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Five creative ways to promote reproducible science

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The importance of reproducible scientific practices is widely acknowledged. However, limited resources and lack of external incentives have hindered their adoption. Here, we explore ways to promote reproducible science in practice.

It has been more than a decade since the recognition that the results of many scientific studies fail to replicate. In the wake of the initial acknowledgement of the 'replication crisis', there is a growing number of scientists who now recognize the importance of reproducible scientific practices and are motivated to use them[1]. Still, despite these internal motivations, many individuals struggle with their implementation owing to limited resources and a lack of external incentives. Indeed, major structural changes to the ways in which scientific research is funded, published, recognized and evaluated are required to ensure optimal implementation of reproducible scientific practices. Nevertheless, smaller-scale initiatives could help to rapidly improve scientific research across fields and serve as catalysers for major transformations.

Here, we describe five focused solutions to incentivize and lift barriers to reproducible science. Some of the ideas described here are not novel, and indeed have already been implemented in some fields or institutions. Our objective here is to provide a consolidated perspective on creative ways to promote reproducibility and awareness of these strategies within the broader scientific community.

Funded project extensions to postgraduate students

Adopting open science practices is time-consuming and might delay project progression[2]. For example, publishing a study as a Registered Report (RR) might extend the project because of the two separate peer-review stages, as well as (in some cases) the requirement for a longer period of data collection owing to higher power requirements. This can pose substantial barriers to the adoption of the RR format for postgraduate students whose funding lasts for a prespecified, and often short, amount of time.

A funded project extension, given evidence of engagement in reproducible practices, would lift this barrier. The scope of these activities might include — for example — evidence of code and data sharing, running a replication study or preregistering the experimental protocol (for example, as a RR or on platforms such as the Open Science Framework). These activities do not need to take place during the extension (and, indeed, to be granted an extension, students should be able to provide evidence that indicates that some activities have already occurred). This approach would enable postgraduate students to avoid a bottleneck toward the end of the course as well as better planning of these activities. It would enable postgraduate students to develop adequate skills and would support them in pursuing reproducible science, without needing to 'sacrifice' their limited contracted time for this purpose.

Guaranteed funding for RRs

A central barrier to the implementation of RRs[3] is that when a 'stage 1' RR is submitted for peer review, authors must be able to guarantee that funding for the project has been secured. Although this requirement is reasonable (and indeed necessary) from the journal's perspective, it adds barriers to the ability of researchers to pursue this option: namely, that securing funding for a full research project is time-consuming. When this adds to the extra time required for RRs, registration often becomes infeasible — especially for researchers with short fixed-term contracts and/or a substantial workload. Nevertheless, from the funders' perspective, funding an RR should be highly desirable and can be viewed as 'low risk, high gain': a stage 1 RR has already been accepted for publication and would therefore undoubtedly produce outcomes.

Therefore, both funders and scientists could benefit from a funding model that incorporates RRs into the funding structure. We propose the allocation of funding for smaller-scale projects that would be submitted as RRs. With this, projects submitted as RRs can receive a guarantee that they will be funded if accepted. For example, external funders and academic institutions can allocate funding to support accepted RRs. As such, researchers who aim to submit a stage 1 RR will apply for funding and — if successful — receive a guarantee for funding once the study protocol is approved (that is, when 'in principle acceptance' is obtained). Another possible mechanism for this adheres to (and can be integrated with) the 'Peer Community In' (PCI) RR initiative, in which RRs are reviewed by the community (that is, both the in principle acceptance and a final 'stage 2' approval are granted by communal peer review), and are then published in PCI-friendly journals without further peer review[4]. An extension of this would be to designate PCI-friendly

Table 1 | A summary of five proposals for incentivizing reproducible science

What	Who	Why	How
Project extension	Postgraduate students	The extra time investment often needed to engage in reproducible research makes it difficult for postgraduate students on fixed short-term contracts to engage in reproducible research. As such many postgraduate students who do so need to extend their project anyway, but this extension is often unpaid.	Funds are allocated via departments and/or training centres, depending on specific contracts. Extensions are considered by a departmental representative, supervisor or PhD committee against evidence provided by the student.
Funding RRs	All scientists, (mainly early-career researchers)	To get stage 1 approval for a RR, one needs to indicate that funding has been secured. At the same time, RRs that have been given stage 1 approval are a 'safe bet' for funders as the study will be published regardless of results.	Funds are allocated via departments or external funders. Funders will need to provide guidelines and assess project suitability (for example, scope, eligibility and intake load). However, in-depth peer review will be provided through the process of obtaining in principle acceptance, and therefore does not impose additional overheads to funders.
Centralized support	All scientists (discipline based)	Would save time spent searching for best practice individually and therefore ease and improve application of reproducible research practices. Can act as a training resource showcasing the 'gold standard' in reproducible practices.	Possibly supported by discipline-specific funders (such as the various UK Research and Innovation branches or the German Research Foundation). Requires communal effort: initial setup by expert and reproducibility supporters, and continuous maintenance further assisted via a pay it forward approach.
Local support	All scientists (location or institution based)	Would save time spent searching for best practices and would create a dependable source of information regarding location-specific practices. Would promote other solutions, such as aiding postgraduate students with the effective implementation of reproducible practices in their research.	Funds for specialized roles should be allocated by institutions or departments. The person holding the position will be in close contact with other relevant bodies within and outside the institution.
Portfolio	Postgraduate students and early-career researchers	Aids postgraduate students and early-career researchers in harnessing and showcasing their specific skillset to potential employers.	Career teams, supervisors and PhD committees should be able to support the preparation of the portfolio

Each idea ('what') is linked to the main beneficiary ('who'), key benefits of the implementation of the idea ('why') and key resources that should be allocated to support its implementation ('how').

funders who commit to fund projects for which in principle acceptance was obtained via PCI. To realize these solutions, eligibility and assessment criteria (for example, the scope of projects), as well as intake load (for example, costs and number of concurrently funded projects), should be predefined on a funder-by-funder basis to avoid a situation in which funders or institutions are committed to more projects than they can support. Nevertheless, this proposal will enable funders to allocate some of their funds to accepted projects that were thoroughly reviewed and judged to be worthwhile by relevant experts within the scientific community.

A reproducible-science centralized knowledge base and 'helpline' by discipline

Recent surveys have shown that a key challenge to performing reproducible science is a lack of knowledge and centralized resources[5,6]. Therefore, scientists will greatly benefit from communal support on reproducibility that targets their particular discipline. Best practices, procedures and data types vary markedly across disciplines and, hence, so do the kinds of support and solutions that are required. A specialized centralized knowledge base and helpline can be established for this purpose that will serve as a main contact point for scientists who wish to engage with reproducible science practices within their discipline.

Such resources could be — and indeed have been — collaboratively developed by researchers from the field who are actively developing or promoting reproducible science practices, integrating their knowledge into a centralized resource[7] — for example, as has been done for neuroimaging. Helplines could take the form of 'Q&As' that cover the main questions and challenges faced by researchers from the field when attempting to adapt reproducible science practices. Additionally, they should include online chats with experts from the field and/or AI-based tools; if this is not possible, offline forums can be used to facilitate communication between researchers in the field, who assist each other when facing problems (as has been done, for example, in neuroimaging). A collection of case studies that show how engagement in reproducible practices can benefit the career progression of early-career researchers would also be beneficial for motivating other researchers to employ them. The forum could also offer an opportunity for the exchange of teaching materials on reproducible practices, and therefore aid in fostering better training in this area. Reproducibility experts in the field should be incentivized to contribute to such efforts, preferably through funding[8] but also through societal recognition and scientific credit. Furthermore, researchers who benefit from these resources could be encouraged to 'pay it forward' by contributing to the knowledge base and helping other researchers.

Institutional or departmental contact point for reproducible research practices

In addition to the 'global' contact point described above, scientists would also benefit from a local contact point within their institution, who would have more-specific knowledge and experience within

specific locations (for example, data sharing or open access options are different in different countries). Currently, some institutions or departments nominate individuals to serve as 'Open Science champions' or to take up similar roles to support reproducible practices. However, these are usually designated as (often unofficial) administrative roles that add to current workloads. It is extremely rare for institutions to create a position for a person who will be dedicated to these issues (although this has been done, for example, in the Tanenbaum Open Science Institute at McGill University, and the Psychology Department at the University of Sussex). However, a dedicated position can ensure that sufficient time is allocated to this purpose, and that the person in charge has the required expertise.

The job specification and career progression for such a role will need to be considered by the individual departments and institutions, but might include in-depth understanding of the publication system (open access and so on), technical understanding of data and code sharing, code and statistical verification, preregistration and so on. Although some of these functions are already partially fulfilled by existing positions (for example, librarians), an overall understanding of the various aspects required to achieve reproducible science is lacking. Furthermore, experience in conducting research by the point of contact will facilitate communication with other researchers and an understanding of the barriers. In the long term, a position such as this can substantially decrease the time that individual researchers spend navigating these issues. In addition, the point of contact can develop courses, hands-on workshops and resources to further facilitate the implementation of reproducible science practices in the department or institution.

Creating and maintaining a reproducible science portfolio

Implementation of reproducible science practices (such as code and data sharing) can help to develop important transferable skills that are required and encouraged in many industries and across scientific disciplines[9]. Consideration of these skills early on enables early-career researchers to develop a convincing portfolio that can be harnessed when applying for jobs within and outside of academia. However, it is sometimes hard to understand how to 'showcase' these skills in different contexts and ensure that they are not only realized but also recognized. As such, it is also of key importance that supervisors, departments and university career teams fully appreciate the importance of these skills for proficiency and employability, support their development and provide guidance to optimize their presentation to potential employers. For example, schemes such as CRediT (Contributor Roles Taxonomy)[10] or 'All Contributors' have created taxonomies of contributions that can be used to show one's experience with specific aspects of research projects or open-source coding projects, respectively. A similar taxonomy could be developed for open science practices to enable individuals to highlight their specific skills in this area. Career teams can then support students in embedding this important information into their CVs and narrative statements. This will increase the motivation for scientists and early-career researchers in particular to engage in reproducible practices, and will also ensure appropriate support to benefit their prospective careers.

Conclusion

All of these proposed initiatives would need to be supported by adequate changes to funding and administrative structures. Table 1 links each of the ideas above to specific resources (mainly funding and personnel) that should be allocated to support it. Nevertheless, although most of these ideas would require some initial investment of resources, we argue that they can potentially reduce costs in the long run. For example, funding projects that have received in principle acceptance following peer review by experts can spare funders' need to provide panel or peer review. Similarly, having a person who supports reproducible science within institutions would reduce the time spent by individual scientists on tackling these issues and thus increase efficacy and productivity. It is also of note that most of these ideas are best implemented conjointly. For example, a reproducibility expert within a department can also aid postgraduate students in implementing reproducible practices within their project and evaluate whether they are eligible for a paid extension.

To conclude, the implementation of practical creative solutions — even at relatively small scales — can accelerate the adoption of reproducible scientific practices.

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Competing interests

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