), 211–213. https://doi.org/10.1038/d41586-022-01512-6 (see p. 22).

Goodhart, C. A. E. (1984). Problems of monetary management: The UK experience. In C. A. E. Goodhart (Ed.), *Monetary theory and practice: The UK experience* (pp. 91–121). Macmillan Education UK. https://doi.org/10.1007/978-1-349-17295-5_4 (see p. 25).

Gould van Praag, C. (2022, May 22). Off the beaten PI track [Organisation for Human Brain Mapping (OHBM) 2022 annual conference, Glasgow, UK.]. https://doi.org/10.5281/ZENODO.6651963 (see p. 22).

Harloe, M., & Perry, B. (2005). Repenser l'université sans la vider de son sens : Engagements externes et transformations internes de l'université dans l'économie du savoir. *Politiques et gestion de l'enseignement supérieur*, *17*(2), 31–45. https://www.cairn.info/revue-politiques-et-gestion-de-l-enseignement-superieur-2005-2-page-31.htm (see p. 22).

Harris, C. R., Millman, K. J., van der Walt, S. J., Gommers, R., Virtanen, P., Cournapeau, D., Wieser, E., Taylor, J., Berg, S., Smith, N. J., Kern, R., Picus, M., Hoyer, S., van Kerkwijk, M. H., Brett, M., Haldane, A., del Río, J. F., Wiebe, M., Peterson, P., … Oliphant, T. E. (2020). Array programming with NumPy [Number: 7825 Publisher: Nature Publishing Group]. *Nature*, *585*(7825), 357–362. https://doi.org/10.1038/s41586-020-2649-2 (see p. 25).

Heesen, R., & Bright, L. K. (2021). Is peer review a good idea? *The British Journal for the Philosophy of Science*, *72*(3), 635–663. https://doi.org/10.1093/bjps/axz029 (see p. 26).

Heffner, A. G. (1979). Authorship recognition of subordinates in collaborative research. *Social Studies of Science*, *9*(3), 377–384. https://doi.org/10.1177/030631277900900305 (see p. 21).

Hettrick, S. (2016, August 17). *A not-so-brief history of research software engineers* [Software sustainability institute]. Retrieved April 7, 2022, from https://web.archive.org/web/20220407191258/https://www.software.ac.uk/blog/2016-08-17-not-so-brief-history-research-software-engineers-0 (see p. 23).

Holcombe, A. O., Kovacs, M., Aust, F., & Aczel, B. (2020). Documenting contributions to scholarly articles using CRediT and tenzing (C. R. Sugimoto, Ed.). *PLOS ONE*, *15*(12), e0244611. https://doi.org/10.1371/journal.pone.0244611 (see p. 28).

Holdgraf, C., Solvik, K., Ogasawara, I., Brett, M., Sundell, E., gaow, Chen, Z., Joseph, M., Lau, S., Rokem, A., Willing, C., Nicholson, D., Mason, J., Wasser, L., Bantilan, N., Moss, S., & Kashyap, S. (2022, September 21). *pyOpenSci/contributing-guide: Pre release 0.3* (Version v0.3). Zenodo. https://doi.org/10.5281/ZENODO.7101778 (see p. 26).

Huber, J., M. Inoua, S., Kerschbamer, R., König-Kersting, C., Palan, S., & Smith, V. L. (2022). Nobel and novice: Author prominence affects peer review. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4190976 (see p. 26).

Huebner, B., & Bright, L. K. (2020). Collective responsibility and fraud in scientific communities. In S. Bazargan-Forward & D. Tollefsen (Eds.), *The Routledge handbook of collective responsibility* (1st ed.). Routledge. https://doi.org/10.4324/9781315107608 (see p. 23).

Huebner, B., Kukla, R., & Winsberg, E. (2017). *Making an author in radically collaborative research* (Vol. 1). Oxford University Press. https://doi.org/10.1093/oso/9780190680534.003.0005 (see p. 21).

Independent Review of Research Bureaucracy. (2022). *Independent review of research bureaucracy - final report*. UK Government - Department for Business, Energy & Industrial Strategy. (See p. 27).

INORMS. (2022). *The SCOPE framework, a five-stage process for evaluating research responsibly* (No. 10). Retrieved August 30, 2022, from https://web.archive.org/web/20220801134009/https://inorms.net/scope-framework-for-research-evaluation/ (see p. 24).

Jetten, M., Grootveld, M., Mordant, A., Jansen, M., Bloemers, M., Miedema, M., & Van Gelder, C. W. G. (2021, March 19). *Professionalising data stewardship in the Netherlands. competences, training and education. Dutch roadmap towards national implementation of FAIR data stewardship*. Zenodo. https:/ / doi.org/ 10.5281/ ZENODO.4320504 (see p. 26).

Jobin, A., Ienca, M., & Vayena, E. (2019). The global landscape of AI ethics guidelines. *Nature Machine Intelligence*, *1*(9), 389–399. https://doi.org/10.1038/s42256-019-0088-2 (see p. 21).

Journal of Open Source Software. (2022). *Review criteria*. Retrieved May 11, 2022, from https://web.archive.org/web/20220511204643/https://joss.readthedocs.io/en/latest/review_criteria.html (see p. 26).

Limas, J. C., Corcoran, L. C., Baker, A. N., Cartaya, A. E., & Ayres, Z. J. (2022). The impact of research culture on mental health & diversity in STEM. *Chemistry – A European Journal*, *28*(9). https://doi.org/10.1002/chem.202102957 (see p. 22).

Macfarlane, B. (2011). The morphing of academic practice: Unbundling and the rise of the para-academic. *Higher Education Quarterly*, *65*(1), 59–73. https://doi.org/10.1111/j.1468-2273.2010.00467.x (see p. 22).

McInturff, S., & Adenis, V. (2022). It takes a laboratory to avoid data loss. *Nature*. https://doi.org/10.1038/d41586-022-02967-3 (see p. 22).

NCRIS. (2022). Towards better recognition for research infrastructure specialists. the Australian national fabrication facility. https://web.archive.org/web/20230425094426/https://anff.org.au/news/towards-better-recognition-for-research-infrastructure-specialists/ (see pp. 21, 26, 27).

Office of Science and Technology Policy. (2022, August 25). Public access memo (A. Nelson, Ed.). https://www.whitehouse.gov/wp-content/uploads/2022/08/08-2022-OSTP-Public-Access-Memo.pdf (see p. 27).

Onie, S. (2020). Redesign open science for Asia, Africa and Latin America. *Nature*, *587*(7832), 35–37. https://doi.org/10.1038/d41586-020-03052-3 (see p. 21).

Penders, B. (2022). Process and bureaucracy: Scientific reform as civilisation. *Bulletin of Science, Technology & Society*, *42*(4), 107–116. https://doi.org/10.1177/02704676221126388 (see p. 20).

Rennie, D., Yank, V., & Emanuel, L. (1997). When authorship fails. A proposal to make contributors accountable. *JAMA: The Journal of the American Medical Association*, *278*(7), 579–585. https://doi.org/10.1001/jama.278.7.579 (see p. 20).

rOpenSci. (2022). *Software peer review* [rOpenSci]. Retrieved July 4, 2022, from https://web.archive.org/web/20220704125950/https://ropensci.org/software-review/ (see p. 26).

Ross-Hellauer, T. (2017). What is open peer review? a systematic review. *F1000Research*, *6*, 588. https://doi.org/10.12688/f1000research.11369.2 (see p. 26).

Sever, R., & Janssen, K. (2017). Career options for scientists. *Cold Spring Harbor Perspectives in Biology*, *9*(9), 032755. https://doi.org/10.1101/cshperspect.a032755 (see p. 22).

Shirazi, R. (2014, July 15). *Reproducing the academy: Librarians and the question of service in the digital humanities* [Roxanne shirazi]. Retrieved July 6, 2022, from https://web.archive.org/web/20220617010749/https://roxanneshirazi.com/2014/07/15/reproducing-the-academy-librarians-and-the-question-of-service-in-the-digital-humanities/ (see p. 22).

Sims, B. H. (2021). *Research software engineer as an emergent professional identity: A sociological perspective*. https://www.osti.gov/servlets/purl/1784685 (see pp. 22, 23).

Technician Commitment. (2020). *Technicians make it happen* [Technicians make it happen]. Retrieved September 1, 2022, from https://web.archive.org/web/20200809162757/https://www.technicians.org.uk/technician-commitment (see p. 27).

Teperek, M., Cruz, M., & Kingsley, D. (2022). Time to re-think the divide between academic and support staff. *Nature*. https://doi.org/10.1038/d41586-022-01081-8 (see pp. 22, 27).

The Turing Way Community. (2022a). *Record of contributions*. Retrieved June 4, 2022, from https://web.archive.org/web/20220604150908/https://the-turing-way.netlify.app/afterword/contributors-record.html (see p. 25).

The Turing Way Community. (2022b). *Research application managers: Overview* [The Turing Way] [https://doi.org/10.5281/zenodo.6533831]. Retrieved July 12, 2022, from https://web.archive.org/web/20220712021649/https://the-turing-way.netlify.app/collaboration/research-infrastructure-roles/ram.html (see pp. 23, 24).

Tiokhin, L., Panchanathan, K., Smaldino, P. E., & Lakens, D. (2021). *Shifting the level of selection in science*. MetaArXiv. https://doi.org/10.31222/osf.io/juwck (see p. 22).

U. K. Science, Innovation and Technology Committee. (2023). *Reproducibility and research integrity report (sixth report of the session 2022-2023)*. https://committees.parliament.uk/publications/39343/documents/194466/default/ (see p. 27).

UKRI. (2023). 101 jobs that change the world. https://www.ukri.org/news-and-events/101-jobs-that-change-the-world/ (see p. 21).

UKRI-Research England. (2022). *Research culture: A technician lens*. Retrieved September 28, 2022, from https://www.mitalent.ac.uk/Research-Culture (see pp. 21, 22, 27).

UNESCO. (2021). *UNESCO recommendation on open science*. United Nations Educational, Scientific and Cultural Organization. Retrieved August 20, 2022, from https://web.archive.org/web/20220820070614/https://unesdoc.unesco.org/ark:/48223/pf0000379949.locale=en (see p. 27).

University of St. Andrews. (2015). *Job families and generic role descriptors - guidance notes* [University of St Andrews - human resources]. Retrieved September 24, 2022, from https://web.archive.org/web/20151007123310/https://www.st-andrews.ac.uk/hr/gradingrewardandconditions/jobfamiliesgenericroledescriptors/jobfamiliesguidancenotes/ (see p. 26).

University of Sussex. (2019). *Academic role profiles* [University of Sussex]. Retrieved December 20, 2019, from https://web.archive.org/web/20191222011201/https://www.sussex.ac.uk/humanresources/business-services/jobevaluation/academicroleprofiles (see p. 26).

Virágh, E., Zsár, V., & Balázs, Z. (2019). *Research management and administration: A profession still to be formalized*. HÉTFA Research Institute, Center for Economic, and Social Analysis. Budapest, Hungary. https://hetfa.eu/wp-content/uploads/2019/04/Research-managers_final_0408.pdf (see p. 21).

Vitae. (2014). *Vitae researcher development framework*. Retrieved September 1, 2022, from https://web.archive.org/web/20220901044422/https://www.vitae.ac.uk/researchers-professional-development/about-the-vitae-researcher-development-framework (see p. 21).

Weber Mendonça, M. (2020). *Hi, just note that the authorship in this paper reflects contributions of the past 20 years, and the community has [Tweet by @melissawm]*. Retrieved September 16, 2020, from https://web.archive.org/web/20200916224502/https://twitter.com/melissawm/status/1306363367825776640 (see p. 25).

Wellcome Trust. (2020, January 15). *What researchers think about the culture they work in*. Wellcome Trust. https://wellcome.org/reports/what-researchers-think-about-research-culture (see pp. 22, 27).

Whitchurch, C. (2008). Shifting identities and blurring boundaries: The emergence of third space professionals in UK higher education. *Higher Education Quarterly*, *62*(4), 377–396. https://doi.org/10.1111/j.1468-2273.2008.00387.x (see p. 21).

Wolf, A., & Jenkins, A. (2021). *Managers and aca-*

demics in a centralising sector: The new staffing patterns of UK higher education. Nuffield Foundation. Retrieved September 28, 2022, from https://www.kcl.ac.uk/policy-institute/assets/managers-and-academics-in-a-centralising-sector.pdf (see p. 21).

Zollman, K. J. S. (2018). The credit economy and the economic rationality of science. *The Journal of Philosophy*, *115*(1), 5–33. https://doi.org/10.5840/jphil201811511 (see p. 23).