



**Universiteit
Leiden**
The Netherlands

Towards wide-scale adoption of open science practices: the role of open science communities

Armeni, K.; Brinkman, L.; Carlsson, R.; Eerland, A.; Fijten, R.; Fondberg, R.; ... ; Zurita-Milla, R.

Citation

Armeni, K., Brinkman, L., Carlsson, R., Eerland, A., Fijten, R., Fondberg, R., ... Zurita-Milla, R. (2021). Towards wide-scale adoption of open science practices: the role of open science communities. *Science And Public Policy*, 48(5), 605-611. doi:10.1093/scipol/scab039

Version: Publisher's Version

License: [Creative Commons CC BY 4.0 license](#)

Downloaded from: <https://hdl.handle.net/1887/3278231>

Note: To cite this publication please use the final published version (if applicable).

Towards wide-scale adoption of open science practices: The role of open science communities

Kristijan Armeni ^{1,2}, Loek Brinkman^{3,4}, Rickard Carlsson^{5,6},
 Anita Eerland ^{4,7,*}, Rianne Fijten^{8,9}, Robin Fondberg^{6,10},
 Vera E. Heininga^{11,12,13}, Stephan Heunis^{14,15}, Wei Qi Koh^{16,17},
 Maurits Masselink^{12,18,19,20}, Niall Moran^{16,17}, Andrew Ó Baoill^{16,17},
 Alexandra Sarafoglou^{21,22}, Antonio Schettino ^{23,24,25},
 Hardy Schwamm^{16,17}, Zsuzsika Sjoerds^{26,27,28}, Marta Teperek^{29,30},
 Olmo R. van den Akker^{31,32}, Anna van't Veer^{27,28,33} and
 Raul Zurita-Milla ^{34,35}

¹Donders Institute for Brain, Cognition and Behaviour, Radboud University, 6525AJ Nijmegen, The Netherlands, ²Open Science Community Nijmegen, 6525AJ Nijmegen, The Netherlands, ³Centre for Education, University Medical Center Utrecht, 3584CG Utrecht, The Netherlands, ⁴Open Science Community Utrecht, 3584CS Utrecht, The Netherlands, ⁵Department of Psychology, Linnaeus University, 39234 Kalmar, Sweden, ⁶Open Science Community Sweden, 17165 Solna, Sweden, ⁷Department of Languages, Literature, and Communication, Utrecht University, 3512JK Utrecht, The Netherlands, ⁸Department of Radiation Oncology (MAASTRO Clinic), GROW School for Oncology and Developmental Biology, Maastricht University Medical Centre, 6202AZ Maastricht, The Netherlands, ⁹Open Science Community Maastricht, 6200MD Maastricht, The Netherlands, ¹⁰Department of Clinical Neuroscience, Karolinska Institutet, 17165 Solna, Sweden, ¹¹Department of Developmental Psychology, University of Groningen, 9712TS Groningen, The Netherlands, ¹²Open Science Community Groningen, 9700AB Groningen, The Netherlands, ¹³Quantitative Psychology and Individual Differences, University of Leuven, 3000 Leuven, Belgium, ¹⁴Eindhoven MedTech Innovation Center, Eindhoven University of Technology, 5612AP Eindhoven, The Netherlands, ¹⁵Open Science Community Eindhoven, 5612AP Eindhoven, The Netherlands, ¹⁶National University of Ireland, H91 TK33 Galway, Ireland, ¹⁷Open Scholarship Community Galway, H91 TK33 Galway, Ireland, ¹⁸Interdisciplinary Center Psychopathology and Emotion Regulation (ICPE), University Medical Center Groningen, 9713GZ Groningen, The Netherlands, ¹⁹Department of Psychiatry, Radboud University Medical Center, 6525GA Nijmegen, The Netherlands, ²⁰Radboud University Behavioural Science Institute, 6525XZ Nijmegen, The Netherlands, ²¹Department of Psychology, Psychological Methods, University of Amsterdam, 1001NK Amsterdam, The Netherlands, ²²Open Science Community Amsterdam, 1081HV Amsterdam, The Netherlands, ²³Erasmus Research Services, Erasmus University Rotterdam, 3062PA Rotterdam, The Netherlands, ²⁴Institute for Globally Distributed Open Research and Education (IGDORE), Ubud, Indonesia, ²⁵Open Science Community Rotterdam, 3062PA Rotterdam, The Netherlands, ²⁶Department of Cognitive Psychology Leiden, Institute of Psychology, Leiden University, 2333AK Leiden, The Netherlands, ²⁷Leiden University Leiden Institute for Brain & Cognition, 2333AK Leiden, The Netherlands, ²⁸Open Science Community Leiden, 2333AK Leiden, The Netherlands, ²⁹Technical University Delft Library, 2628CD Delft, The Netherlands, ³⁰Open Science Community Delft, 2628CD Delft, The Netherlands, ³¹Department of Methodology and Statistics, Tilburg University, 5037AB Tilburg, The Netherlands, ³²Open Science Community Tilburg, 5037AB Tilburg, The Netherlands, ³³Department of Methodology and Statistics, Institute of Psychology, Leiden University, 2333AK Leiden, The Netherlands, ³⁴Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, 7500AE Enschede, The Netherlands and ³⁵Open Science Community Twente, 7500AE Enschede, The Netherlands

*Corresponding author. E-mail: a.eerland@uu.nl

Abstract

Despite the increasing availability of Open Science (OS) infrastructure and the rise in policies to change behaviour, OS practices are not yet the norm. While pioneering researchers are developing OS practices, the majority sticks to *status quo*. To transition to common practice, we must engage a critical proportion of the academic community. In this transition, OS Communities (OSCs) play a key role. OSCs are bottom-up learning groups of scholars that discuss OS within and across disciplines. They make OS knowledge more accessible and facilitate communication among scholars and policymakers. Over the past two years, eleven OSCs were founded at several Dutch university cities. In other countries, similar OSCs are starting up. In this article, we discuss the pivotal role OSCs play in the large-scale transition to OS. We emphasize that, despite the grassroots character of OSCs, support from universities is critical for OSCs to be viable, effective, and sustainable.

Key words: open science; science policy; community management; open access; open source

1. Introduction

Over the past years, science has witnessed a shift towards openness, transparency, and reproducibility—a movement known under the umbrella term ‘Open Science’ (OS).¹ In response to increased awareness on existing challenges related to the reliability and accountability in scientific work, scholars² are motivated to increase the transparency of various aspects of their work, starting from the initial research and analysis plans to the dissemination of the final product (Bezjak et al. 2018; Munafò et al. 2017; Nosek et al. 2015, 2018; Stall et al. 2019). In parallel, expectations from journals, funders, and policy makers to improve the accessibility and transparency of scholarly products are steadily increasing (Aczel et al. 2019; Burgelman et al. 2019; Morey et al. 2016; Perkel 2019; SPARC Europe 2019; Teytelman 2018), further feeding the upward spiral towards more transparent workflows.

By opening up their practices, scholars make their work less error-prone (Fosang and Colbran 2015; Hales et al. 2019) and more visible, not only to peers from the same and other scientific disciplines—as evidenced by higher citation rates (Colavizza et al. 2020; McKiernan et al. 2016; Piwowar and Vision 2013)—but also the general public, who can appreciate the economic benefits of knowledge dissemination (Fell 2019). Moreover, engaging in OS practices facilitates the sharing and reuse of data, materials, and code in the scientific community (Allen and Mehler 2019; Milham et al. 2018), contributes to enriched scholarly output and literacy, and increases trust in the scholarly process (Tennant et al. 2016), a strong *desideratum* in times of increased scrutiny and opinionated discussions over scientific findings (Baker 2016; Cook et al. 2018; Jamieson et al. 2019). As such, adopting OS practices provides tangible benefits for individual researchers, the scientific community, and society at large.

This new drive towards openness and transparency has been accompanied by attempts to change how open workflows are facilitated. On the one hand, technological and methodological innovations are spearheaded by the research community and provide open solutions for individual scholars (e.g. the OS Framework,³ a project management platform for sharing data, code, and preprints). On the other hand, and possibly also as a reaction to bottom-up initiatives, OS is encouraged through changes in policy and reward structures, for example, through badges for crediting OS practices (Aczel et al. 2019; Kidwell et al. 2016; Nosek et al. 2015), dedicated funding for replication research,⁴ or the OS Policy Platform established by the European Commission (EC).⁵

Yet, many OS events (e.g. workshops, conferences, symposia, and discussion groups) often attract innovators and early adopters only, creating so-called ‘open science bubbles’. While these scholars are central to the initial creation and adoption of innovative workflows, a critical mass is needed for wide-scale adoption; moving from OS advocacy to an actual change in behaviour remains challenging when OS is not accepted as normative by the wider scientific communities (e.g. Houtkoop et al. 2018). In this article, we showcase the role of OS communities (OSCs) as learning groups of scholars that facilitate effective adoption, and thus normalization, of policy changes and technological innovation in contemporary science (Nosek 2019).

2. The transition to OS

The rise of the OS movement comes with an increasing need for research environments to adapt to the new societal and technological realities of the past decade (Burgelman et al. 2019). For example, many OS practices are linked to the use of web-based technologies and social media networks, which are becoming regular tools for data collection, sharing, analysis, and collaboration (Voytek 2017). There is no single definition or agreement on what the core components of OS practices are; it ultimately depends on the goals of the stakeholders affected by the changes (Fecher and Friesike 2014). For example, for individual scholars, OS might come down to the skills and research practices themselves, as suggested in the training handbook of the FOSTER project (Pontika et al. 2015). For librarians, the priority might instead be the sustainable dissemination of information within the academic community (Deville et al. 2019), whereas policy makers might be more interested in quantifying the societal impact of scholarly output (Bornmann 2017). In qualitative social science research, there is a long-standing interest in developing an ethical and mutually respectful relationship between researcher and participant, and in developing and promoting research that ‘make[s] a difference in everyday lives’ (Denzin and Giardina 2009: 13). As OSCs, we align with the EC and emphasize the collaborative aspect of OS:

Open Science represents a new approach to the scientific process based on cooperative work and new ways of diffusing knowledge by using digital technologies and new collaborative tools. The idea captures a systemic change to the way science and research have been carried out for the last fifty years: shifting from the standard practices of publishing research results in scientific

publications towards sharing and using all available knowledge at an earlier stage in the research process (European Commission 2016: 33).

Regardless of the role of each stakeholder, the transition towards OS can occur in two ways: bottom up and top-down.

2.1 Bottom up push: innovators are adopting OS

Major OS applications frequently originate from individual (or small groups of) innovators. The history of software development offers particularly strong examples of wide-scale adoption of the work of individual innovators. In 1991, Linus Torvalds began developing the Linux kernel by building on top of the pioneering GNU open-source project,⁶ which was further developed by a large Internet community of volunteer developers (Raymond 2001). Linux has since made a significant global impact in computational sciences, with GNU/Linux being the operating systems of choice in high-performance computing; as of 2019, the world's 500 most powerful supercomputers use GNU/Linux (Henry-Stocker 2020).⁷ To take another example, the open-source Python plotting software *matplotlib* (Hunter 2007) was developed by a single innovator, but has since matured into a global collaborative development community and even played a role in generating the first-ever image of a black hole (Kazunori et al. 2019). A similarly successful individual OS initiative with broad application and influence among the computational biologists is the *Galaxy Community Hub*,⁸ a web-based platform for accessible, reproducible, and transparent computational research that has supported over 10,000 publications since 2005.⁹

Another example of bottom-up push towards OS comes from the practice of publicly sharing research outcomes before peer-review—that is, publishing preprints. Preprinting has been facilitated by the availability of publicly accessible preprint repositories. Preprints have been a common practice in the physics community since 1991, when the public preprint server *arXiv.org* was launched (Vale 2015). In the biology community, although a precursor of a preprint system was proposed among individual researchers as early as the 1960s (Cobb 2017), such practice has taken off substantially since 2013 with the launch of the *bioRxiv* server. Similar trends can now be observed in other disciplines, thanks to preprint infrastructures such as *PsyArXiv*, *SocArXiv*, *EarthArXiv*, *MetaArXiv*, and *AfricArXiv*.

Apart from technical innovations, bottom-up initiatives also focus on promotion and curation of OS knowledge in novel formats. An example of a successful bottom-up initiative is the *ReproducibiliTea*¹⁰ journal club, where scholars read and discuss papers and other documents on various OS topics (e.g. reproducibility, statistics, and meta-science; Orben 2019). At the time of writing, there are *ReproducibiliTea* journal clubs at more than 120 institutions in 25 different countries, predominantly led by early-career scholars. Similar initiatives include *Papers we love*,¹¹ which uses open collaborative tools to help organize communities around reading and appreciating computer science papers, and *SciRate*,¹² an open peer-review archive with an open-source rating and commenting system for preprints in the subfields of physics and computer science.

Bottom-up initiatives are also relevant for OS education and outreach. Notably, the Framework for Open and Reproducible Research Training (FORRT, 2019) revolves around open mentorship and aims to provide educators with a feasible pathway towards the adoption of principled teaching and mentoring practices, including open and reproducible research. It provides teachers with

resources to include in their courses and tools to assess the current level of OS training that students receive. In moving beyond the openness for researchers alone, *The Pint of Science Festival*¹³ and *SoapboxScience*¹⁴ are examples of global platforms for engaging (female) researchers and explaining scientific topics to the broader audience in informal settings.

These examples show that bottom-up initiatives to facilitate OS can lead to technical, theoretical, didactical, and/or citizen-engaging solutions to the challenges of transitioning towards OS. By allowing research output to be shared and repurposed for novel uses, OS increases the efficiency, quality, and impact of science.

2.2 Top-down push: the role of policy makers and funding agencies

In concert with the adoption of OS by (individual) innovators, there has been a recent top-down push for OS by policy makers and funding agencies. In September 2018, the EC, in collaboration with the European Research Council and several international funders, launched an initiative called *Plan S*,¹⁵ which requires recipients of research grants from European and national funding agencies to publish their research Open Access from 2021 onwards. This initiative is part of the overarching goal of funding agencies to stimulate OS. For example, the Dutch Research Council (NWO) provides information to scholars to make it easier to publish their work Open Access,¹⁶ and offers templates for data management plans that can be used to make their data accessible and reusable.¹⁷ Similarly, Wellcome Trust¹⁸ develops platforms for scholars to quickly and transparently publish and share their findings, offers several awards to stimulate OS practices, and allows scholars to include their preprints in funding applications. Moreover, these funding agencies continually monitor scholars' needs through large-scale surveys (e.g. van den Eynden et al. 2016).

In a recent perspective piece, the Directorate General for Research and Innovation of the EC has positioned OS as part of the vision to achieve a holistic science policy under the European agenda (Burgelman et al. 2019). For example, the new Horizon Europe 2021–7 research and innovation programme will require open access to publications, data, and research data management plans, and will support the proliferation of findable, accessible, interoperable, and re-usable data (European Commission & Directorate-General for Research and Innovation 2018). The proposed budget allocations for 2021–27 Horizon Europe included €25.8 billion for research and infrastructure (OS Pillar) and additional €13.5 billion on innovation (Open Innovation Pillar).

These top-down policy initiatives send a clear and important message to European academic institutions: transparency and openness are not an afterthought, but an expected outcome of the research process. However, they risk having little tangible repercussions if not accompanied by a simultaneous restructuring of the reward system in academia. A well-known international initiative aimed at rewarding OS practices is the San Francisco Declaration on Research Assessment (DORA; Cagan 2013). DORA recognizes the need to improve the evaluation of scholarly output by refraining from using journal impact factors to judge individual scholars. Proponents and signatories of DORA advise, among others, to highlight the importance of the content of a paper rather than the journal in which it was published, and to consider all research output, including datasets, software, and other materials when evaluating research. In the Netherlands, there is an encouraging shift in priorities in this direction, as exemplified by the new

national strategic research evaluation protocol,¹⁹ recent agreements on the change to be made in the recognition, and rewards system to further facilitate positive incentives towards OS,²⁰ and by some universities that have started reserving funds for OS implementation in their strategic plans.²¹ Of note, the Dutch The Ministry of Education, Culture and Science, following Finland, in 2017 adopted the integral practice of OS, including Open Access (OA), as standard in government-funded science and launched a national plan to implement OS (OCW 2017).

Although both bottom-up and top-down efforts and initiatives are promising, so far they have not had the fortitude to usher in a wide-scale culture change in academia. Below we describe three challenges that this transition currently faces.

3. Challenges in widespread adoption of OS

3.1 Reaching critical mass: from pioneers to common practice

Despite the presence of individual innovators and recent policy-, funding-, and incentive-driven changes towards the adoption of OS, the challenge remains how to mobilize a critical mass of scholars to achieve this cultural change. On the one hand, only limited impact is achieved by individual innovations that do not reach widespread adoption by the community. On the other hand, policy changes cannot afford to bypass the sentiment of the communities in which they are adopted, else they risk being misdirected, ineffective, and possibly even counterproductive. Experts involved in central policy organs (such as the EC) responsible for encouraging OS from a top-down perspective may find it difficult to effectively reach scholars. Although there is likely no societal agent that can single-handedly solve the problem of widespread OS adoption (see Munafò 2019 for a discussion on the role of institutions), we argue that bottom-up OSCs, due to their peer-based character and format, have the strongest leverage to reach a critical mass by giving voice to the scholars themselves.

3.2 The perceived costs of change

Whereas the advantages of OS may appear clear from a principled perspective, introducing and adopting change *in practice* can be met with some resistance. In a workshop report, Sholler et al. (2019) noted different sources of resistance among scholars. For example, those willing to adopt OS practices may encounter inertia from their collaborators or supervisors who prefer their established, closed, workflows due to their (perceived) past efficiency. Additionally, reluctance may stem from fear of close scrutiny of their work, or from fear of getting scooped. Similarly, one can encounter unwillingness to adopt change because the immediate costs of the switch can be deemed too high relative to the potential long-term benefits. In some cases—and especially when a network of easily accessible information is not in place—it may seem costly or daunting to find out how to handle a situation. For instance, it is sometimes unclear whether publicly sharing data would pose a risk to vulnerable populations. This uncertainty could further increase the tendency to follow established routines (i.e. no data sharing). Such resistant behaviour finds fertile ground in local environments where OS practices are not seen as normative (Houtkoop et al. 2018). As mentioned above, innovation must thus be made both visible and rewarding for scholars. OSCs can aid in making OS practices visible through different platforms and workshops by creating a low-threshold exchange of knowledge, lowering the bar for scholars to adopt new workflows and find support from colleagues and mentors.

3.3 Disciplinary differences

Lastly, the need for adoption of OS practices varies across disciplines. For example, working with open data and materials is more customary in biomedicine than in psychology or other social sciences, while publishing open access is more popular in psychology (Hardwicke et al. 2019). In some disciplines, particularly the social sciences, principles that overlap significantly with those of OS have been associated with calls for civic engagement (McIlrath and Lyons 2012), community-based research (Munck et al. 2014), and other activities that integrate transparency, reflexivity, and public engagement, such as service learning (Bingle and Hatcher 1996; Giles and Eyer 1994). Such diversity opens fruitful avenues to share best practices across disciplines. By virtue of their interdisciplinary character and university-wide involvement, OSCs form the ultimate platform to combine multidisciplinary insights and knowledge and provide broad, but at the same time tailored, advice and knowledge exchange among scholars who have different backgrounds, questions, and needs.

4. Open science communities

4.1 The role of communities in shaping the transition

Incentivizing OS policies and providing OS infrastructure for scholars are important steps in promoting scientific values such as transparency, reproducibility, accessibility, and inclusivity. In order to change the current research culture, however, it is crucial that the scholarly community *itself* aligns with these values and adopts OS practices as the new standard. As mediators between policy makers and scholars, local bottom-up networks play a central role in identifying obstacles that hinder scholars in opening up their workflows, and provide the support needed to foster cultural change at the institutional or organizational level (Nosek 2019).

Through the wide variety of backgrounds and scientific expertise of their members, bottom-up networks create a learning environment where scholars can acquire the skills to conduct open, transparent, and reliable research, and are able to discuss OS practices among their peers. Moreover, local grassroot networks increase the visibility of these practices within their local communities, which in turn contributes to changing the descriptive norm of how research is conducted. As of today, more than 200 networks exist worldwide to increase transparency and accountability of scholarly products in various scientific fields.²² The International Network of OS Communities (INOSC) constitutes a collaborative network that currently comprises eleven Dutch university cities, one in Ireland, and a consortium of universities in Sweden.

4.2 Target audience: early majority

Wide-scale adoption of innovation takes time, as individuals are not equally open to change. According to Rogers (2003), adopters of innovation can be categorized as innovators, early adopters, early majority, late majority, or laggards. *Early majority* comprises individuals that are open and curious with regards to OS but, as of yet, have little to no experience with OS practices. They want to learn more, understand why it is important, and are willing to implement (some) OS practices in their daily workflow. Encouraging adoption of OS by the early majority can facilitate a paradigm shift in research practices, and is therefore the needed step to engage the *late majority* in adopting OS practices. The *early majority* is thus the main target audience for OSCs.

We emphasize that, although the greatest opportunity to facilitate the transition to OS at a large scale lies within the early and late

majorities, OSCs cannot provide the necessary knowledge, training, and help without the *innovators* and *early adopters* of OS practices. These people bring critical knowledge and skills to the table, so that the majority can benefit, contribute, and build upon them. At the same time, solutions developed by early adopters benefit from having a usage base that can test the effectiveness of proposed solutions and provide feedback for improvement. Such knowledge transfer and interaction is one of the key goals of OSCs.

4.3 Inclusiveness

In line with the wider aims of OS, we believe OSCs should be open to people of all stripes. Researchers are the main target audience, but students, research support staff, and other individuals and communities interested in OS practices are equally welcome. To join the local OSC, no prior knowledge about OS is needed, nor are members in any way required to commit to certain ways of transitioning towards OS.

To organize fruitful events, OSCs should seek to actively engage with representatives from all faculties, and in all positions in the academic hierarchy. This diversity can be quite rewarding as people in different fields and with different positions can have widely differing OS experiences. For example, we often see in our OSCs that ECRs generally tend to be more open to (and have more direct experience with) OS practices than senior researchers, which makes them good candidates to educate other members about the merits and potential downsides of these practices. However, as role models, senior researchers have the leverage to encourage such efforts and help broaden the network. When people from different fields meet during OSC activities, these different experiences can be successfully synthesized, thus leading to more widespread and diverse OS expertise. In addition, new collaborations can emerge because most problems are quite complex and require the combination of skills and know-how from a diverse set of disciplines.

OSCs are also encouraged to actively seek out collaborations with similar communities in the same region. The OSCs involved in this article are connected to form INOSC, which greatly improves the reach of the movement by increasing learning opportunities and facilitating collaboration. These developments can also occur more locally: for instance, the University of Amsterdam, the VU Amsterdam, and the University of Applied Sciences Amsterdam work together as OSC Amsterdam to increase the adoption of OS in their institutions.

Finally, to facilitate learning and trust among OSC members, OSCs should be dedicated to diversity, equity, inclusion, and the

free expression of ideas. Therefore, they should provide an environment in which participants may learn, discuss, network, and enjoy each other's company in an environment of mutual respect. To safeguard such an environment, OSCs are required to draft a Code of Conduct, which can be adapted from the INOSC Code of Conduct.²³

4.4 Initiating an OSC

OSCs are typically initiated by scholars themselves as part of an institutional body (e.g. a university), and—at least to our experience so far—rarely by institutions. Such a bottom-up initiative contributes to the grassroots character of OCSs, and this might make it more approachable for other scholars to join. Nonetheless, support by institutions is very much needed for these bottom-up initiatives to be sustainable and rewarding (see **Box 1** for recommendations). To facilitate wide-scale adoption of OS practices, it is important to: (1) make OS knowledge more visible; (2) make OS knowledge more accessible; and (3) communicate effectively within (e.g. interactions among members) and beyond the OSC (e.g. with university support staff, policy makers, and research funders). A more elaborate description of the design of an OSC is provided in the INOSC Starter Kit.²⁴

4.5 Governance and funding

The elements described above require time investment from the community (i.e. OSC activities are organized by and for the OSC members), preferably in combination with financial support from governing bodies. An OSC's success in facilitating the widespread adoption of OS practices depends on the amount of time people from the community are willing and able to invest voluntarily. Experience within the OSCs so far has shown that time investment from the community can be accelerated by appointing at least one OSC coordinator.

Funding is fundamental to the continuation of local OSCs. While OSCs have so far mostly started on a voluntary basis, the goal is to obtain specific funding (structural or otherwise) as soon as possible. Structural funding would mean that at least one OSC coordinator is explicitly paid (part- or full-time) to manage the OSC. An alternative solution is to embed the OSC coordinator in an existing academic unit (e.g. library and research support office) to provide formal support for the OSC. In this way, the OSC is part of a larger unit—which is then invested in the success of the project—rather than being isolated as an independent pilot. However, funders (e.g. faculty or university boards) may want to see the added value of a (local) community in relation to

Box 1. Recommendations for institutions to support the activities of OSCs.

1. Encourage creation of OSCs
Although OSCs are driven by communities of scholars, their jump-start and efficiency can be facilitated if they are welcomed at the institutional level. This can be as simple as words of encouragement for community creation from senior institutional management directed at institutional leaders in OS
2. Provide funding to sustain the activities of OSCs
Community coordination takes time and it is beneficial for long-term sustainability of OSCs if individuals providing support for community activities are funded to do so (e.g. through official posts of community coordinators). Communities will also benefit from funding to support their core activities (e.g. organization of workshops, events, and training sessions)
3. Support OSCs in identifying local ambassadors within more granular institutional units
A network of ambassadors is an excellent way to connect with diverse research communities across the campus. Heads of departments/faculties may encourage interested researchers to dedicate a portion of their time to develop materials for OSC-related activities
4. Reward and recognize efforts invested in sustaining the OSCs
Include questions about OS education and research practices as part of regular progress review meetings. Include questions about Open Science practices in job adverts

existing tools and courses (e.g. offered by support staff or the university library). Therefore, a strategic plan is advisable. For instance, the OSC coordinator could schedule an appointment with a faculty dean (or, if possible, the university president/rector and/or the executive board), explain the added value of an OSC to the existing local offers, and ask whether the faculty or university would be willing to fund such an initiative if it proves ‘successful’ one year after kick-off. If needed, the RE-AIM planning and evaluation framework (Glasgow et al., 2019) may be used as an evaluation tool to evaluate the success of the initiative. For instance, the outcomes of measures taken to increase the visibility of OSCs may be measured through reach (i.e. the number of scholars that have enrolled in their local OSC communities), and surveys may be used to understand the adoption and/or perceived effectiveness of OS practices.

5. Conclusion

OS is becoming an increasingly necessary and recognized *modus operandi* in scholarly environments, but actual adoption lags behind on the widely shared vision. Bottom-up innovations by pioneers, paralleled by top-down OS incentives and policies, are crucial steps in the direction towards change. However, wide-scale adoption of OS practices requires a culture change that leads to normalization among members of the scientific community. In this article, we have identified three challenges that stand in the way of wide-scale adoption of OS practices: (1) reaching a critical mass; (2) the perceived cost of change; and (3) disciplinary differences. We have argued that a network of local OSCs can overcome these challenges. OSCs play a central role in identifying obstacles that hinder scholars in opening up their workflows, hence providing the needed support to foster culture change at the institutional level. Together, we make science more open for the benefit of science and society.

Funding

This work was supported by (1) a talent grant from the Netherlands Organisation for Scientific Research (NWO) to AS (406-17-568), (2) the European Research Council (Grant no. 726361), (3) the foundation Health-Holland LSH-T KI [grant number LSHM16053-SGF], and (4) Philips Research.

Acknowledgements

A.Sc. would like to thank the 2020 eLife Innovation Leaders program (in particular, the organizer Dr Emmy Tsang) for providing a clear structure to chaotic thoughts. K.A. would like to thank Dr Robert Oostenveld for encouragement and mentoring during the process of growing the Open Science Community Nijmegen. INOSC would like to thank Frank Miedema for feedback on the preprint of this paper and the late Jon Tennant and other OS pioneers for their inspiring work.

Authors' contributions

Authorship is based on alphabetical order of the last names and does not necessarily reflect the relative contributions of authors. Author contributions are clarified below, using an adapted version of the CRediT taxonomy (Allen et al. 2014). Conceptualization: L.B. and A.E. Writing—original draft: K.A., L.B., A.E., V.E.H., M.M., Z.S., A.V., A.Sc., and O.R.A. Writing—editing: K.A. (lead), A.Sc., L.B., and Z.S. Feedback on draft: K.A., L.B., R.C., A.E., R.Fi., R.Fo., V.E.H., S.H., W.Q.K., M.M., N.M., A.O.B., A.Sa., A.Sc., H.S., Z.S., M.T., O.R.A., A.V., and R.Z.M. Figures: AE (licensed under CC BY-ND 3.0).

Competing interest statement

Most authors of this article (K.A., L.B., R.C., A.E., R.Fi., R.Fo., V.E.H., S.H., M.M., A.Sa., A.Sc., H.S., Z.S., M.T., O.R.A., A.V., and R.Z.M.) are involved as coordinators in local OSCs, and are involved in organising, promoting, and facilitating open science (events).

Notes

1. In this document, we use the term ‘Open Science’ following the result of the public consultation on Science 2.0 Science in Transition (<https://tinyurl.com/sci2-2015>; see also Burgelman et al. 2019), which popularized the term. Thus, the term ‘science’ is used in its broadest sense and includes humanities, social sciences, and engineering; that is, it more suitably refers to any form of scholarship.
2. The term ‘scholars’ is used here as an umbrella term for all individuals who are in some way involved in research practices within academia as well as broader research areas.
3. <https://osf.io/>
4. <https://tinyurl.com/25r7wuxf>
5. <https://tinyurl.com/EU-OSPolicy-Platform>
6. <https://www.gnu.org/>
7. The count of supercomputing systems running on Linux can be viewed at: <https://www.top500.org/statistics/details/osfam/1/>
8. <https://galaxyproject.org>
9. <https://galaxyproject.org/blog/2020-08-10k-pubs/>
10. <https://reproducibilitea.org/>
11. <https://paperswelove.org/>
12. <https://scirate.com/>
13. <https://pintofscience.com>
14. <http://soapboxscience.org/>
15. <https://www.coalition-s.org/>
16. <https://www.nwo.nl/en/policies/open+science/data+management>
17. <https://dmponline.dcc.ac.uk/>
18. <https://wellcomeopenresearch.org/>
19. https://www.vsnu.nl/files/documenten/Domeinen/Onderzoek/SEP_2021-2027.pdf
20. <https://tinyurl.com/room-talent>
21. See, for instance, recent strategic plans at Utrecht University (<https://www.uu.nl/en/research/open-science/about-us>), University of Twente (<https://www.utwente.nl/en/organisation/about/shaping2030/>), and Delft University of Technology (Haslinger 2019).
22. A crowdsourced list of grassroot initiatives is available at <https://tinyurl.com/y2l9gpxc>.
23. The INOSC Code of Conduct template can be found at <https://osf.io/6gsye/>.
24. <http://www.startyourosc.com/>

References

- Acelz, B., Szasz, B., Sarafoglou, A. et al. (2019) ‘A Consensus-Based Transparency Checklist’, *Nature Human Behaviour*, 4: 4–6.
- Allen, C., and Mehler, D. M. A. (2019) ‘Open Science Challenges, Benefits and Tips in Early Career and Beyond’, *PLoS Biology*, 17(5): e3000246.
- Allen, L., Scott, J., Brand, A. et al. (2014) ‘Publishing: Credit where Credit is Due’, *Nature News*, 508/7496: 312.
- Baker, M. (2016) ‘1,500 Scientists Lift the Lid on Reproducibility’, *Nature*, 533/7604: 452–4.
- Bezjak, S., Clyburne-Sherin, A., Conzett, P. et al. (2018) *Open Science Training Handbook*. Genève, Switzerland: Zenodo.

- Bornmann, L. (2017) 'Measuring Impact in Research Evaluations: A Thorough Discussion of Methods for, Effects of and Problems with Impact Measurements', *Higher Education*, 73/5: 775–87.
- Bringle, R. G., and Hatcher, J. A. (1996) 'Implementing Service Learning in Higher Education', *The Journal of Higher Education*, 67/2: 221–39.
- Burgelman, J. C., Pascu, C., Szkuta, K. et al. (2019) 'Open Science, Open Data, and Open Scholarship: European Policies to Make Science Fit for the Twenty-First Century', *Frontiers in Big Data*, 2: 43.
- Cagan, R. (2013) 'The San Francisco Declaration on Research Assessment', *Disease Models & Mechanisms*, 6/4: 869–70.
- Cobb, M. (2017) 'The Prehistory of Biology Preprints: A Forgotten Experiment from the 1960s', *PLoS Biology*, 15/11: e2003995.
- Colavizza, G., Hrynaszkiwicz, I., Staden, I. et al. (2020) 'The Citation Advantage of Linking Publications to Research Data', *PLoS One*, 15/4: e0230416.
- Cook, B. G., Lloyd, J. W., Mellor, D. et al. (2018) 'Promoting Open Science to Increase the Trustworthiness of Evidence in Special Education', *Exceptional Children*, 85/1: 104–18.
- Denzin, N. K., and Giardina, M. D. (Eds.). (2009) *Qualitative Inquiry and Social Justice: Toward a Politics of Hope*. Walnut Creek, CA: Left Coast Press.
- Deville, J., Sondervan, J., Stone, G. et al. (2019) 'Rebels with a Cause? Supporting Library and Academic-led Open Access Publishing', *LIBER Quarterly*, 29: 1: 1–28.
- European Commission. (2016) *Open Innovation, Open Science, Open to the World: A Vision for Europe*. Luxembourg: Publications Office of the European Union.
- European Commission & Directorate-General for Research and Innovation. (2018) *OSPP-REC Open Science Policy Platform Recommendations*. Bruxelles, Belgium: European Commission & Directorate-General for Research and Innovation.
- van den Eynden, V., Knight, G., and Vlad, A. (2016) *Open Research: Practices, Experiences, Barriers and Opportunities*. Colchester, Essex: UK Data Archive. DOI: 10.5255/UKDA-SN-852494
- Fecher, B., and Friesike, S. (2014) 'Open Science: One Term, Five Schools of Thought'. In: Bartling S., and Friesike S. (eds.) *Opening Science*, pp.17–47. Cham, Switzerland: Springer International Publishing. DOI: 10.1007/978-3-319-00026-8_2
- Fell, M. J. (2019) 'The Economic Impacts of Open Science: A Rapid Evidence Assessment', *Publications*, 7/3: 46.
- FORRT. (2019) 'Introducing a Framework for Open and Reproducible Research Training (FORRT) (preprint)', *Open Science Framework* <<https://osf.io/bnh7p>> accessed 28 April 2020.
- Fosang, A. J., and Colbran, R. J. (2015) 'Transparency Is the Key to Quality', *Journal of Biological Chemistry*, 290/50: 29692–4.
- Giles, D., and Eyler, J. (1994) 'The Theoretical Roots of Service-Learning in John Dewey: Toward a Theory of Service-Learning', *Michigan Journal of Community Service Learning*, 1/1: 7–85.
- Hales, A. H., Wesselmann, E. D., and Hilgard, J. (2019) 'Improving Psychological Science Through Transparency and Openness: An Overview', *Perspectives on Behavior Science*, 42/1: 13–31.
- Hardwicke, T. E., Wallach, J. D., Kidwell, M., Bendixen, T. et al. (2019) 'An Empirical Assessment of Transparency and Reproducibility-related Research Practices in the Social Sciences (2014–2017) (preprint)', *MetArXiv* <<https://osf.io/6uhg5>> accessed 24 January 2020.
- Haslinger, I. M. (2019) 'TU Delft Strategic Plan Open Science 2020–2024: Research and Education in the Open Era', *Delft University of Technology*.
- Henry-Stockler, S. (2020) *Linux Dominates Supercomputing*. Network World.
- Houtkoop, B. L., Chambers, C., Macleod, M. et al. (2018) 'Data Sharing in Psychology: A Survey on Barriers and Preconditions', *Advances in Methods and Practices in Psychological Science*, 1/1: 70–85.
- Hunter, J. D. (2007) 'Matplotlib: A 2D Graphics Environment', *Computing in Science & Engineering*, 9/3: 90–5.
- Jamieson, K. H., McNutt, M., Kiermer, V. et al. (2019) 'Signaling the Trustworthiness of Science', *Proceedings of the National Academy of Sciences United States of America*, 116/39: 19231–6.
- Kazunori A, W., Asada, K., Azulay, R. et al. (2019) 'First M87 Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole', *The Astrophysical Journal Letters*, 875/1: L1.
- Kidwell, M. C., Lazarević, L. B., Baranski, E. et al. (2016) 'Badges to Acknowledge Open Practices: A Simple, Low-Cost, Effective Method for Increasing Transparency', *PLoS Biology*, 14/5: e1002456.
- McIlrath, L., and Lyons, A. (eds). (2012) *Higher Education and Civic Engagement: Comparative Perspectives*. London: Palgrave Macmillan.
- McKiernan, E. C., Bourne, P. E., Brown, C. T. et al. (2016). 'How Open Science Helps Researchers Succeed', *eLife*, 5: e16800.
- Milham, M. P., Craddock, R. C., Son, J. J. et al. (2018) 'Assessment of the Impact of Shared Brain Imaging Data on the Scientific Literature', *Nature Communications*, 9/1: 1–7.
- Morey, R. D., Chambers, C. D., Etschells, P. J. et al. (2016) 'The Peer Reviewers' Openness Initiative: Incentivizing Open Research Practices through Peer Review', *Royal Society Open Science*, 3/1: 150547.
- Munafò, M. R. (2019) 'Raising Research Quality Will Require Collective Action', *Nature*, 576/7786: 183.
- Munafò, M. R., Nosek, B. A., Bishop, D. V. M. et al. (2017) 'A Manifesto for Reproducible Science', *Nature Human Behaviour*, 1/1: s41562016–0021–016.
- Munck, R., McIlrath, L., Hall, B. et al. (2014) *Higher Education and Community-Based Research: Creating a Global Vision*. London: Palgrave Macmillan.
- Nosek, B. A. (2019) 'Strategy for Culture Change', *COS Blog*, <<https://cos.io/blog/strategy-for-culture-change/>>
- , Alter, G., Banks, G. C. et al. (2015) 'Promoting an Open Research Culture', *Science*, 348/6242: 1422–5.
- , Ebersole, C. R., DeHaven, A. C. et al. (2018) 'The Preregistration Revolution', *Proceedings of the National Academy of Sciences of the United States of America*, 115/11: 2600–6.
- OCW. (2017) 'National Plan Open Science. Ministerie van Onderwijs', *Cultuur en Wetenschap*, <<http://resolver.tudelft.nl/uuid:9e9fa82e-06c1-4d0d-9e20-5620259a6c65>> accessed 23 March 2021.
- Orben, A. (2019) 'A Journal Club to Fix Science', *Nature*, 573: 475.
- Perkel, J. M. (2019) 'Make Code Accessible with These Cloud Services', *Nature*, 575: 247–8.
- Piwozar, H. A., and Vision, T. J. (2013) 'Data Reuse and the Open Data Citation Advantage', *PeerJ*, 1: e175.
- Pontika, N., Knoth, P., Cancellieri, M. et al. (2015) 'Fostering open science to research using a taxonomy and an eLearning portal', *Proceedings of the 15th International Conference on Knowledge Technologies and Data-Driven Business - i-KNOW*, Vol. 15, 1–8. Presented at the 15th International Conference, Graz, Austria: ACM Press.
- Raymond, E. S. (2001) *The Cathedral & the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary*. 1st edn. Newton, MA: O'Reilly Media.
- Rogers, E. M. (2003) *Diffusion of Innovations*. 5th ed. New York, NY: Free Press of Glencoe.
- Sholler, D., Stoudt, S., Kennedy, C. J. et al. (2019) 'Resistance to Adoption of Best Practices', *SocArXiv*, doi: 10.31235/osf.io/qr8cz.
- SPARC Europe. (2019) 'Open Science Essential for new Horizon Europe Funding Programme', *SPARC Europe*, <<https://sparceurope.org/open-science-essential-for-new-horizon-europe-funding-programme/>> accessed 13 December 2019.
- Stall, S., Yarmey, L., Cutcher-Gershenfeld, J. et al. (2019) 'Make Scientific Data FAIR', *Nature*, 570/7759: 27–9.
- Tennant, J. P., Waldner, F., Jacques, D. C. et al. (2016) 'The Academic, Economic and Societal Impacts of Open Access: An Evidence-Based Review', *F1000Research*, 5: 632.
- Teytelman, L. (2018) 'No More Excuses for Non-Reproducible Methods', *Nature*, <<http://www.nature.com/articles/d41586-018-06008-w>> accessed 23 August 2018.
- Vale, R. D. (2015) 'Accelerating Scientific Publication in Biology', *Proceedings of the National Academy of Sciences of the United States of America*, 112/44: 13439–46.
- Voytek, B. (2017) 'Social Media, Open Science, and Data Science are Inextricably Linked', *Neuron*, 96/6: 1219–22.