OPINION ARTICLE

The case for openness in engineering research [version 1; peer review: 2 approved with reservations]

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Abstract

In this article, we review the literature on the benefits, and possible downsides, of openness in engineering research. We attempt to examine the issue from multiple perspectives, including reasons and motivations for introducing open practices into an engineering researcher's workflow and the challenges faced by scholars looking to do so. Further, we present our thoughts and reflections on the role that open engineering research can play in defining the purpose and activities of the university. We have made some specific recommendations on how the public university can recommit to and push the boundaries of its role as the creator and promoter of public knowledge. In doing so, the university will further demonstrate its vital role in the continued economic, social, and technological development of society. We have also included some thoughts on how this applies specifically to the field of engineering and how a culture of openness and sharing within the engineering community can help drive societal development.

Keywords

open science, open engineering, engineering, open access, research dissemination

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Introduction

Working openly should be the default mode of science—after all, how can we advance knowledge “by standing on the shoulders of giants”^a if we cannot access or see those shoulders? This paper operates on the following definition of open science:

Open science, or more broadly open research, describes the activity of performing scientific research in a manner that makes products and findings accessible to anyone. This includes sharing data openly (open data), publicly releasing the source code for research software (open-source software), and making the written products of research openly accessible (open access).

The field of engineering provides an interesting case study for examining the impacts of open practices since engineering touches every aspect of human life. Engineering research is inherent to the development of goods and products such as medical devices and pharmaceuticals, so issues around the protection of intellectual property and innovation draw stark contrasts, for some, with the tenets of open science. On the other hand, work being done in open-source software and open-source hardware can enable us to engineer the tools of modern scientific discovery, greatly reducing the costs of scientific research¹.

In a time of constrained university budgets, which are not expected to improve as long as most public universities rely heavily on state funding, many universities are being forced to evaluate their institutional priorities². For some, particularly state universities subject to the whims of state legislation, this could mean abandoning the pursuit of fundamental or basic knowledge generation in favor of more marketable vocational training models that cater more directly to industry needs. While this model is in line with the Morrill Act of 1862, which underpins the missions of many US institutions, the university has evolved since that time to encompass a much greater proportion of the economic development of the country². Despite the challenges faced by institutions today, it is critical for the university to continue to position itself as a center of societal development—economically, technologically, and socially. Additionally, the university should push this model further towards positioning itself as the main driver of social and technological innovation. To achieve this, it is necessary to position and market the business of the university, as clearly as possible, as a service provider to many relevant stakeholders. This can be best accomplished by disseminating and distributing the products of university activities as widely as possible through open access publishing, open research, and open innovation, and further demonstrating the impact that these products have on local, state, national, and international populations. As

stated by Ashley Farley of the Gates Foundation, “Open research should be the norm. Knowledge should be a public good”³.

Importance of open science

Conducting open research is an act of assigning value to the work to which you are passionately committed. This includes all of the final, polished products of that work—including papers, software, and data—as well as the half-baked ideas, the napkin sketches, the first drafts, and the failures. The dissemination of these artifacts may on occasion comprise an act of humility, but ultimately it recognizes that each of these items is a piece of the research process and that even your failures have value in the lessons you learned and can be passed on to others. Transforming research communities from traditional, closed environments to open ones is important for a number of reasons, including (but not necessarily limited to) the following six. McKiernan *et al.*⁴ discuss these and additional benefits for researchers working openly. Tennant *et al.*⁵ review in detail the benefits of open-access publications to academics and society.

Accessibility: Openness in research ensures that research products, particularly written output, remain accessible to all. This includes the research community, funders, policy makers, and the general public. Accessibility of research products is particularly important for publicly funded research—since the public paid for the research, the public should have access to, and be able to benefit from, it. (This does not prevent innovators or other parties from developing commercial intellectual property based on the findings, but ensures that the original discovery, when funded by the public, remains accessible to all.) While the body of published work available freely through open access or online social networks has approached 50%, this percentage is notably lower in engineering at approximately 35%⁶. However, Piwowar *et al.*⁷ found that this percentage drops below 20% when not considering articles self-archived on author websites, which can lack assurance of long-term availability.

Reproducibility: Releasing products of research, including software and data, helps enable reproducibility. This is particularly true for computational science, where a written description of methods can never describe an approach as completely as the source code⁸. In general, access to research software used to perform a computational study, or the data from an experimental study, should enable others to reproduce the findings of the original researchers. However, open science is a necessary but not sufficient aspect of reproducibility, as it can be challenging to reproduce or replicate results even with available research software and data^{9,10}.

Impact: As a selfish motivation, performing research openly helps increase the impact of the work. Studies have shown that open-access papers are cited more in most research fields. In engineering, open-access papers are cited around 1.5 times more often than non-open-access papers^{6,11}. Similarly, papers with associated open data were cited 9–50% more than those

^a“If I have seen further, it is by standing on the shoulders of giants.” Isaac Newton (1676), although similar statements can be found as far back as the 12th century.

without^{4,12}. Vandewalle¹³ showed that papers in the image-processing field receive up to three times the number of citations when source code is made available. We must note, however, that the concept of impact should not be solely regarded through the measure of citations. The true societal impact of the work is likely more important but also more difficult to quantify¹⁴.

Establish priority: Some researchers hesitate to embrace open science out of a fear of being “scooped,” where competitors will use some findings, software tools, or data made available and then publish first. However, contrary to this belief, practicing open science can actually prevent being scooped: releasing preprints can establish priority of discoveries or techniques prior to the publication of a traditional peer-reviewed journal article^{15,16}.

The peer-review and editorial process of such papers can take many months or years, but journal articles are still necessary for research findings to be considered valid (and for researchers to receive credit). Publishing a preprint of an article publicly time-stamps the work, even as it undergoes peer review and possible revision.

Encourages trust: Embracing openness in scientific research can help encourage other researchers to trust published results, by giving the ability to inspect data or software. Soergel¹⁷ estimated that 5–100% of computational results given by software may be incorrect or inaccurate. While simply releasing source code openly will not solve this problem, this is a necessary step towards verification and reproducibility.

It’s nice: In addition to the above benefits, sharing products of research openly is kind to colleagues and the greater research community, as it prevents people from wasting time by unnecessarily repeating work. For example, many graduate students begin working on their dissertation research by attempting to reimplement another group’s methods and reproduce some of their published results. However, lacking access to software source code or datasets can hinder this work. As a result, significant time can be wasted guessing about minor implementation details or inputs not discussed in the corresponding published papers. This can be avoided by sharing the source code and data, which would allow these junior researchers to more quickly move on to new work. Graduate students and other researchers constantly face similar challenges that could be avoided by greater openness in research.

Openness increases societal impact of research

Many published journal articles go unread, even in their topical domains. One study of citation rates found that 27% of papers published in the natural sciences and engineering go uncited^{18 b}. Those who do read most papers likely come from research

institutions similar to those of the authors, even if the findings could be impactful beyond these confines, for example by leading to policy changes or technological solutions for humanitarian purposes. In part, this is due to the challenging technical content, jargon, and niche topics—but it is also due to a lack of access to the journals where most research findings reside. (Making the content of these papers actually understandable or digestible by most potential readers is another challenge.) Considering the high and ever-increasing cost of scholarly journal subscriptions, research results should not be limited to those with the means to purchase access. By self-archiving (i.e., green open access) or publishing articles in open-access journals, researchers can ensure access for all members of society, including policymakers, funders, members of the media, entrepreneurs, and the general public—as well as scientists and engineers in the Global South.

Furthermore, being more open with all of the outputs of research (e.g., papers, software, data) could help improve the general public’s perception and trust in scientific research. Simply making research products available will not solve all of these problems—for one, it will not sway those who strongly believe ideas contrary to fact. However, ensuring everyone has access to the data researchers generate and analyze, and the software tools on which we rely, could eliminate one major barrier to trust in our findings¹⁹.

Looking specifically at the field of engineering, we can also find examples of the positive effects of open knowledge dissemination. According to Chris Ategeka, founder of Health Access Corps, “Patenting a social-impact product hinders scale, ultimately obstructing the maximum impact that particular product would have in the world if it was open source”²⁰. Thus, the clear benefit of using open research and development practices is achieving greater impact with your research products. The counter argument to this is that, through patenting, the entrepreneur can more easily market and sell their product in developed markets, which could then increase their ability to affect change by subsidizing their efforts in developing nations. This situation may hold true for products with broad appeal and therefore it is necessary for the inventor to assess which path will produce the greatest impact. Assuming, also, that we encourage and reward *impact*. It could be argued that in the majority of scenarios, open dissemination will yield greater impact through simplified adoption and adaptation by others—especially if the front-end development activities are incentivized in other ways.

Open science and the scholar’s research agenda

For the new researcher looking to build their profile and develop their research agenda, we present a vision and plan for performing research openly, synthesized from literature practices and advice. The ideas presented here are heavily inspired by examples from others active in this work, such as Lorena Barba’s Reproducibility PI Manifesto²¹, the Peer Reviewers’ Openness Initiative²², and others. While these exemplars provide

^bOf course, papers that are read may not be cited, and papers that are cited may not actually be read.

useful case studies, it is important to emphasize that each individual must define for themselves a workflow that works for them. Sometimes it is enough to simply be more open than the current norms in their field.

Many fields within engineering lack reputable open-access journals; indeed, only 17% of published manuscripts in engineering can be accessed by the public for free legally, while some sub-disciplines, such as chemical engineering, are lower at 9% available⁷. Thus, the engineering researcher looking to publish in open-access venues can quickly become discouraged. For the early career researcher looking to make their work available while operating within this research environment can take simple steps such as submitting preprints of any publications to the engrXiv^c, and deposit (otherwise non-accessible) conference papers or slide decks on Figshare^d.

For the researcher looking to develop their open workflow further, we recommend the following steps:

- Make all written research products openly accessible, either through green or gold open-access avenues. For fields which lack recognized, fully open-access journals, this objective is typically met by submitting preprints to services such as arXiv, engrXiv, PeerJ Preprints, or Figshare, depending on the topic. Conference papers, when not submitted to an open venue, can also be made openly available. Where possible, release all preprints under the Creative Commons Attribution (CC BY) license^e. If funds are available through research grants or designated library OA funding, a researcher may choose to follow the hybrid gold open-access model by paying a non-fully open journal to make a paper accessible. Note, however, that the fees associated with hybrid open access journals are detrimental to researchers at smaller institutions²³ and thus this model should not be viewed as the solution in keeping with the open-access movement.
- Any new research software developed should be done openly (e.g., on GitHub) and released publicly under a permissive license, such as the BSD 3-clause license. The Git version-control system (or equivalent) should be used to track the history of software projects, and software releases associated with publications or data should be archived (with DOIs) using Zenodo^f. In addition, implementation details should be described as thoroughly as necessary to reproduce the work.
- All data generated through research, when serving as the basis for a publication, should be archived publicly and cited appropriately in manuscripts or other

documents. This data may also include figures and the plotting scripts that produce them, which can then be shared under a CC BY license and cited where appropriate.

As a means of supporting these efforts, researchers should take care to implement these policy statements by incorporating them into funding proposals, for example in Data Management Plans. Note that policies where data and code are made “available upon request” are generally not sufficient for reproducibility²⁴.

Several community efforts have developed in recent years with the goal of defining and supporting open science practices. Some examples include the Workshop on Sustainable Software for Science: Practice and Experiences (WSSSPE)²⁵ and the FORCE11 Software Citation Working Group which developed the Software Citation Principles²⁶ with the goal of standardizing software citation to help ensure authors/developers receive academic credit for their work in releasing open research software. On the publishing side, community driven research journals have been built to promote open publishing practices. Some examples include the *Journal of Open Source Software*^g ²⁷ and the *Journal of Open Engineering*^h ²⁸. Similarly, engrXiv, an open archive for engineering publications, has been developed to serve the engineering community, inspired by the success of the arXiv.

Challenges to performing open science

The primary challenges facing those individuals interested in conducting open research generally involve incentives (or the lack thereof) and restrictive policies maintained by traditional publishers, in addition to the lack of a culture of sharing within the researcher’s disciplinary field. First, researchers are often pressured to carefully consider the venue in which they publish their work and to select only those that are “well established” and “high impact.” However, if these venues are not amenable to open research activities such as the posting of preprints, these challenges disincentivize those activities. To remedy this, the research community must continue to pressure publishers to modify their copyright transfer policies. Some progress has already been made in this effort through policies from funding sources such as the National Institutes of Healthⁱ, the National Science Foundation^j, the Bill & Melinda Gates Foundation^k, and the Wellcome Trust^l or from research institutions who require deposition in a repository. More information on these policies can be found on the Registry of Open

^c<https://engrxiv.org>

^d<https://figshare.com>

^e<https://creativecommons.org/licenses/by/4.0/legalcode>

^f<https://zenodo.org>

^g<http://joss.theoj.org/>

^h<https://www.tjoe.org/>

ⁱNIH Public Access Policy <https://publicaccess.nih.gov/index.htm>

^jNSF Public Access Plan <https://www.nsf.gov/pubs/2015/nsf15052/nsf15052.pdf>

^kBill & Melinda Gates Foundation Open Access Policy <http://www.gatesfoundation.org/How-We-Work/General-Information/Open-Access-Policy>

^lWellcome Trust Open Access Policy <https://wellcome.ac.uk/funding/managing-grant/open-access-policy>

Access Repository Mandates and Policies^m. Additionally, authors themselves can in some cases work with publishers to modify the standard publisher copyright transfer agreements allowing the author to retain more rightsⁿ.

Additionally, promotion and tenure requirements typically focus exclusively on the final published manuscript and associated metrics, neglecting other research outputs such as code, data, solid models, etc., and their associated impacts. Some institutions actively discourage making these alternative research products available due to idealistic dreams of future income generation from licensing revenues. However, in reality, the majority of universities *lose* money through their technology commercialization offices, since translation of university intellectual property to commercial success is generally poorly realized^{29,30}. Some institutions are instead pursuing alternatives such as EasyAccessIP^o which promotes universal knowledge dissemination as a mechanism “to create impact from university research outcomes as opposed to monetary aims.” Ultimately it is likely that societal pressure is necessary to push more institutions to participate in such initiatives. For that to happen, the public first needs to be aware of the possible benefits of broad knowledge dissemination and needs to experience those benefits first hand. Researchers may even see benefits in terms of their scholarly productivity, as Frankenhuis and Nettle³¹ argue that open-science practices may actually increase creativity and researcher output.

It seems the challenges impeding greater adoption of open-science practices are mainly institutional and cultural, rather than technical. General venues for sharing and developing the products of research openly abound these days, with the availability of services like arXiv, engrXiv, and PeerJ Preprints for ensuring open access of publications; repositories like GitHub for developing (and version-controlling) research software openly; and data and software archives like Zenodo and Figshare, which practically have no file size limitations^p. Of course, some technical problems remain: How do we make results of computational science, particularly when it involves demanding high-performance computing resources, truly reproducible? How can we cite software and data consistently, when the version might change regularly? How can open practices be integrated into a researcher’s workflow without further straining the researcher’s already overburdened time?

As cultural inertia and lack of institutional recognition/ rewards pose significant challenges to increased openness in science, the

biggest barrier to greater openness in research may be ambivalence or outright hostility in many research communities. Many academic researchers either disagree on or are unaware of the importance (and benefits) of working openly. Since they were not trained in doing this, e.g., during graduate school or during postdoctoral training, they also may simply be unaware of how to research openly, or the resources that are available to do so. Furthermore, since most of their colleagues, collaborators, and competitors do not practice open science, no pressure comes from the research community to change. In addition, some communities do not support or actively oppose activities such as submitting preprints.

This lack of pressure is related to the other major issue: lack of institutional recognition and reward for open practices. In general, academic researchers will work on what gets them credit for promotion and tenure—anything beyond that requires strong intrinsic motivation, or external motivators from the research community. At most institutions, promotion and tenure review includes some judgment (whether explicit or implicit) of where faculty publish their work, but many, “high-impact” traditional publication venues—particularly domain journals—may not support, e.g., the posting of preprints.

Recommendations for university leaders

As already discussed, there are real career advantages to open-access publishing and open dissemination of data, code, or other research products and therefore, for some, the incentives to conduct open research may already be in place. However, for many, citation metrics alone are not enough to ensure success in promotion and tenure, and therefore they must play to the norms of their field, department, and institution. Therefore, the institution (and the department) should be looking to institute policy that redefines how we measure success in academic engineering research. Some suggestions include focusing less on journal-level metrics and lending greater credibility to article-level metrics. For article-level metrics, go beyond the citation count and look for other evidence of research impact such as alternative metrics (tweets, blog posts, media coverage) and replication by others. Lastly, look for evidence of broader implications such as economic development, student development, or even lives saved. Encourage your researchers to aim for those broader impacts and value them greater than the publishing of *one more paper*.

Thinking about what institutions can do to promote open engineering research and create support structures around open dissemination, we provide the following recommendations:

- Require research products to be made openly available and then support this requirement by having a high-quality institutional repository, supporting other open repositories, and lobbying publishers to modify their copyright policies to promote the publishing of preprints and other products prior to journal submission as well as archiving of final version manuscripts.

^mROARMAP <http://roarmap.eprints.org/>

ⁿSPARC Author Addendum <https://sparcopen.org/our-work/author-rights/#addendum>

^o<http://easyaccessip.com/>

^pZenodo currently accepts datasets up to 50GB, but stores data in the CERN Data Center, along with 100PB of physics data from the Large Hadron Collider (<https://zenodo.org/faq>).

- Convert technology commercialization offices into research impact offices. Use these offices as a mechanism for helping researchers broaden their impact through open research best practices, for funding social entrepreneurship, and for advocating these institutional activities at the state, national, and international levels.
- Empower and fund our university libraries to help with open knowledge dissemination. Others have described ways in which research outputs can be pushed public in real time with the support of the library³², institutions should promote and support these efforts.
- Educate our undergraduate and graduate students on the importance of open knowledge dissemination and the practices that support it. Create and sponsor workshops that train participants in open source software development, open research dissemination, and global development. Many institutions embrace service learning as a mechanism for greater civic engagement³³—broaden this approach in a thoughtful and impactful manner, being careful to ensure that students are learning the right lessons and that partnering communities are not unduly burdened³⁴. These approaches can help ensure that young engineers remain passionate about the field and hold onto the core societal mission of engineering³⁵.

Thinking specifically about the perspective of the researcher within an institution, the following list of recommendations for departments are mostly targeted at changing criteria for promotion and tenure, and performance reviews, to encourage faculty to practice more open science:

- Consider accessibility/openness of research products along with quantity and “quality” in promotion and tenure review. Mandate self-archiving of publications (i.e., green open access).
- Recognize research products such as software and data, and their associated impacts (e.g., citations), as equal to traditional publications in scholarly impact.

- Reduce the importance of publishing in traditional venues for promotion and tenure, recognizing these may be barriers to openness.
- Provide educational opportunities that train faculty and other researchers in open science skills, and those necessary to work with software and data.

Research communities that impede openness cannot be forced to change from the outside. Instead, by making changes to institutional reward systems, researchers will be encouraged to improve their open practices, and thus evolve communities from the inside.

Conclusions

In this paper we have reviewed the existing state of knowledge on the benefits and challenges of practicing openness in engineering research. We have further briefly outlined our thoughts on how open research practices in the sciences, engineering, and other fields can and should be employed by public universities to position themselves as centers for the creation and broad dissemination of knowledge as a public resource. The opposition to this proposal is immense, particularly in a political climate that devalues an educated populace and with systemic practices and policies that exclusively reward the monetization of any form of intellectual property. Change likely needs to be driven with grassroots initiatives that demonstrate the possible benefits and make it clear that tax dollars could fund these efforts if distributed properly and with accountability.

Data availability

No data are associated with this article.

Competing interests

DRB is the founder of engrXiv and the Journal of Open Engineering; KEN is on the Editorial Board of the Journal of Open Source Software.

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References

- Pearce JM: **Materials science. Building research equipment with free, open-source hardware.** *Science*. 2012; **337**(6100): 1303–1304. ISSN 0036-8075, 1095-9203.
[PubMed Abstract](#) | [Publisher Full Text](#)
- Public Research Universities: **Public Research Universities: Recommitting to Lincoln's Vision—An Educational Compact for the 21st Century.** American Academy of Arts & Sciences, Cambridge, MA. 2016; ISBN 0-87724-109-0.
[Reference Source](#)
- Tennant J: **Ashley Farley of the Gates Foundation: “Knowledge should be a public good.”.** 2017.
[Reference Source](#)
- McKiernan EC, Bourne PE, Brown CT, *et al.*: **How open science helps researchers succeed.** *eLife*. 2016; **5**: pii: e16800.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Tennant JP, Waldner F, Jacques DC, *et al.*: **The academic, economic and societal impacts of Open Access: an evidence-based review [version 3; referees: 4 approved, 1 approved with reservations].** *F1000Res*. 2016; **5**: 632.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Archambault E, Amyot D, Deschamps P, *et al.*: **Proportion of open access papers published in peer-reviewed journals at the european and world levels—1996–2013.** 2014. European Commission.
[Reference Source](#)

7. Piwowar H, Priem J, Larivière V, *et al.*: **The state of OA: a large-scale analysis of the prevalence and impact of Open Access articles.** *PeerJ*. 2018; 6: e4375.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
8. Buckheit JB, Donoho DL: **WaveLab and Reproducible Research.** Springer New York, New York, NY, 1995; 55–81. ISBN 978-1-4612-2544-7.
[Publisher Full Text](#)
9. Mesnard O, Barba LA: **Reproducible and replicable CFD: it's harder than you think.** 2016. [physics.comp-ph].
[Reference Source](#)
10. Barba LA: **The hard road to reproducibility.** *Science*. 2016; 354(6308): 142.
[PubMed Abstract](#) | [Publisher Full Text](#)
11. Antelman K: **Do open-access articles have a greater research impact?** *Coll Res Libr*. 2004; 65(5): 372–382.
[Publisher Full Text](#)
12. Piwowar HA, Vision TJ: **Data reuse and the open data citation advantage.** *PeerJ*. 2013; 1(3): e175.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
13. Vandewalle P: **Code sharing is associated with research impact in image processing.** *Comput Sci Eng*. 2012; 14(4): 42–47.
[Publisher Full Text](#)
14. Howe A, Howe M, Kaleita AL, *et al.*: **Imagining tomorrow's university in an era of open science [version 2; referees: 3 approved].** *F1000Res*. 2017; 6: 405. ISSN 2046-1402.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
15. Berg JM, Bhalla N, Bourne PE, *et al.*: **SCIENTIFIC COMMUNITY. Preprints for the life sciences.** *Science*. 2016; 352(6288): 899–901.
[PubMed Abstract](#) | [Publisher Full Text](#)
16. Strasser C: **Preprints: The bigger picture.** *The Winnower*. 2016; 3: e146955.56313.
[Publisher Full Text](#)
17. Soergel DA: **Rampant software errors may undermine scientific results [version 2; referees: 2 approved].** *F1000Res*. 2015; 3: 303.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
18. Larivière V, Gingras Y, Archambault É: **The decline in the concentration of citations, 1900–2007.** *J Am Soc Inf Sci Tec*. 2009; 60(4): 858–862.
[Publisher Full Text](#)
19. Grand A, Wilkinson C, Bultitude K, *et al.*: **Open science: A new 'trust technology'?** *Sci Commun*. 2012; 34(5): 679–689.
[Publisher Full Text](#)
20. Goodier R: **The case for open source design in low-cost medical patient transport.** 2016.
[Reference Source](#)
21. Barba LA: **Reproducibility PI manifesto.** 2012.
[Publisher Full Text](#)
22. Morey RD, Chambers CD, Etchells PJ, *et al.*: **The peer reviewers' openness initiative: incentivizing open research practices through peer review.** *R Soc Open Sci*. 2016; 3(1): 150547.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
23. Siler K, Haustein S, Smith E, *et al.*: **Authorial and institutional stratification in open access publishing: the case of global health research.** *PeerJ*. 2018; 6: e4269.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
24. Stodden V, Seiler J, Ma Z: **An empirical analysis of journal policy effectiveness for computational reproducibility.** *Proc Natl Acad Sci U S A*. 2018; 115(11): 2584–2589.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
25. Katz DS, Choi SCT, Niemeyer KE, *et al.*: **Report on the third workshop on sustainable software for science: Practice and experiences (WSSPE3).** *J Open Res Softw*. 2016; 4(1): e37.
[Publisher Full Text](#)
26. Smith AM, Katz DS, Niemeyer KE, *et al.*: **Software citation principles.** *PeerJ Comput Sci*. 2016; 2: e86.
[Publisher Full Text](#)
27. Smith AM, Niemeyer KE, Katz DS, *et al.*: **Journal of open source software (JOSS): design and first-year review.** *PeerJ Comput Sci*. 2018; 4: e147.
[Publisher Full Text](#)
28. Berg D, Niemeyer KE, Fleischfresser L: **[Editorial] Open publishing in engineering.** *J Open Eng*. 2016.
[Publisher Full Text](#)
29. Valdivia WD: **University start-ups: Critical for improving technology transfer.** Technical report, Center for Technology Innovation at Brookings. 2013.
[Reference Source](#)
30. Sanami M, Flood T, Hall R, *et al.*: **Translating healthcare innovation from academia to industry.** *Adv Mech Eng*. 2017; 9(3). ISSN 1687-8140.
[Publisher Full Text](#)
31. Frankenhuis W, Nettle D: **Open Science is Liberating and Can Foster Creativity.** *Open Science Framework*. 2018.
[Publisher Full Text](#)
32. Brems B: **Open Science: Too much talk, too little action.** 2017.
[Reference Source](#)
33. Bringle RG, Hatcher JA: **Innovative practices in service-learning and curricular engagement.** *New Dir Higher Educ*. 2009; 2009(147): 37–46.
[Publisher Full Text](#)
34. Berg DR, Lee T, Buchanan E: **A methodology for exploring, documenting, and improving humanitarian service learning in the university.** *Journal of Humanitarian Engineering*. 2016; 4(1).
[Publisher Full Text](#)
35. Eseonu C, Cortes MA: **Engineering for Good: A Case of Community Driven Engineering Innovation.** *Journal of Humanitarian Engineering*. 2018; ISSN 2200-4904.
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Joshua M. Pearce

Department of Electrical and Computer Engineering, Michigan Technological University,
Houghton, MI, UK

This is an important paper - and sadly still needs to be written in 2018 - as open science should clearly be the default for the maximum rate of progress in any field. It is clear that we are headed this way but the rate of change could certainly be faster. In addition to the comments from the other reviewers I offer the following constructive points:

1. Although this is an opinion piece I would encourage the authors to avoid all unsubstantiated claims. Ideally every fact not derived from the authors' own work should have a citation.
2. Although I agree with the first line - the article would be stronger if the footnote offered either a substantial list of referenced arguments for it -- or wait until the end to make the claim.
3. Instead of simply saying open source software - it would be better to use FOSS (and explain the difference).
4. To be correct in the definition of open science - the use of free and open source hardware should be included in addition to FOSS.
5. I am not sure that open science is benefited by "the half-baked ideas, the napkin sketches, the first drafts, and the failures." For example, engineers working on water purification technology should not publish their tech until they are sure it works unless it has warning notices all over it.
6. It would be interesting to speculate on why engineers lag so far behind say physicists in making their work open access. Is it because the various engineering societies have more restrictive publishing agreements than the major publishers?
7. There are some examples of method to quantify the impact of research on society. There is a rich literature showing high ROIs for industry funded research for the business world. In addition using the concept of downloaded substitution value one can calculate the value to society for open source scientific hardware designs as well as software.
8. Increasing societal impact of research + you make a good point about the scientists in the Global South - but you should consider going one step further and encouraging engineers

working on technologies that can solve the problems of the world's poorest people to make sure they are released as open source appropriate technologies.

9. Impact - you can make a stronger case. Patenting slows innovation (and there are a ton of studies showing this) and increases costs for consumers. One of the most clear recent examples is the staggering decrease in costs and increases in performance of 3D printers following the open source release of the RepRap project.
10. Engineering journals + most of them do offer some sort of open access policy - either to post preprints or pay for open access.
11. Open workflow should encourage the use of FOSS and FOSH whenever possible.
12. pg 5 seems overly pessimistic and also does not cite proof. I have found that most researchers are sympathetic to open science and that many forward-thinking institutions are pushing open access pretty hard.
13. Even just going to article level metrics - where OA has an advantage for citations should be useful and already has a built in incentive.
14. Something should be said about open source business models. Patents are not the only way to go -- i.e. RedHat is a multi-billion per year open source company.
15. Finally, many of your suggestions are good but could be strengthened if you hone in on university leaders self interest for encouraging them to actually implement them.

Is the topic of the opinion article discussed accurately in the context of the current literature?

Yes

Are all factual statements correct and adequately supported by citations?

Partly

Are arguments sufficiently supported by evidence from the published literature?

Partly

Are the conclusions drawn balanced and justified on the basis of the presented arguments?

Partly

Competing Interests: Co-Editor and Chief of HardwareX

Reviewer Expertise: open hardware, solar photovoltaics, sustainability, energy policy

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 08 Oct 2018

Devin Berg, University of Wisconsin-Stout, Menomonie, USA

Dr. Pearce,

Thank you for your thorough review. We agree that open science practices should indeed

be the default for engineering research and progress. We'd like to address your individual points below.

1) Although this is an opinion piece I would encourage the authors to avoid all unsubstantiated claims. Ideally every fact not derived from the authors' own work should have a citation.

We have gone through the paper again and attempted to address any issues with uncited statements. Several new citations and references have been added.

2) Although I agree with the first line - the article would be stronger if the footnote offered either a substantial list of referenced arguments for it -- or wait until the end to make the claim.

The first line is stated as an opinion, which we intend to use as the basis for the rest of the paper. This statement is fleshed out more fully with references to other related works in the following paragraphs.

3) Instead of simply saying open source software - it would be better to use FOSS (and explain the difference).

We have added language to make this distinction.

4) To be correct in the definition of open science - the use of free and open source hardware should be included in addition to FOSS.

Agreed. We have added hardware to this definition.

5) I am not sure that open science is benefited by "the half-baked ideas, the napkin sketches, the first drafts, and the failures." For example, engineers working on water purification technology should not publish their tech until they are sure it works unless it has warning notices all over it.

We agree with the first sentence here and have modified the language to word this differently. For the second sentence, we agree that there needs to be more education on what early work is and its use cases. However, we don't feel that this is limited to any one sub-discipline such as "water purification technology" and is actually an issue that applies to virtually all of engineering.

6) It would be interesting to speculate on why engineers lag so far behind say physicists in making their work open access. Is it because the various engineering societies have more restrictive publishing agreements than the major publishers?

This is a difficult question to answer. Perhaps there are cultural limitations due to the applied or industry connected nature of engineering. We've added some discussion to the "Challenges" section to try to address this better.

7) There are some examples of method to quantify the impact of research on society. There is a rich literature showing high ROIs for industry funded research for the business world. In addition using the concept of downloaded substitution value one can calculate the value to society for

open source scientific hardware designs as well as software.

We have added some discussion and relevant citations to the societal impact section of the paper.

8) Increasing societal impact of research + you make a good point about the scientists in the Global South - but you should consider going one step further and encouraging engineers working on technologies that can solve the problems of the world's poorest people to make sure they are released as open source appropriate technologies.

Agree and we have added some additional discussion to this section of the paper.

9) Impact - you can make a stronger case. Patenting slows innovation (and there are a ton of studies showing this) and increases costs for consumers. One of the most clear recent examples is the staggering decrease in costs and increases in performance of 3D printers following the open source release of the RepRap project.

Have added some discussion and references to support this.

10) Engineering journals + most of them do offer some sort of open access policy - either to post preprints or pay for open access.

We have to generally disagree with this point. Several of the larger engineering societies are lagging in explicit support of preprinting. Additionally, we don't view hybrid OA journals as a solution to this problem as they are largely shifting the fees and associated publisher profits from one hand to the other. We view hybrid OA journals as a temporary solution on the path towards full OA journals with reasonable APCs operated by societies or other non-profit academic institutions.

11) Open workflow should encourage the use of FOSS and FOSH whenever possible.

Have edited the language to match.

12) pg 5 seems overly pessimistic and also does not cite proof. I have found that most researchers are sympathetic to open science and that many forward-thinking institutions are pushing open access pretty hard.

We have edited the language here. Also, it seems that these forward-thinking institutions are pushing OA publishing but not open science.

13) Even just going to article level metrics - where OA has an advantage for citations should be useful and already has a built in incentive.

True, we have reiterated this point.

14) Something should be said about open source business models. Patents are not the only way to go, RedHat is a multi-billion per year open source company.

This is true, though we've tried to focus this paper more on research than industry/innovation.

15) Finally, many of your suggestions are good but could be strengthened if you hone in on university leaders self interest for encouraging them to actually implement them.

Have edited language to reiterate the benefits of self-interest.

Competing Interests: No competing interests were disclosed.

Reviewer Report 30 April 2018

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Nathan L. Vanderford

Markey Cancer Center, Department of Toxicology and Cancer Biology, College of Medicine, University of Kentucky, Lexington, KY, USA

This is a well-written opinion article that presents a well-articulated argument for the science community to increase the practice of “openness” in research. After clearly defining “open” research (caveat below), key components of the article include a discussion on the importance of open research to science, some recommendations on how researchers can conduct their research “openly” and how universities can support such work, and there is a discussion about challenges to open science. The article is a valuable contribution to this growing movement.

Although the article is well written and the argument is clearly articulated with appropriate references to the literature, I believe that there are a few points that the authors should consider and respond to prior to this work being approved for indexing.

1. The authors reference the work as a “review” but in the parlance of F1000Research, it is an opinion article and it is written as such since it is an argument for conducting more open research. Thus, this reviewer suggests not referring to the work as a “review.”
2. The article title and a few areas within the text are written specifically toward engineering research, but this topic transcends disciplines and much of the content can be applied broadly. As such, the authors should consider whether the title and respective text should be less restricted to engineering. Perhaps the authors could present the topic as one that is more broadly applicable but then more clearly state that they are using engineering as a case study/example to illustrate their points.
3. The authors begin the main text with a clear definition of open science, but it is unclear if

this is the authors' definition or if it is taken from the literature. This should be clarified.

4. The authors should consider adding a bit more discussion on the challenges associated with open research. For example, more could be said about how the culture of academia doesn't particularly value open research currently. Today's academic culture is still too focused on where a journal is ranked based on impact factor and this plays into aspects of faculty life such as faculty hiring, promotion/tenure, faculty performance evaluations, post-tenure review, etc. While the authors touch on some of these points, a greater discussion and recommendation for a culture change could be a valuable, thought-provoking addition to the article. More could also be said regarding some of the minutia of how open research needs to be implemented especially related to the infrastructure needed to support it and the financial costs associated with the infrastructure. Who should pay for hosting, pay publications costs, etc.?

In summary, this is a well-articulated article on an important, timely topic. The few points above slightly dampen this reviewer's enthusiasm at this time related to giving full approval. As such, I look forward to reviewing a revised version of the article.

Is the topic of the opinion article discussed accurately in the context of the current literature?

Yes

Are all factual statements correct and adequately supported by citations?

Yes

Are arguments sufficiently supported by evidence from the published literature?

Yes

Are the conclusions drawn balanced and justified on the basis of the presented arguments?

Yes

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 05 Oct 2018

Devin Berg, University of Wisconsin-Stout, Menomonie, USA

Dr. Vanderford,

Thank you for your thoughtful review of our paper and for your specific suggestions for improvement. We've attempted to address your comments in this revision as outlined below.

1. The authors reference the work as a “review” but in the parlance of F1000Research, it is an opinion article and it is written as such since it is an argument for conducting more open research. Thus, this reviewer suggests not referring to the work as a “review.”

We've revised the language to make it more clear that this is not a review article and more of an opinion article.

2) The article title and a few areas within the text are written specifically toward engineering research, but this topic transcends disciplines and much of the content can be applied broadly. As such, the authors should consider whether the title and respective text should be less restricted to engineering. Perhaps the authors could present the topic as one that is more broadly applicable but then more clearly state that they are using engineering as a case study/example to illustrate their points.

We agree that many of the issues that we've addressed are not unique to engineering and do indeed apply more broadly. However, our goal with this work was to write a targeted paper for the engineering community that specifically addresses the issues from that frame. There are other works in the literature that take a more general approach and we've tried to reference them appropriately to bring them to the reader's attention.

3) The authors begin the main text with a clear definition of open science, but it is unclear if this is the authors' definition or if it is taken from the literature. This should be clarified.

The definition of open science included in our paper is a synthesis of other available definitions found elsewhere. We've edited to make this more clear and inserted some references to support this.

4) The authors should consider adding a bit more discussion on the challenges associated with open research. For example, more could be said about how the culture of academia doesn't particularly value open research currently. Today's academic culture is still too focused on where a journal is ranked based on impact factor and this plays into aspects of faculty life such as faculty hiring, promotion/tenure, faculty performance evaluations, post-tenure review, etc. While the authors touch on some of these points, a greater discussion and recommendation for a culture change could be a valuable, thought-provoking addition to the article. More could also be said regarding some of the minutia of how open research needs to be implemented especially related to the infrastructure needed to support it and the financial costs associated with the infrastructure. Who should pay for hosting, pay publications costs, etc.?

We have addressed issues around a lack of valuation for open science practices and the need for change in promotion/tenure evaluation criteria. We've tried to emphasize this more in the paper. We would also point out that many of our recommendations do not require financial support to be feasible and indeed would be possible under existing funding models.

Competing Interests: No competing interests were disclosed.

Comments on this article

Version 1

Author Response 09 Oct 2018

Devin Berg, University of Wisconsin-Stout, Menomonie, USA

Dr. Irawan,

Thank you for your comment. We agree that engineers are often positioned as *problem solvers* within society and if this expectation is to be met, then open practices would lead to more positive outcomes. We hope that this comes across in the revision to our paper.

Thank you so much for your wonderful sketchnote!

Competing Interests: No competing interests were disclosed.

Author Response 09 Oct 2018

Devin Berg, University of Wisconsin-Stout, Menomonie, USA

Dr. Katz,

Thank you for taking the time to comment on our paper and to provide your suggestions for improvement here. We've considered each of your comments and have edited our paper accordingly.

- *It's not clear to me that "most public universities rely heavily on state funding". Can you provide some evidence of this?*

This may be true for some institutions. We've edited to broaden the language to "public funding".

- *Regarding "Despite the challenges faced by institutions today, it is critical for the university to continue to position itself as a center of societal development—economically, technologically, and socially. Additionally, the university should push this model further towards positioning itself as the main driver of social and technological innovation." This appears to be opinion. Can you explain why you believe this? Or if you think it's more than your opinion, perhaps you can explain further?*

Yes, this is an opinion. We have edited the language to make this more clear and that we are providing our interpretation of the mission of the land-grant university model. In this context, we use the phrase "main driver" to mean regionally.

- *"Conducting open research is an act of assigning value to the work to which you are passionately committed" doesn't seem to exactly right, in the sense that this is saying that these items have value, but it is not assigning a specific value to each.*

Agreed. We've revised the language here to take this into account.

- While reading the Importance of open science section, I notice that credit is not really discussed. It's somewhat embedded in impact and priority, but perhaps should be brought out as a high-level concern, particularly since incentives is later discussed as a primary challenge.

To address this point, along with the previous point, we've created a new paragraph on "Value and Credit".

- The next section, Openness increases societal impact of research, seems to repeat the impact point in the previous section. Why expand just this one point?

These two sections were discussing two different forms of impact. We've renamed the "Impact" paragraph to "Recognition" to make this more clear.

- "Assuming, also, that we encourage and reward impact." is not a sentence. Something seems to be missing in this part of the paper.

This is fixed.

- In "fully openaccess journals", a space is missing in "openaccess"

Fixed, thanks.

- Figshare seems to be emphasized repeatedly, without mention of alternatives, such as slideshare, zenodo, etc...

We could only find one location where Figshare was mentioned alone and not alongside alternatives. We have added some alternatives to this spot.

- You might add that data should be archived in research data repositories listed in <https://www.re3data.org>

Have added this.

- "the arXiv" doesn't sound right to me, vs the more simple "arXiv". Note that arXiv itself does not use the "the" phrasing in <https://arxiv.org/help/general>

Fixed.

- By using the term "technology commercialization offices", I think you are falling into the trap that you are describing. These offices are more frequently "technology transfer offices", but indeed, they miss the objective of transferring technology and instead focus on commercializing it, even at the cost of transferring it.

Fixed.

- *I would drop "It seems" from "It seems the challenges impeding greater adoption".*

Fixed.

- *I disagree with "The opposition to this proposal is immense ..." in the conclusions. I think the opposition is, in large part, reluctance to change, not active disagreement.*

We have revised the language to address this.

- *In note p, I think a space should be used between the value and the units.*

Fixed.

Competing Interests: No competing interests were disclosed.

Reader Comment 13 Sep 2018

Dasapta Erwin Irawan, Institut Teknologi Bandung, Indonesia

The authors have put so much effort in writing this paper. They pointed out some important aspects and perspectives that need to be addressed to improve engineering research by promoting openness. However, it would be great if the authors can put a message that people expect solution from engineering to their problem, and problem is the starting point of every engineering project. Then how we can answer the expectation by providing better answer to every problem in closed research ecosystem, while better answer is most likely built upon previous answer. This is also another reason why we should do open engineering research.

I made this sketchnote as my effort to understand the content of this paper that could be useful to the authors. I uploaded it here <https://flic.kr/p/28hAWSS>.

Competing Interests: I don't have competing interests.

Reader Comment 01 May 2018

Daniel S. Katz, University of Illinois at Urbana-Champaign, USA

Some general and detailed comments follow:

- It's not clear to me that "most public universities rely heavily on state funding". Can you provide some evidence of this?
- Regarding "Despite the challenges faced by institutions today, it is critical for the university to continue to position itself as a center of societal development—economically,

technologically, and socially. Additionally, the university should push this model further towards positioning itself as the main driver of social and technological innovation." This appears to be opinion. Can you explain why you believe this? Or if you think it's more than your opinion, perhaps you can explain further?

- "Conducting open research is an act of assigning value to the work to which you are passionately committed" doesn't seem to exactly right, in the sense that this is saying that these items have value, but it is not assigning a specific value to each.
- While reading the Importance of open science section, I notice that credit is not really discussed. It's somewhat embedded in impact and priority, but perhaps should be brought out as a high-level concern, particularly since incentives is later discussed as a primary challenge.
- The next section, Openness increases societal impact of research, seems to repeat the impact point in the previous section. Why expand just this one point?
- "Assuming, also, that we encourage and reward *impact*." is not a sentence. Something seems to be missing in this part of the paper.
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- Figshare seems to be emphasized repeatedly, without mention of alternatives, such as slideshare, zenodo, etc...
- You might add that data should be archived in research data repositories listed in <https://www.re3data.org>
- "the arXiv" doesn't sound right to me, vs the more simple "arXiv". Note that arXiv itself does not use the "the" phrasing in <https://arxiv.org/help/general>
- By using the term "technology commercialization offices", I think you are falling into the trap that you are describing. These offices are more frequently "technology transfer offices", but indeed, they miss the objective of transferring technology and instead focus on commercializing it, even at the cost of transferring it.
- I would drop "It seems" from "It seems the challenges impeding greater adoption".
- I disagree with "The opposition to this proposal is immense ..." in the conclusions. I think the opposition is, in large part, reluctance to change, not active disagreement.
- In note p, I think a space should be used between the value and the units.

Competing Interests: I have published papers, including some cited in this paper, with one of the co-authors.

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